Rocky Mountain Bighorn Sheep Habitat and Population Assessment for the East Kootenay Trench

15 March 2007

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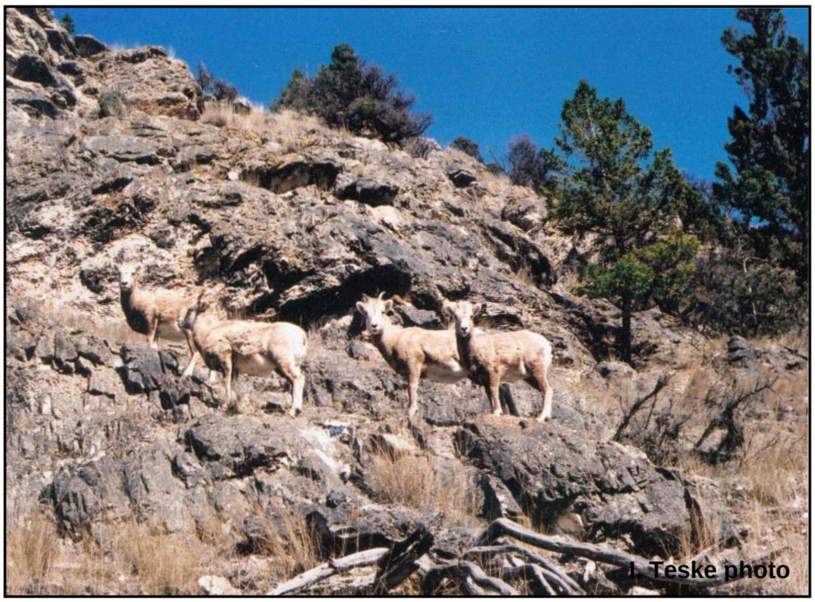

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Explanatory Note

The East Kootenay Wildlife Association coordinated a comprehensive research program on 4 winter ranges and 3 herds of Rocky Mountain Bighorn sheep in the East Kootenay region of British Columbia from 1997 through 2001. The wintering areas studied were Columbia Lake, Premier Ridge, Bull River and Mount Broadwood. Immediately following the field work, most of the analysis and writing was done and portions of it were made available to managers. However, some sections were incomplete and the results as a whole were not assembled and distributed. This document (2007) compiles all components of the research and correlates results and conclusions across those components. Material presented in this report is organized according to major themes of the research program, with chapters covering:

- study rationale and objectives, study area, animal capture and radiotelemetry;
- mortality causes and survivorship rates;
- micro-habitat modeling;
- regional habitat modeling;
- low-elevation (winter) range conditions and use of forage;
- predicted capacity of winter ranges to support sheep; and
- potential areas in which to conduct habitat restoration.

Where chapters already existed as complete entities, they are presented here (with minor formatting changes) under the original author's name. In cases where sections were largely finished in the past but had been finalized here, authorship is indicated as being jointly that of the original author and the compiler. Still other chapters have been written as essentially new material, with authorship by the compiler.

Report Summary[1]

Ten to 12 ewes were radiocollared on each of the Columbia Lake, Bull River and Mount Broadwood winter ranges and monitored for 2 to 3 years. Mortalities were due to cougar predation, avalanches, drowning and unknown causes. Annual survivorship rates of about 0.9 were estimated, except for an annual equivalent of 0.8 for Mount Broadwood sheep during summer. There was no strong evidence for differences in survivorship among study areas, though sample sizes were limited. These values do not suggest the likelihood of population declines, and this is supported by increasing populations since the time of research.

At each study area, micro-habitat modeling used discriminant function techniques to identify locally-preferred winter habitats. Results were relatively consistent among herds, with preferred habitat being typically associated with bluebunch wheatgrass site series in early structural stages, and also fields at Bull River and Mount Broadwood. Depending on the herd, selection was also generally evident for lower greenness values (based on satellite imagery), lower elevations, steeper terrain, shorter distances to steep terrain, greater terrain ruggedness and more southerly aspects.

Regional habitat modeling (combining home ranges of all 3 herds in comparison to the surrounding regional landscape along the western flank of the Rocky Mountains) provided similar results. Elevation, distance to steep slopes, terrain ruggedness, greenness score and

[1] More detailed summaries are provided at the beginning of most chapters.

early-winter solar irradiance were the best predictors of sheep habitat. Applying the model results to GIS mapping, the habitat was strongly concentrated along the toe of the Rocky Mountains. The model appeared to slightly overestimate the extent of habitat, portraying it in the lower portions of tributary valleys and at some locations distant from the face of the Rockies. This reflected limitations in the scales and variables used.

Range characteristics were investigated at the 3 principal study areas, and on the Premier Lake winter range. In general, range quality was low to moderate, with abundant weeds and agronomic species (particularly at Bull River and Mount Broadwood), and evidence of overuse in many areas. Winter diet was dominated by grasses, particularly needlegrasses, wheatgrasses and fescues. These species had low apparent nutritional value and there was some limited use of species having higher energy, protein or micronutrients, but in general the diet appeared to be suboptimal relative to the requirements of domestic sheep. It is not clear if the diet was in fact deficient, related to the inaccessibility of higher-value plants or their unpalatability, or alternatively if the diet was adequate for bighorn sheep during the winter. Range carrying capacity was estimated from each of grass forage production and grass forage utilization. The 2 estimates were similar for all but Bull River. Combining the raw numbers with other observations, considering the growth of both bighorn and other ungulate populations since the time of research, and reflecting the need for 50% carry-over of forage annually to maintain range condition, there is evidence of the ranges being near or over sustainable capacity at Premier Lake, Mount Broadwood and especially Columbia Lake. Carrying capacity estimates were so low at Bull River as to be inconsistent with the recent population growth there, even with ongoing range degradation. It appears that sheep are obtaining a significant portion of their winter forage from areas or forage types outside of those recorded during the research, with anecdotal evidence of the use of a hay field. This places the Bull River herd in a vulnerable position with regard to future forage availablility, as the native ranges only appear capable of supporting a considerably smaller herd than the one currently there.

The widespread distribution of introduced plants such as cheatgrass, sulphur cinquefoil, common St. John’s-wort, spotted knapweed and variety of agronomic grasses and forbs is affecting the ability of winter ranges to support bighorn sheep, so weed control would provide a significant benefit. However, unless carefully planned, burns of existing grasslands may not reduce weed coverage and may actually increase it. Burns of grassland also provide only short-term forage enhancement. Habitat restoration, i.e. the removal of conifers that have encroached on historic grasslands under fire-control regimes, is likely to be more beneficial and has already shown success on bighorn sheep range in the East Kootenay. However, mechanical removal and fire, without weed control, may worsen the long-term forage and range-quality situation. It is recommended that a program of habitat restoration integrated with weed control be used to recover historic bighorn sheep habitat in and adjacent to current winter range. Potential restoration sites were identified for each herd. These were within areas classified as habitat through regional modeling, while also being within winter composite home ranges of collared ewes and within 1 km of locations where collared ewes were recorded. Within those areas, potential restoration sites were delimited by identifying preferred site series that occurred at older (less favored) structural stages. All sites identified as candidates for restoration require ground-truthing before further planning is done.

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Acknowledgements

All stages of this project – planning, coordination, funding, fieldwork, analysis, and writing – involved collaboration. Several dozen people had a hand in at least one aspect of it, and their contributions are noted in the Acknowledgements section of each chapter. Those involved in directing the project and writing the chapters are summarized below. The East Kootenay Wildlife Association, particularly Dave and Jill White and Mario Rocca, initiated and coordinated the program, obtained funding, and provided many hours of volunteer fieldwork. Martin Jalkotzy was the project biologist, overseeing fieldwork and analysis along with the late Ian Ross, who darted and collared the study animals and managed the population data. Range research was conducted and reported by Bryne Weerstra and Anne Holcroft Weerstra. Anne and Bryne also provided a constructive review of this document. John Boulanger developed survivorship models. Much of the habitat modeling analysis was conducted by Jack Wierzchowski. Irene Teske and Tara Szkorupa, Ministry of Environment, Cranbrook provided advice and files needed to complete some of the analyses. Irene has been an outstanding source of on-the-ground knowledge and data files for this project, reviewed an earlier draft of this document, provided photos, and did the majority of telemetry work prior to her employment with the Ministry. Financial or logistical support was provided by the Habitat Conservation Trust Fund, the Columbia Basin Fish and Wildlife Compensation Program, the Wild Sheep Society of B.C., the Foundation for North American Wild Sheep, the East Kootenay Wildlife Association, and the Ministry of Environment, Lands and Parks.

[2] Detailed tables of contents are provided at the beginning of each chapter.

Chapter 1. Introduction and Animal Monitoring Results

30 September 2006

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[3] This chapter draws heavily on material prepared by the authors of chapters 2, 3 and 5, and on other reports prepared by M. Jalkotzy.

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Acknowledgements

The late Ian Ross was responsible for animal capture and collaring, and population data management. Irene Teske (now with the Ministry of Environment, Cranbrook) conducted the majority of the telemetry work, and provided photographs and data files.

1.0 Project Rationale

1.1 Background

In southeastern British Columbia, native herds of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) occur in the Rocky Mountain chain and along its western margin in the Rocky Mountain Trench, within an area known as the East Kootenay. As of 2005 there were an estimated 2020 animals of this subspecies within 24 recognized herds in the Rocky Mountains and Trench from Golden southward (I. Teske, Ministry of Environment, Cranbrook, unpubl. data). Populations vary dramatically over time, partly in response to epizootic die-offs that have occurred with a roughly 20-year period. Factors contributing to these rapid population declines are not completely understood and likely vary geographically, but poor nutrition and high densities have been implicated in at least some cases (Shackleton 1999). While die-offs and recovery have been occurring since at least the 1800s, it appears that overall numbers for herds wintering along the Trench are lower now than historically (H. Schwantje, Ministry of Environment, Victoria, pers. comm.). Concern has been expressed that ongoing loss of open range habitat to conifer ingrowth (RMTERSC 2006) may be leading to a lower carrying capacity, increased crowding on the remaining range, less ability to detect and avoid predators, a greater susceptibility to die-offs, and a reduced ability to withstand periodic deep-snow winters.

Considerable research and planning has been conducted on bighorn sheep herds in the East Kootenay (e.g. Schwantje 1988, Stelfox 1990, Davidson 1991, Demarchi and Demarchi 1994) and is continuing in the Radium Hot Springs area (Dibb 2006). In addition, efforts are being made to reduce disease transfer from domestic to wild sheep (Adams and Zehnder 2002). However, the ecology of bighorns is dynamic and to some extent herd-specific, and it is not clear what the current status is of habitat use, range condition and mortality patterns, nor how these factors may differ among herds. To better understand current, herd-specific conditions for Rocky Mountain bighorn sheep wintering in the Rocky Mountain Trench, the East Kootenay Wildlife Association embarked on a 5-year project to investigate habitat use, habitat selection, range condition and mortality for 3 herds and 4 winter ranges along the eastern edge of the Rocky Mountain Trench.

1.2 Objectives

The project objectives were as follows:

1. Determine rates and causes of mortality among radiotagged ewes. See Chapter 2.
2. Determine the patterns of habitat use on each fall-winter-spring range (hereafter “winter range”), with reference to the vegetative and terrain characteristics selected by sheep. See Chapter 3 (micro-habitat modeling) and Chapter 4 (regional habitat modeling).
3. Determine the range characteristics, quality, and trends in habitats that are seasonally selected by sheep, with emphasis on preferred plant species. See Chapter 5.
4. Based on #1, 2 and 3 above, determine if there is evidence for currently low sheep numbers being attributable to (a) high predation and other mortality in relation to recruitment or (b) present populations of sheep and other ungulates degrading range quality in the habitat types. See Chapter 6.
5. Assess the need and possibilities for improving the quality, quantity, or distribution of habitat through enhancement or, alternatively, to determine whether further investigation is required regarding parasitism, disease, predation, harassment, or other factors that may be limiting sheep populations or contributing to increased risk of die-off. See Chapter 6.

2.0 Study Areas

Research occurred at 4 defined winter ranges in the Kootenay Region of British Columbia, (Figure 1). Radiotelemetry and habitat modeling were undertaken at Columbia Lake, Bull River and Mount Broadwood (Wigwam Flats). Range assessments were conducted at those 3 sites and Premier Ridge.

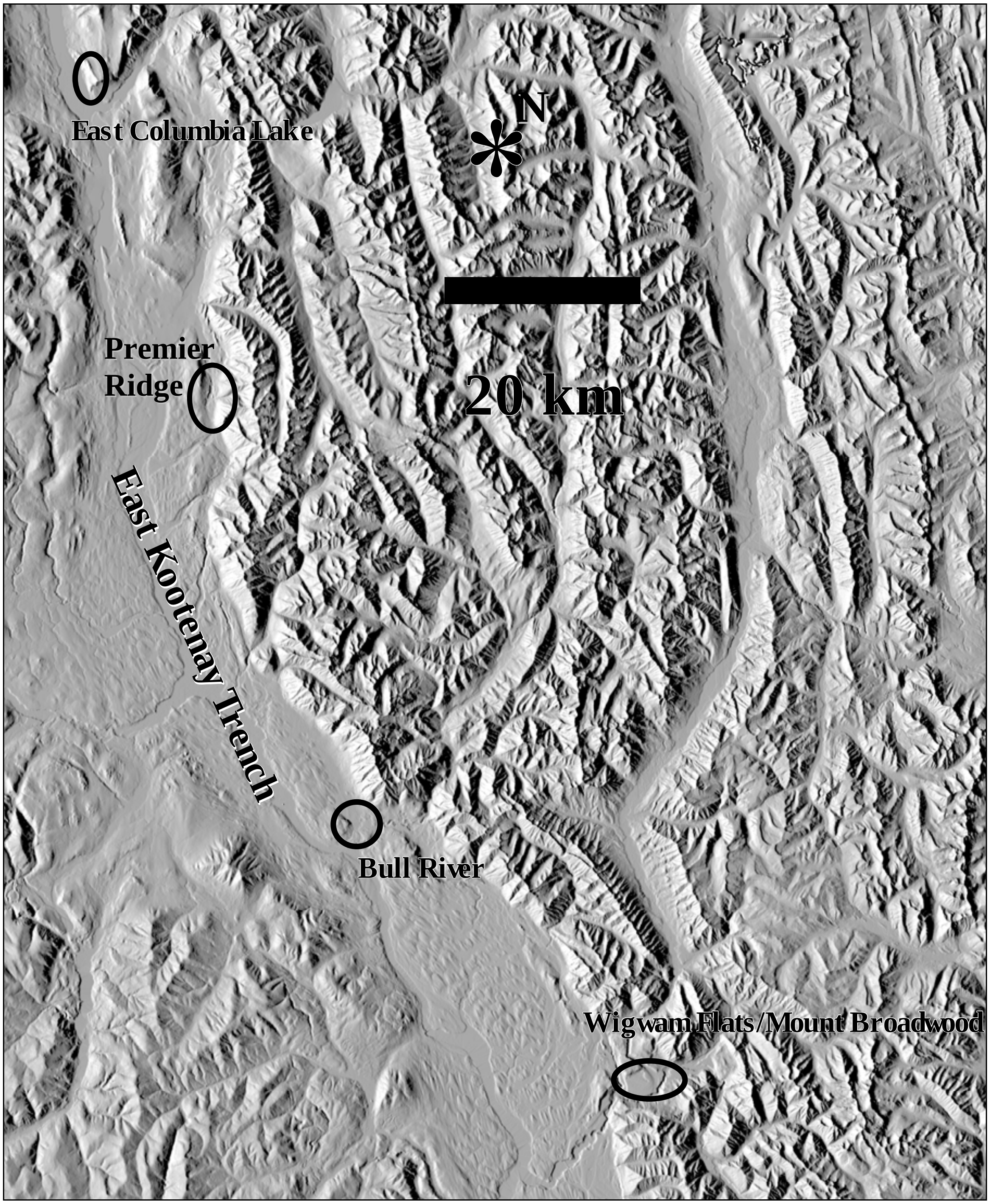

Figure 1. Study areas for East Kootenay bighorn sheep research, 1997 to 2000. Range research only (no telemetry) occurred at Premier Ridge.

2.1 Terrain

All 4 study area units lie along the eastern edge of the Rocky Mountain Trench immediately adjacent to, and in some cases overlapping with, the Rocky Mountains. This area is within the East Kootenay Trench, Southern Park Ranges and Border Ranges ecosections (Demarchi et al. 2000). Within the winter ranges studied, the portions in the Trench are flat to rolling and are at elevations of roughly 800 to 1000 m. Those parts of the winter ranges extending into the Southern Park and Border ranges rise steeply through broken terrain and have a generally west to southwest aspect, with activity strongly concentrated at the lower elevations but including some use up to roughly 1400 m.

2.2 Climate

The East Kootenay Trench has a continental climate. The general distribution of precipitation is affected by the north-south orientation of mountain ranges to the west, which act as barriers to easterly movements of damp air from the Pacific Ocean. A dry climate results in the Trench (Kelly and Holland 1961). The Rocky Mountains form a barrier against polar air masses moving southward through Alberta, although sometimes the cold air spills through the mountain passes into the Trench. Yukon air moving southward in the mountain valleys of British Columbia normally brings the coldest weather. Dry, warm air from the plateaux of the northwest United States sometimes penetrates into the Trench. In the summer these conditions produce hot daytime temperatures with cool nights (Kelly and Holland 1961).

Within the dominant biogeoclimatic subzone (the IDFdm2; Section 2.3) there are hot, very dry summers and cool winters with very light snowfall (Braumandl et al. 1996). Mean summer temperatures are expected to be between 10.1 and 12.5°C, with less than 200 mm of precipitation in that season. Mean winter temperatures between -1.9 and -0.1°C are typical, with less than 200 mm of winter precipitation (Braumandl et al. 1996). As a result, moisture deficiencies occur periodically throughout the year, particularly during late summer. Climate varies throughout the Trench but at all stations March and April are the driest months (McLean and Holland 1958).

2.3 Biogeoclimatic Zonation

Winter ranges occur almost entirely within the Interior Douglas-fir (IDF) biogeoclimatic zone, with limited extension into the Montane Spruce (MS) zone (Braumandl et al. 1996). Biogeoclimatic subzones and variants include the IDFxk, IDFdm2 and MSdk at Columbia Lake, the IDFdm2 at Premier Ridge, and the IDFdm2 and MSdk at Bull River and Mount Broadwood (Ministry of Forests and Range 2006). Under climax conditions, the IDF typically consists of both open and closed stands of Douglas-fir (*Pseudotsuga menziesii*) on zonal sites. Where ground fires were frequent, large, widely spaced, mature trees with thick bark are prevalent. Where crown fires have occurred, lodgepole pine (*Pinus contorta*) typically occurs amongst the Douglas-fir, and trembling aspen (*Populus tremuloides*) clones are common on mesic sites, especially on alluvial fans. Grasslands or grass-shrublands often occupy more xeric sites in the IDF, especially those with an extensive fire history. These typically occur as small, isolated patches (e.g. Bull River), but larger grasslands do occur in some portions of the Trench (e.g. Mount Broadwood, east Columbia Lake, Premier Ridge). Adjacent to rivers and some streams and ponds, the IDF is typified by marsh or by forested riparian habitat dominated by hybrid white spruce (*Picea engelmannii* x *glauca*) and black cottonwood (*Populus balsamifera trichocarpa*). Climax conditions described above have been altered to a large extent by variable patterns of wildfire or fire suppression and a history of logging, agricultural and residential development, Christmas tree culturing, road building, off-road vehicle use, and grazing by livestock and wildlife. Within the MSdk, sheep winter ranges in the study areas are limited almost entirely to lower-elevation sites dominated by open-growing lodgepole pine stands or exposed rock. Whether in the IDF or MS, sheep winter ranges are dominated by mesic to xeric moisture regimes.

2.4 Vegetation

Although biogeoclimatic zone, subzone, variant and site series designations have evolved considerably in the past 5 decades, one of the original classification schemes for the IDF in the Columbia valley (McLean and Holland 1958) provides an excellent, simplified framework for discussing vegetation patterns on bighorn winter ranges. Those authors divided the IDF into two subzones and the wetlands (hydroseres). The subzones have been designated as Douglas-fir groveland and Douglas-fir forest (McLean and Holland 1958).

The Douglas-fir groveland subzone occupies the driest portions of the valley, and generally occurs on dry benches and south-facing lower slopes. With an increase in moisture-holding capacity, reduced evaporation or increased precipitation, this subzone develops into the Douglas-fir forest subzone (McLean and Holland 1958). Vegetation expression is influenced greatly by extreme terrain variability (i.e. aspect, slope and exposure). This results in a mosaic of vegetation associations within a relatively small geographic area.

2.4.1 Douglas-fir Groveland Subzone

Due to the savannah or park-like nature of this subzone, islands of grassland occur amongst scattered scrubby trees of Douglas-fir and Rocky Mountain juniper (*Juniperus scopulorum*). The fescue/snowberry and Douglas-fir/wheatgrass associations can be found within this subzone (McLean and Holland 1958). The first association is characterized by an equal occurrence of bluebunch wheatgrass (*Elymus spicatus*) and fescue (both *Festuca idahoensis* and *F. campestris*). Commonly associated shrub and forb species include: western snowberry (*Symphoricarpos occidentalis*), saskatoon (*Amelanchier alnifolia*), rose (*Rosa* spp.), soopolallie (*Shepherdia canadensis*), kinnikinnick (*Arctostaphylos uva-ursi*), rosy pussytoes (*Antennaria microphylla*), timber milk-vetch (*Astragalus miser*), hairy golden-aster (*Heterotheca villosa*), brown-eyed Susan (*Gaillardia aristata*), lemonweed (*Lithospermum ruderale*), long-leaved daisy (*Erigeron corymbosus*) and thread-leaved daisy (*Erigeron filifolius* var*. filifolius*). In some shrubland areas, antelope-bush (*Purshia tridentata*) predominates.

The second association (Douglas-fir/wheatgrass) represents the climatic climax for this subzone (McLean and Holland 1958). Although the ground cover is similar to the previous association, there is an increase in snowberry and rose. Sandberg bluegrass (*Poa secunda*) is common and pinegrass (*Calamagrostis rubescens*) may occur locally in moist sites, especially on east slopes. In sandy areas, common rabbit-brush (*Chrysothamnus nauseosus*), wolf-willow (*Elaeagnus commutata*) and creeping juniper (*Juniperus horizontalis*) are common. This association can also be found within the bluebunch wheatgrass/fescue association, where it is restricted to the driest sites and shallow soils.

2.4.2 Douglas-fir Forest Subzone

This subzone is the most extensive plant community in the study area and consists of a number of different associations depending upon the site factors. Two of the most prominent associations are the Douglas-fir/pinegrass and the Douglas-fir/snowberry. The former represents the climatic climax for this subzone (McLean and Holland 1958).

The principal shrubs include soopolallie, rose, kinnikinnick and twinflower (*Linnaea borealis*). After fire, willows (*Salix* spp.) and dwarf blueberry (*Vaccinium caespitosum*) are common during the early seral stages. Associated forb species include: showy aster (*Aster conspicuus*), timber milk-vetch, creamy peavine (*Lathyrus ochroleucus*), wild strawberry (*Fragaria virginiana*) and heart-leaved arnica (*Arnica cordifolia*). American vetch (*Vicia americana*) and peavine are common on the moister sites especially within aspen clones on deeper soils. Pinegrass and kinnikinnick constitute the dominant species depending upon the fire history. The latter is very susceptible to fire damage.

In moist depression areas and on deep soils, common snowberry (*Symphoricarpos albus*) increases in abundance, resulting in the Douglas-fir/snowberry association. Associated species include rose, birch-leaved spirea (*Spiraea betulifolia*), creeping Oregon-grape (*Mahonia repens*), wolf-willow, soopolallie and saskatoon.

Throughout this subzone, tame forage mixes have been seeded in an attempt to increase the forage production for cattle grazing and for reclamation. This has introduced species such as Canada bluegrass (*Poa compressa*), Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratense*), white clover (*Trifolium repens*), yellow clover (*Trifolium aureum*), alfalfa (*Medicago sativa*), black medick (*Medicago lupulina*) and sweet-clover (*Melilotus alba* and *M. officinalis*). These species have spread throughout the Bull River and Mount Broadwood study areas and threaten many native rangeland species.

3.0 Capture and Monitoring

For the 3 radiotelemetry study areas, 33 adult bighorn ewes were darted with a ketamine hydrochloride/xylazine hydrochloride mixture and fitted with VHF radiocollars (Table 1). Collaring occurred on 27 January 1997 (10 ewes) and 28 January 1998 (1 ewe) at Columbia Lake, 20 February 1997 (10 ewes) and 27 January 1998 (2 ewes) at Bull River, and 12-20 January 1999 (10 ewes) at Mount Broadwood. Sheep collared are listed in Table 1.

Sheep were radiotracked mainly from vehicles and by foot using triangulation, with visual confirmation of locations whenever possible. Aerial telemetry from a fixed-wing aircraft was occasionally undertaken when sheep could not be located from the ground. Universal Transverse Mercator (UTM) coordinates were recorded for each location, along with notes regarding the habitat type and any other sheep present. For the first 2 years after collaring, radiocollared ewes were located roughly 3 times per week during winter (1 December through 30 April), with less intensive monitoring (typically less than once per week) in other seasons and years. Monitoring continued from the date of collaring until death, loss of radio signal (either due to collar malfunction or perhaps emigration), or 28 April 2000, whichever came first. Incidental observations of untagged ewes were also recorded. During this period, 2171 radiolocations were obtained (Figure 2), including 1844 from radiotagged ewes on winter ranges (primarily 1 December to 30 April), 89 on winter ranges from ewes that were untagged and not accompanied by tagged ewes, and 237 aerial locations (93 of which were made during December – April but were not on winter ranges).

Table 1. Bighorn ewes radiocollared on 3 East Kootenay winter ranges, 1997-1999. Data missing for ewes collared to replace those dying at Columbia Lake and Bull River.

Sheep	Date Collared	Frequency	L Eartag	R Eartag
Columbia Lake 1	27-Jan-97	153.927	blue 130	green 125
Columbia Lake 2	27-Jan-97	153.898	orange 147	blue 139
Columbia Lake 3	27-Jan-97	153.965	blue 136	orange 149
Columbia Lake 4	27-Jan-97	153.808	blue 143	yellow 142
Columbia Lake 5	27-Jan-97	153.875	yellow 140	orange 150
Columbia Lake 6	27-Jan-97	153.838	orange 148	yellow 144
Columbia Lake 7	27-Jan-97	153.948	yellow 150	blue 138
Columbia Lake 8	27-Jan-97	153.651	blue 137	blue 141
Columbia Lake 9	27-Jan-97	153.987	yellow 149	yellow 145
Columbia Lake 10	27-Jan-97	153.858	orange 142	orange 143
Columbia Lake 11	28-Jan-98			
Bull River 1	20-Feb-97	153.846	orange 7	orange 6
Bull River 2	20-Feb-97	153.885	yellow 9	yellow 10
Bull River 3	20-Feb-97	153.827	blue 12	blue 11
Bull River 4	20-Feb-97	153.977	yellow 6	blue 13
Bull River 5	20-Feb-97	153.917	orange 13	blue 15
Bull River 6	20-Feb-97	153.864	orange 12	yellow 7
Bull River 7	20-Feb-97	153.629	yellow 21	orange 5
Bull River 8	20-Feb-97	153.958	blue 16	orange 18
Bull River 9	20-Feb-97	153.937	blue 14	yellow 16
Bull River 10	20-Feb-97	153.610	blue 6	
Bull River 11	27-Jan-98			
Bull River 12	27-Jan-98			
Mount Broadwood 1	12-Jan-99	153.716	blue 8	yellow 8
Mount Broadwood 2	12-Jan-99	153.864	orange 1	blue 3
Mount Broadwood 3	13-Jan-99	153.495	yellow 3	orange 3
Mount Broadwood 4	14-Jan-99	153.563	yellow 4	yellow 5
Mount Broadwood 5	14-Jan-99	153.726	orange 2	orange 4
Mount Broadwood 6	14-Jan-99	153.286	blue 4	blue 5
Mount Broadwood 7	19-Jan-99	153.319	yellow 11	blue 7
Mount Broadwood 8	20-Jan-99	153.435	blue 9	orange 8
Mount Broadwood 9	20-Jan-99	153.535	orange 11	yellow 13
Mount Broadwood 10	20-Jan-99	153.447	yellow 12	

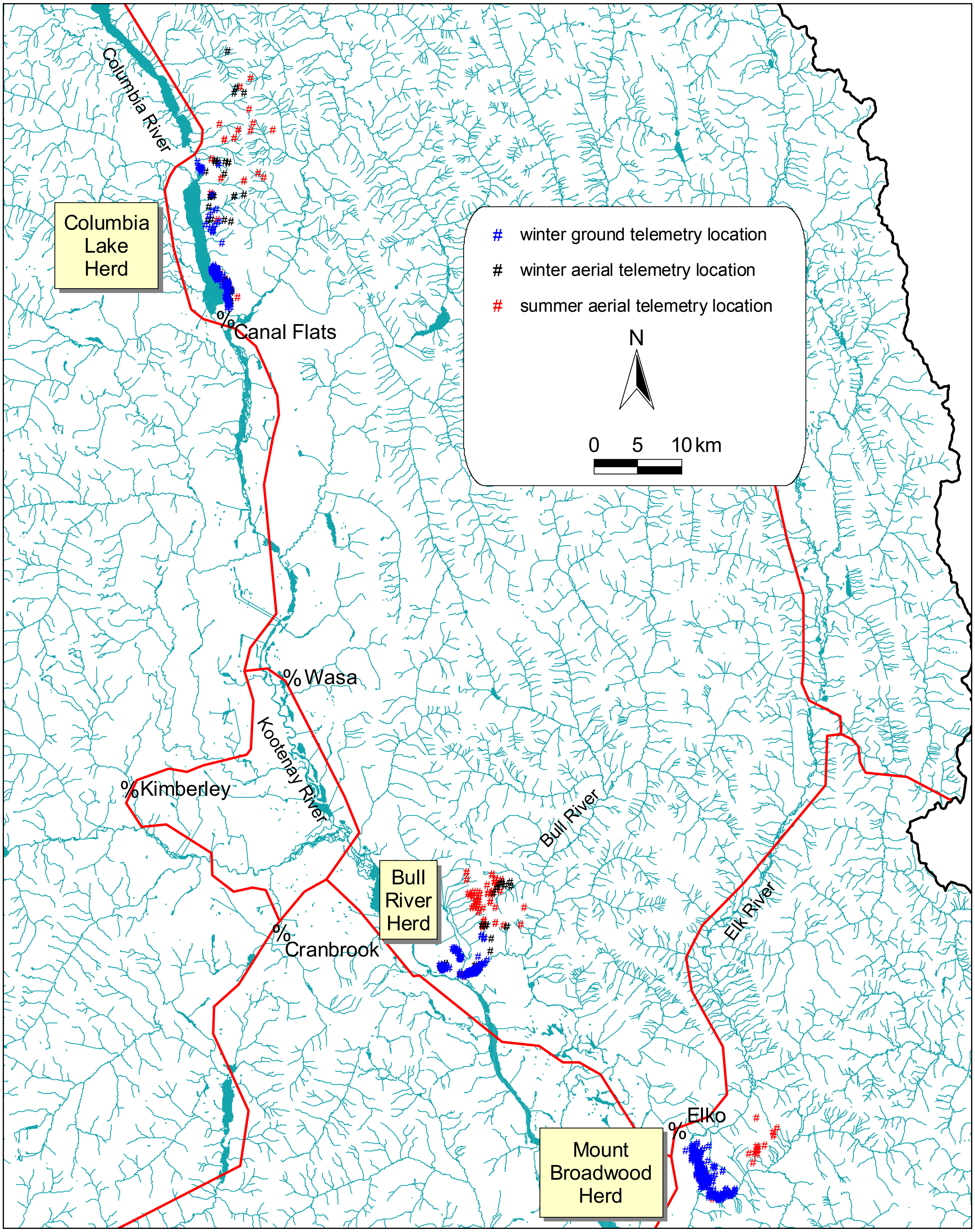

Figure 2. Winter (Dec – Apr) and summer (May – Nov) telemetry locations for bighorn ewes collared on Columbia Lake, Bull River and Mount Broadwood winter ranges, 1997-2000.

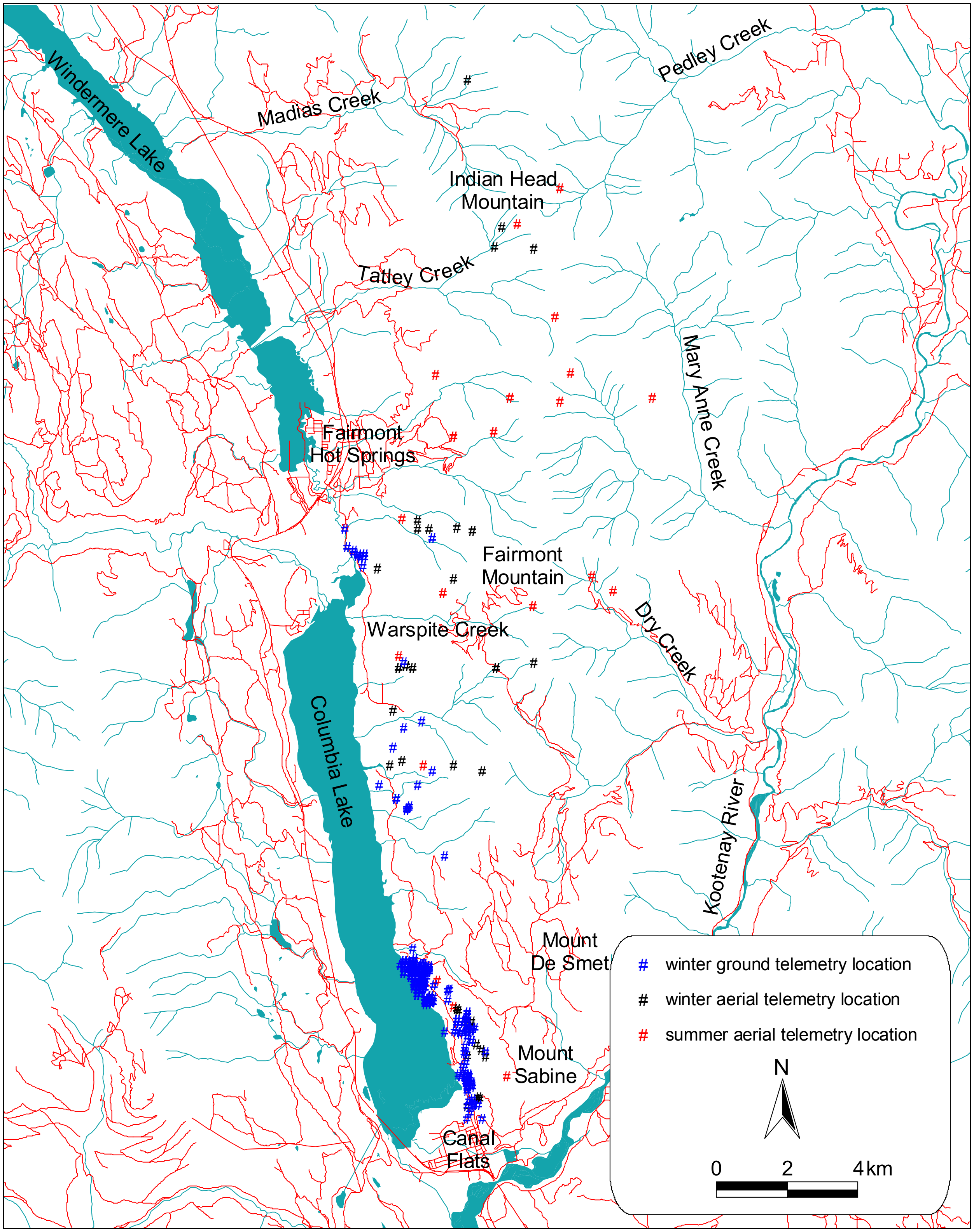

Figure 3. Winter (Dec – Apr) and summer (May – Nov) telemetry locations for bighorn ewes collared on Columbia Lake winter range 1997-2000.

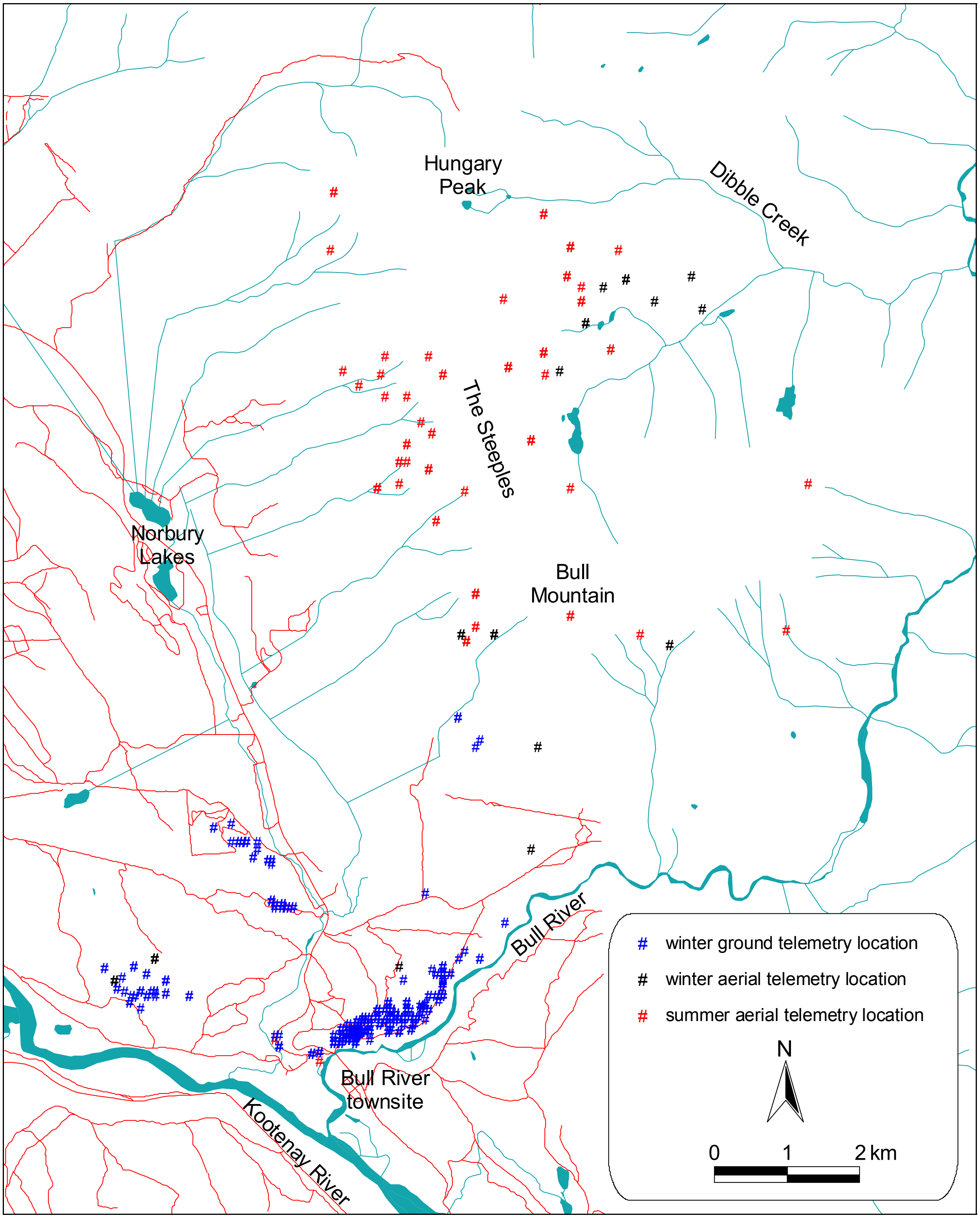

Figure 4. Winter (Dec – Apr) and summer (May – Nov) telemetry locations for bighorn ewes collared on Bull River winter range, 1997-2000.

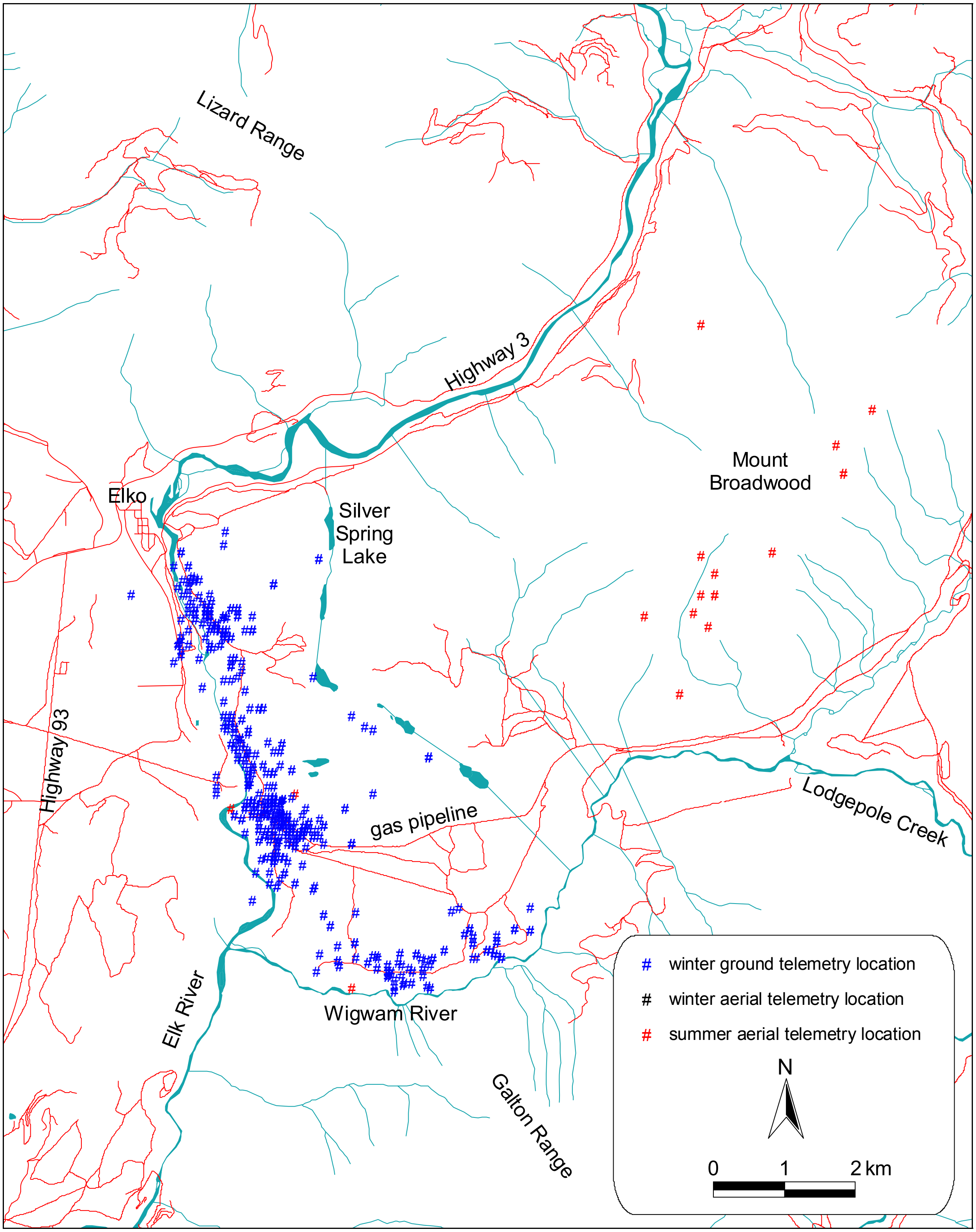

Figure 5. Winter (Dec – Apr) and summer (May – Nov) telemetry locations for bighorn ewes collared on Mount Broadwood winter range, 1999-2000.

4.0 Mortalities

Of the 33 ewes, 3 died at each of the 3 study sites during the monitoring period. Mortalities at Columbia Lake and Bull River were of variable causes, but those at Mount Broadwood were all cougar kills (Table 2). Survivorship rates and models describing mortality are outlined in Chapter 1.

Table 2. Bighorn ewe mortality causes and dates at 3 East Kootenay study sites, 1997-2000. Monitoring ended 18 April 2000.

Sheep ID	Collaring Date	Mortality Date	Mortality Cause
Columbia Lake 1	27-Jan-97	20-Apr-00	cougar predation
Columbia Lake 8	27-Jan-97	10-Mar-99	avalanche/rock fall
Columbia Lake 9	27-Jan-97	14-Jul-97	unknown (not predation)
Bull River 1	20-Feb-97	11-Jan-98	avalanche
Bull River 3	20-Feb-97	28-May-97	drowning
Bull River 6	20-Feb-97	06-May-98	unknown (possible predation)
Mount Broadwood 4	14-Jan-99	20-Apr-00	cougar predation
Mount Broadwood 9	20-Jan-99	02-Feb-00	cougar predation
Mount Broadwood 10	20-Jan-99	12-Mar-99	cougar predation

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Chapter 2. Survival Rates

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Summary

Of 33 bighorn sheep collared at Columbia Lake, Bull River and Mount Broadwood, 9 died during the course of the study. The main known cause was predation by cougars. The "known fate" binomial model survival rate analysis method, as incorporated in program MARK, was used to obtain survival rate estimates. The most supported model pooled survival rates from all the areas and seasons, suggesting that there was minimal difference between study areas given the sample sizes and subsequent variances of survival rate estimates. Other models potentially indicated differences between Mount Broadood and the other study areas, either with or without a seasonal effect (possibly because sheep were monitored later at Mount Broadwood than at the other study areas), but these models were less supported by study results. Seasonal (winter or summer) estimates of annual survivorship among the 3 herds ranged from 0.81 to 0.90.

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1.0 Introduction

The main purpose of this report is to provide survival rate estimates for bighorn sheep collared in the southeast Kootenay between 1997 and 2001.[4]

2.0 Methods

2.1 Data Screening

The survival rate data used in this study came from 12, 11, and 10 collared bighorn ewes in the Bull River, Columbia Lake and Mount Broadwood areas. Most of the sheep in the Bull River and Columbia Lake area were collared in January and February 1997. The sheep in the Mount Broadwood area were collared in January of 1999. Collars were monitored until April 28, 2000.

The most biologically meaningful sampling periods correspond to winter and summer and therefore sighting data was broken down into these primary periods for the analysis. The period from December to April was used as the winter period (5 months) with the other 7 months pertaining to the summer period. Data were compiled into a “Live-Dead” x-matrix format for input into program MARK (White and Burnham 1999). This resulted in 4 winter and 3 summer sampling sessions for the Bull River and Columbia Lake areas and 2 winter and 1 summer sampling session for the Mount Broadwood area. Each of the areas was entered as a group into program MARK therefore allowing all areas to be considered simultaneously in model fitting efforts.

2.2 Survival Analysis

The “known fate” binomial model survival rate analysis method, as incorporated in program MARK, was used to obtain survival rate estimates. The known-fate models allow staggered entry of data into models (Pollock et al. 1989), therefore allowing the Mount Broadwood sheep to be added to the data set at a later date in the analysis. The survival rate unit used in the analysis was annual survival since this is the most easily interpreted unit.

The fundamental objective of estimation is to use the simplest model which explains the most variation in the data for survival estimates. Various models were built in program MARK that considered time-specific variation in survival rates and other relationships as described in the next section. The fit of models was evaluated using the Akaike Information Criterion (AIC) index of model fit. The model with the lowest AICc score was considered the most parsimonious thus minimizing estimate bias and optimizing precision (Burnham and Anderson 1998). Delta AICc (ΔAICc) values were also used to evaluate the fit of models when their AICc scores were close. In general, any model with a Delta AICc score of less than 2 was considered to be tied with the most supported model and therefore also considered.

[4] The original intent of this chapter was likely to provide mortality data to combine with recruitment estimates for predicting population status changes. However, in the 5 or 6 years since the chapter was written, updated population estimates have indicated substantial growth in all 3 herds (see Chapter 6), making such estimates unnecessary. Thus, the main value of this paper will be for potential future analyses examining long-term demographic trends.

It often occurs that more than one model explains the variation in a data set. In this case many models will be shown to be supported by the data (as indicated by ΔAICc values of less than 2). Model averaging was used to confront this problem. Model averaging averages the parameter estimates from each model by the degree of support that the model receives from the data as indexed by AICc weights. An AICc weight is simply the proportional degree of support for each model in the data set. The models with larger AICc weights contribute more to the model-averaged estimate. This approach is much more robust than using one model (as with most traditional analyses) especially when data are sparse (Burnham and Anderson 1998).

2.3 Models Proposed

The following general models were proposed and evaluated in program MARK using AICc methods.

Study area effects on survival
It is possible that sheep in each area exhibited different survival rates. One reason for this might be different predation pressure, disturbance, or other habitat-based variables. Another sampling-based reason is that the Mount Broadwood area was only monitored for the last three sessions of the survival analysis. Therefore, this area may show a different rate of survival especially if survival rates were different during the last years of the study. Different survival-rate models were introduced for sheep at Mount Broadwood than those at Columbia Lake and Bull River.

Seasonal effects on survival
It is probable that sheep exhibit different survival rates as a function of season. Building models that estimated survival rates for seasons separately explored this effect. The fit of these models was compared with models that pooled survival rates.

Collaring effects on survival rates
One assumption of the estimation of survival rate is that the collared sheep represent a random sample of the population of bighorn sheep. One potential way that this assumption can be violated is if capture for collaring affects immediate survival rates after capture. If capturing reduces immediate survival, then survival rates for the population will be negatively biased. The effect of collaring on survival rate was tested by explicitly estimated the survival rates for sheep for the period after capture. This would have been the winter of 1997 for Bull River and Columbia Lake sheep and the winter of 1999 for Mount Broadwood sheep. This survival rate was then compared with survival rates for other sampling periods. If survival was reduced substantially, then an immediate collaring effect might have been possible.

3.0 Results

Of the 33 collared sheep, 9 died during the course of the study. Of the 9 that died, 4 were due to cougar predation, 2 were due to avalanche, 1 drowned, and 2 died due to unknown causes. The most supported model (Table 1, Model 1) pooled survival rates from all the areas, suggesting that there was minimal difference between areas given the sample sizes and subsequent variances of survival rate estimates. A model that pooled Bull River and Columbia Lake but estimated Mount Broadwood separately (Model 2) was also supported as indicated by

ΔAICc values of less than 2. Support for this model suggested that survival rates between Mount Broadwood and other areas may be different, potentially due to the different period of monitoring for the Mount Broadwood area. Another model, which provided season-specific estimates for the pooled Bull River and Columbia Lake and separate season-specific estimates for the Mount Broadwood, was also supported suggesting that there was a potential difference in estimates between areas as a function of season. A model which estimated survival rates for the immediate post-collaring and subsequent sessions was also supported, but the estimate for initial collaring was higher than subsequent sessions suggesting that there was no collaring effect. Other models which considered pooled season effects (Model 5), area effects (Model 6), area and season effects (Model 7), temporal effects (Model 8) and area and temporal effects (Model 9) were not supported by the data.

Table 1. AIC model selection results.

No.	Model	Model Description	AICc	ΔAICc	AICc Weight	No. Par.[1]
1	S(.)	All areas pooled	71.661	0.000	0.281	1
2	S(br-cl & mb)	Bull R. - Columbia L. pooled	72.291	0.630	0.205	2
3	S((br&cl-mb)*season)	Model 2 season specific	72.527	0.866	0.182	4
4	S(collar effect)	Collaring effects	73.488	1.827	0.113	2
5	S(season)	Seasonal effects	73.664	2.003	0.103	2
6	S(areas)	Study areas separate	74.368	2.707	0.073	3
7	S(areas*season)	Model 6 season specific	76.812	5.151	0.021	6
8	S(t)	Areas pooled session specific	76.883	5.222	0.021	7
9	S(areas*t)	Areas separate session specific	93.395	21.734	0.000	17

[1]Number of parameters in model

The pooled survival rate estimate from model 1 was 0.886, (SE=0.035. CI=0.795-0.939). This estimate pertains to all study areas and all seasons under the assumption that there is minimal difference between study areas and seasonal survival rates. The best way to interpret area and season specific estimates is through model-averaged estimates (Table 2).

Table 2. Model-averaged area and season estimates.

Area	Season	Estimate	SE	CI
Bull River	Winter	0.890	0.047	0.76-0.95
	Summer	0.897	0.047	0.75-0.96
Columbia Lake	Winter	0.903	0.047	0.76-0.96
	Summer	0.887	0.046	0.75-0.95
Mount Broadwood	Winter	0.884	0.086	0.59-0.97
	Summer	0.808	0.085	0.48-0.95

From Table 2 it can be seen that the difference between seasonal survival rates is minimal for Bull River and Columbia Lake, and slightly more substantial for Mount Broadwood. However, the larger variance and confidence interval width of the Mount Broadwood estimates (presumably due to the low number of sessions monitored) limits interpretation of this finding.

4.0 Discussion

This analysis has several assumptions that should be considered when interpreting estimates. First, it is assumed that the radiocollared sheep are a random and representative sample of all bighorn sheep from each study area. Second, it assumes that collaring and the presence of collars does not affect survival of an individual collared sheep. Of the assumptions listed, the only one which was tested was the effect of initial collaring on survival rates. Analysis suggests that there is minimal difference between these rates. These assumptions should be scrutinized carefully; if they are violated then the estimates in this paper only pertain to the collared sheep, and not the entire bighorn sheep population.

A more important limitation is low sample sizes of monitored sheep especially for the Mount Broadwood sheep population. AICc model fitting in program MARK allows objective pooling of data between study areas and therefore partially minimizes the problem of low sample sizes for each area. For example, precision of survival rate estimate would be much lower if each area was analyzed separately. However, survival rate estimates should be interpreted in unison with confidence interval widths and variance estimates, especially in the case of the Mount Broadwood study area.

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Chapter 3. Micro-habitat Selection

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Executive Summary

Bighorn sheep wintering at low elevations in the East Kootenay Trench are well below historic numbers. Reasons for these low numbers are not known, although speculation abounds regarding habitat degradation, predators, disease, and human harassment on winter ranges. Habitat management prescriptions have been suggested but specific plans cannot be formulated without an objective assessment based on current empirical data collected in the East Kootenay Trench. The East Kootenay Wildlife Association embarked on a 5 year project to examine the ability of the fall through spring bighorn ranges at Columbia Lake, Bull River, and Mount Broadwood to support bighorns.

Bighorn ewes were radiocollared and radiotracking was conducted between 1997 and 2000 at the 3 fall through spring ranges. Radiotracking occurred primarily from the ground. Each study area was monitored intensively over 2 winters. The winter period was defined as from the beginning of December through until the end of April. During winters of intensive monitoring, all radiocollared ewes were located approximately 3 times per week. In statistical tests, we contrasted bighorn ewe radiolocations collected between December and April with available habitat. Sheep locations were buffered with a 100-m radius circle to take into account mapping error, and the areas within the buffered points were sampled randomly. Available habitat was determined using a stratified random sample of the 100% minimum convex polygon (MCP) winter range of all radiocollared sheep at each study area. Variables used in the analysis were primarily topographical (e.g., elevation, aspect) or derived from 1:20,000-scale ecosystem mapping of the 3 ranges, that is, terrestrial ecosystem mapping (TEM). In addition, a greenness index derived from Landsat 5 TM satellite imagery was used to examine possible relationships between bighorn sheep distribution and this index of landscape productivity. Using TEM, univariate crosstabulations of use versus availability were conducted for site series and structural stages of the 2 primary vegetation communities within each ecosite. Discriminant function analysis (DFA) was used to conduct a multivariate analysis of bighorn sheep habitat use within the 3 study areas. Two DFAs were conducted for each study area, one including all variables and the second excluding variables from the TEM data. Binary models were developed to contrast land used by bighorn sheep with land that was not used within the 100% MCP cumulative winter range.

Thirty-two bighorn ewes were radiotracked at the 3 study areas and 2,092 radiolocations were collected between December and April. Radiocollared bighorn ewes used habitat in a predictable fashion in all 3 study areas. Results from the different univariate and multivariate analyses of the radiotelemetry data showed strong correlations between ewe distribution and several habitat types that provided life requisites: forage, security, and thermal cover. Over all 3 study areas, bluebunch wheatgrass site series were selected for, typically in the earlier seral stages such as grass/forb and shrub/herb. Selection for these within the second decile (the second most abundant site series within an ecosite) was sometimes directed toward older structural stages in which open stands of Douglas-fir occurred with understories of bluebunch wheatgrass. In addition, the attraction to artificial opening was evident at 2 of the 3 study areas. Abandoned fields at Bull River and Mount Broadwood were strongly selected in the first decile. All site series strongly selected by bighorn ewes contained forage in the form of grasses, herbs, and/or shrubs. This emphasizes the generalist foraging strategy of bighorn sheep. They are capable of digesting a wide variety of plant species and many different forage species contribute to their diet. Site series in the second decile were an important part of bighorn ewe habitat selection. The DFA using all variables demonstrated this; site series in the second decile were contributors to the multivariate model in all 3 study areas. In some cases (e.g., Columbia Lake), a bluebunch wheatgrass site series from the second decile was ranked higher in importance to

the model than the same site series in the first decile. These site series may be smaller inclusions of preferred habitat in a matrix of less suitable habitat. Crosstabulations of use versus availability showed the importance of escape terrain in the second decile at Bull River and Columbia Lake. Rock outcrops were strongly selected at Columbia Lake while at Bull River, talus was strongly selected in the second decile. A greenness band derived from Landsat 5 TM satellite images appear to be well-correlated with ewe winter range use in the East Kootenay Trench. Radiocollared bighorn ewes strongly selected lower greenness values than would be expected by chance. Topographical variables demonstrated the importance of terrain attributes to bighorn ewe habitat selection. Elevation, and bighorns' selection for lower elevations within their winter ranges, was ranked high in all models. Lower elevations within the winter ranges likely have less snow accumulation through the winter than higher elevations making for easier foraging by bighorns. Steep terrain, distance to steep terrain, and terrain ruggedness all provide some measure of ewe habitat selection for security. These attributes appear to correlate well with escape terrain. In most DFAs, at least one of these variables was a significant contributor to the model. Increased terrain ruggedness, increased slope, and decreased distance to steep terrain characterized ewe habitat selection. Aspect, another topographical variable, was another frequent contributor to the DFAs. In particular, southerly aspects tended to be strongly selected. Southerly aspects have greater exposure to solar radiation in the winter and as such accumulate less snow. In the same manner as lower elevations, southerly aspects are preferred feeding sites since bighorns have to dig less to gain access to forage.

This analysis emphasizes some of the strengths and weaknesses of using TEM as a tool to examine bighorn sheep habitat relationships. The TEM variables showed strong correlations with bighorn sheep habitat use. By identifying site series and structural stages that are strongly selected as well as those strongly avoided by bighorn ewes, habitat manipulations can be specifically targeted to increase the ability of the winter range to support sheep. In particular, ecosites with preferred site series (e.g., a bluebunch wheatgrass type) but occurring in structural stages that are avoided by bighorns can be targeted for habitat enhancement. These sites could be manipulated to bring them back to an earlier seral stage (i.e., a lower structural stage), one that is preferred by sheep. These management prescriptions can be very specific so that only those ecosites that are occurring in proximity to ecosites that are heavily used by bighorns are manipulated. This should increase the likelihood that habitat enhancement sites will be discovered quickly by bighorns on the winter range. A weakness of the TEM data is its limited areal extent. Even though sheep populations at the 3 study areas are currently low relative to historic numbers, the 100% MCP winter range in each study area extended beyond the boundaries of the TEM area. Data regarding habitat selection of ewes outside the TEM boundaries couldn't be used. Similarly, the results of the habitat selection analysis can only be applied to areas with TEM data in place. Bighorn winter ranges without TEM data cannot benefit from the analysis.

The topographical and satellite image based variables do not suffer from this problem. They are available across the landscape and relationships developed in the 3 study areas can be applied throughout low elevation sheep range on the east side of the Trench. In addition, although the DFAs which excluded the TEM variables were weaker than DFAs which used all available variables, they were not significantly weaker. Because the DFAs which did not incorporate the TEM variables used fewer variables that are more widely available and yet did not have significantly lower classification success, they are the preferred model from a regional perspective.

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Acknowledgements

A project of this size requires many helping heads, hands, and legs, too. Ian Ross was responsible for all the bighorn capture work. Saundi Stevens and many East Kootenay Wildlife Association volunteers helped out in the first year during mass captures. Irene Teske was responsible for the majority of the radiotelemetry work in the field. Sean Beswick, Saundi Stevens, and Danah Duke also contributed much time and effort. Jack Wierzchowski of Geomar Ltd. ably conducted the statistical analyses. B.C. Wildlife Branch personnel, particularly Gary Tipper, Bob Forbes, and Anna Fontana, provided government support. The East Kootenay Wildlife Association, and particularly Dave White, also provided many hours of volunteer assistance with project administration and fund raising support. Financial support was provided by British Columbia's Habitat Conservation Trust Fund, the Columbia Basin Fish and Wildlife Compensation Program, the Wild Sheep Society of B.C., the Foundation for North American Wild Sheep, and the East Kootenay Wildlife Association.

1.0 Introduction

Bighorn sheep populations in the East Kootenay Trench have undergone cyclic epizootic die-offs followed by slow recovery, with a general trend toward lower numbers. Bighorn sheep wintering at low elevations at East Columbia Lake, Bull River, and Mount Broadwood are well below historic numbers. Reasons for these low numbers are not known, although speculation abounds regarding habitat degradation, predators, disease, and human harassment on winter ranges. Habitat management prescriptions have been suggested but specific plans cannot be formulated without a objective assessment based on current empirical data collected in the East Kootenay Trench. The East Kootenay Wildlife Association embarked on a 5 year project to examine the ability of the fall through spring bighorn ranges at Columbia Lake, Bull River, and Mount Broadwood to support bighorns. Bighorn ewes were radiocollared and radiotracking has been conducted between 1997 and 2000 at the 3 winter ranges. This report is a preliminary statistical assessment of habitat selection by radiocollared ewes on these winter ranges.

2.0 Study Areas

Bighorn ewes have been radiotracked at 3 low-elevation winter ranges, Columbia Lake, Bull River, and Mount Broadwood, on the east side of the Kootenay Trench (Figure 1). See Chapter 1 for a description.

3.0 Methods

3.1 Radiotracking

Radiotracking occurred primarily from the ground. Each study area was monitored intensively over 2 winters. The winter period was defined as from the beginning of December through until the end of April. During winters of intensive monitoring, all radiocollared ewes were located approximately 3 times per week. Locations of radiocollared sheep were initially determined by triangulation. When the general area of a collared sheep was determined, then a visual location was determined whenever possible. Once a sighting was made, the general habitat type was recorded, as well as the presence of conspecifics.

3.2 Analysis

In statistical tests, we contrasted bighorn ewe radiolocations collected between December and April with available habitat. Sheep locations were buffered with a 100-m radius circle to take in account mapping error and the areas within the buffered points were sampled randomly. Available habitat was determined using a stratified random sample of the 100% minimum convex polygon (MCP) winter range of all radiocollared sheep at each study area. Variables used in the analysis are listed in Table 1 and were primarily topographical (e.g., elevation, aspect) or derived from 1:20,000-scale ecosystem mapping of the 3 winter ranges (terrestrial ecosystem mapping or earlier variants of it; hereafter TEM). In addition, a greenness index derived from Landsat 5 TM satellite imagery was used to examine possible relationships between bighorn sheep distribution and this index of landscape productivity.

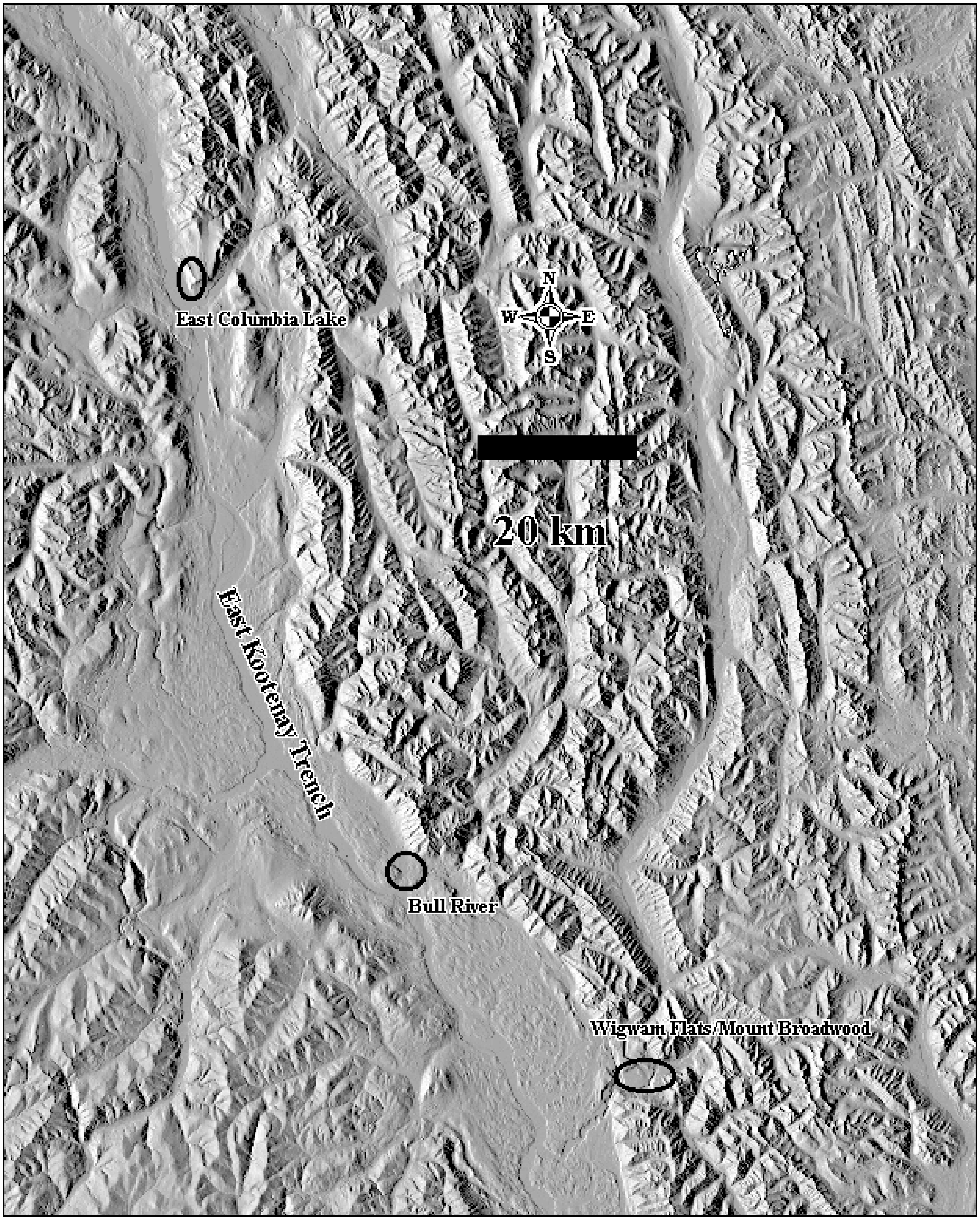

Figure 1. Locations of 3 low-elevation sheep ranges, Columbia Lake, Bull River and Mount Broadwood, in the East Kootenay Trench.

3.2.1 Univariate Analysis of Terrestrial Ecosystem Mapping Variables

Using TEM, univariate crosstabulations of use versus availability were conducted for site series and structural stages of the 2 primary vegetation communities within each ecosite to determine if radiocollared ewes were using the winter range within their 100% MCP winter ranges in a random manner. The sign and value of adjusted residuals were used to determine the strength of selection or avoidance. Absolute values of adjusted residuals of greater than or equal to 3 standard deviations indicated significant selection or avoidance at the 99% level.

3.2.2 Discriminate Function Analysis

Discriminant function analysis (DFA) was used to conduct a multivariate analysis of bighorn sheep habitat use within the 3 study areas. Two DFAs were conducted for each study area, one including all variables and the second excluding variables from the TEM data. We used the Mahalanobis distances criterion in the stepwise method for variables' entry and removal. Binary models were developed to contrast land used by bighorn sheep with land that was not used within the 100% MCP cumulative winter range. We judged the relative contribution of the variables by analyzing the order in which the variables were entered/removed, combined with the analysis of the structure matrix and the magnitude of the Standardized Canonical Coefficients. If DFA is to be used as a predictive tool, then the Standardized Canonical Coefficients should be given a greater weight. However, if there are several variables with Standardized Canonical Coefficients of significant size, then interpretation is more complex and the value of the Standardized Canonical Coefficients for individual variables may be misleading. A better understanding of the individual variables can be attained by examining the absolute value of the Structure Matrix Coefficients; higher values indicate greater importance to the model. We estimated the overall power of the models by scrutinizing the Eigenvalues, Wilk's Lambdas, Canonical Correlation Coefficients, and the percentage of correctly classified cases.

Table 1. Variables used in the analysis of bighorn sheep distribution in the Columbia Lake, Bull River and Mount Broadwood study areas.

Variable	Source
Site Series – first decile Structural Stage – first decile Site Series – second decile Structural Stage – second decile	1:20,000 scale Terrestrial Ecosystem Mapping (TEM)
Elevation Terrain ruggedness Slope (degrees) Aspects, 8 cardinal directions and flat	Digital Elevation Model (DEM)
Greenness	Landsat 5 satellite imagery, Bull R. & Columbia L. only (no image available at Mt. Broadwood)

3.2.3 General Linear Modeling (GLM)

General linear modeling (GLM) was used to examine the similarities and differences in availability and use of habitat within the 3 study areas. Estimated marginal means of topographical variables were contrasted between Columbia Lake, Bull River, and Mount Broadwood to test whether habitat availability and use were significantly different between the 3 winter ranges. TEM variables could not be used in this analysis because classification of site series and structural stages was not consistent across the 3 study areas.

4.0 Results

4.1 Radiotelemetry

4.1.1 Columbia Lake

Ten ewes were radiocollared in late January, 1997. These ewes were radiotracked on average 3 times per week until they left their winter range to lamb in early summer 1997. When they returned to the winter range in fall 1997, intensive radiotracking resumed. An additional ewe was radiocollared to replace a ewe that had died. Radiolocations were again collected on average 3 times per week for all ewes until they left their winter range in early summer 1998. Opportunistic monitoring, at an intensity of once per week or less was continued between December and April in 1998-99 and in 1999-2000. Six hundred thirty-two radiolocations were collected from ewes using the Columbia Lake winter range between 1997 and 2000. Most radiolocations, 73%, were collected during the first 2 winters (Table 2). Use of the Columbia Lake winter range was concentrated at the south end of the lake immediately north of Canal Flats (Figure 2). However, the cumulative 100% MCP for all radiocollared ewes included the entire east side of Columbia Lake between Canal Flats and Fairmont.

Table 2. Radiolocations collected each December – April period on each winter range.

Study Area	Year			
	1997	1997-1998	1998-1999	1999-2000
Columbia Lake	224	238	38	132
Bull River	170	340	45	167
Mount Broadwood			274	464

4.1.2 Bull River

Ten ewes were radiocollared in February, 1997. As was the case with the Columbia Lake ewes, these ewes were radiotracked on average 3 times per week until they left their winter range to lamb in early summer 1997. An additional 2 ewes were radiocollared to replace ewes that had died. When ewes returned to the winter range in fall 1997, intensive radiotracking resumed. Radiolocations were collected on average 3 times per week for all ewes until they again left their winter range in early summer 1998. Opportunistic monitoring, at an intensity of once per week or less was continued between December and April in 1998-99 and in 1999-2000. Seven hundred twenty-two radiolocations were collected from ewes using the Bull River winter range between 1997 and 2000. Most radiolocations, 70.6 %, were collected during the first 2 winters (Table 2). The majority of locations were along the north side of the Bull River although there were also centres of activity in the hills above and to the west of the Kootenay Trout Hatcher and on the Hawke Ranch farther north (Figure 3).

4.1.3 Mount Broadwood

Nine ewes were radiocollared in late January, 1999. These ewes were radiotracked on average 3 time per week until they left their winter range to lamb in early summer 1999. When they returned to the winter range in fall 1999, intensive radiotracking resumed. Radiolocations were collected for all ewes until they again left their winter range in early summer 2000. Seven hundred thirty-eight radiolocations were collected from ewes using the Mount Broadwood winter range between 1999 and 2000 (Table 2). Most radiolocations were in proximity to confluence of the Elk and Wigwam Rivers (Figure 4).

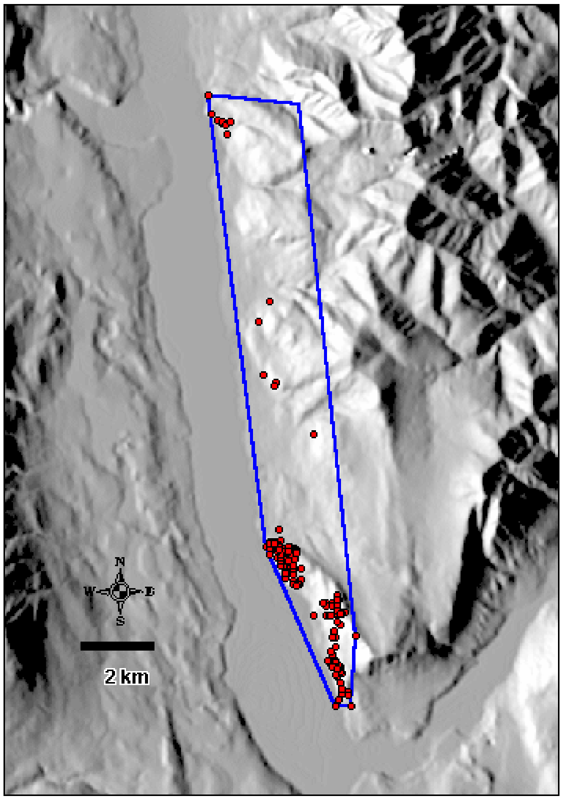

Figure 2. Radiolocations and 100% MCP of radiocollared ewes on the Columbia Lake winter range.

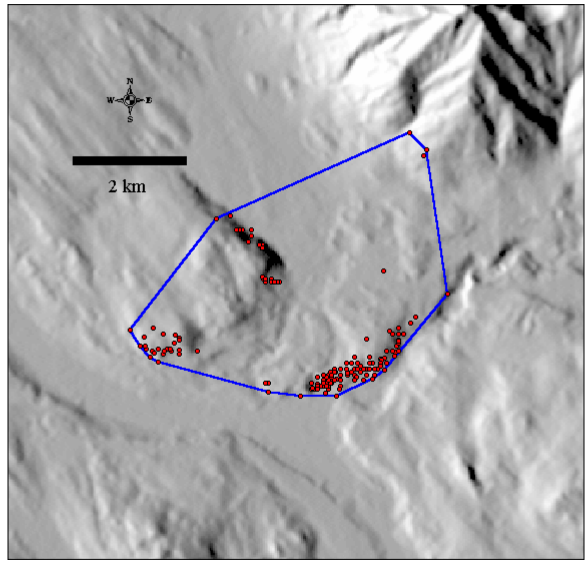

Figure 3. Radiolocations and 100% MCP of radiocollared ewes on the Bull River winter range.

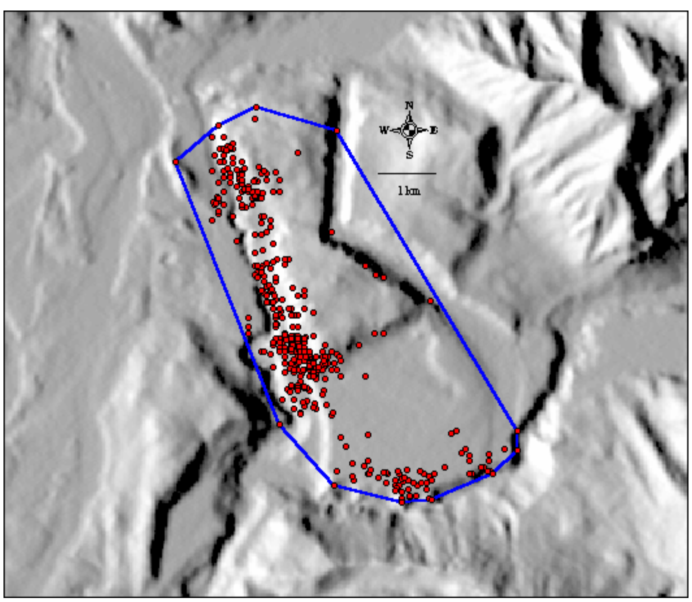

Figure 4. Radiolocations and 100% MCP of radiocollared ewes on the Mount Broadwood winter range.

4.2 Habitat Selection Analysis

Radiocollared bighorn ewes at all 3 study areas appear to be using habitat within their 100% MCP winter ranges in a non-random fashion based on a visual examination of the distribution of radiolocations within each winter range. Habitat selection analysis was conducted 2 ways. First, TEM variables for each winter range were used to examine sheep use relative to availability in a univariate manner. Second, DFA was employed using topographic, satellite, and TEM data to examine multivariate habitat selection.

4.2.1 Terrestrial Ecosystem Mapping (TEM)

Individual ecosites within the TEM database were composed of up to 3 vegetation communities (i.e., site series) and the areal extent of each site series within an ecosite was estimated to the nearest 10%. The first decile represented the most common site series, followed by the second decile, and the third. Each site series was described by dominant plant species (>20% cover) and associates (5-20% cover). In addition, each decile was assigned a structural stage, the current successional or seral stage of the site series at the time of mapping. Structural stage scales varied between the 3 study areas and site series were generally present at only 1 or 2 of the study areas (Table 3, Table 4). Analysis was restricted to the first 2 deciles.

Table 3. Structural stage scales used for the 3 terrestrial ecosystem mapping study areas. Source: JMJ Holdings 1994, Ketcheson et al. 1996, Marcoux et al. 1998.

Structural Stage	Columbia Lake	Bull River	Mount Broadwood
non-vegetated/sparsely vegetated	1	1	
grass/forb	2	2	
shrub/herb	3	3	1
low shrub	3a	3a	
tall shrub	3b	3b	
pole sapling	4	4	2
young forest	5	5	3
mature forest	6	6	4
old forest	7	7	5

<u>Columbia Lake</u>
Four site series were strongly selected by radiocollared bighorn ewes within the first decile. Pasture sage or saskatoon – bluebunch wheatgrass was most strongly selected, followed by the antelope brush – bluebunch wheatgrass, exposed soil, and Douglas-fir – Rocky Mountain juniper types (Figure 5). The most strongly-selected structural stages in the first decile were grass/forb, herb/shrub, and non-vegetated/sparsely vegetated (Figure 6).

Site series and structural stages strongly avoided by bighorn ewes were, in increasing order, black cottonwood/hybrid white spruce – red-osier dogwood, hybrid white spruce/trembling aspen – sarsaparilla, Douglas-fir – pinegrass – step moss, Douglas-fir/western larch – spruce – pine grass, lodgepole pine – Oregon grape – pinegrass, Douglas-fir – snowberry – balsamroot, lodgepole pine – juniper – pinegrass, Douglas-fir/lodgepole pine – pinegrass – twinflower, and hybrid white spruce – soopolallie – grouseberry (Figure 5), and the 4 structural stages avoided were pole sapling, and young, mature, and old forest (Figure 6).

Table 4 Site series from TEM mapping occurring as the primary or secondary constituent of map polygons within the range of collared bighorn ewes at Columbia Lake (CL), Bull River (BR) or Mount Broadwood (MB). Source: JMJ Holdings 1994, Ketcheson et al. 1996, Marcoux et al. 1998.

Symbol	Site Series or Cover Type	Zone[1]	CL	BR	MB
AF	abandoned field	any			x
AW	antelope-brush – bluebunch wheatgrass	IDF	x	x	
BD	Paper birch – red-osier dogwood	MS			x
BH	scrub birch – horsetail	MS			x
BJ	bluebunch wheatgrass – Jacob's ladder	MS			x
BP	bluegrass – pussytoes	MS			x
BS	beaked sedge – swamp horsetail	IDF	x		
BW	bulrush – water reed grass	IDF			x
CD	black cottonwood/hybrid white spruce – red-osier dogwood	IDF	x		
CF	cultivated field	any	x	x	
DB	Douglas-fir – bluebunch wheatgrass	IDF			x
DJ	Douglas-fir – Rocky Mountain juniper	IDF	x		
DM	Douglas-fir – mountain avens	IDF			x
DP	Douglas-fir – pinegrass – stepmoss	IDF	x		
DR	Douglas-fir – red-stemmed feathermoss	MS			x
DS	Douglas-fir – snowberry – balsamroot	IDF	x	x	
DT	Douglas-fir/lodgepole pine – pinegrass – twinflower	IDF	x	x	
ES	exposed soil	any	x		
GB	grey fray-capped moss – bluegrass	MS			x
GP	gravel pit	any		x	
JP	juniper – pinegrass	MS			x
LJ	lodgepole pine – juniper – pinegrass	MS	x		
LP	lodgepole pine – Oregon grape – pinegrass	MS	x		
LS	lodgepole pine – Saskatoon	MS			x
NV	non-vegetated	any		x	x
OV	tall Oregon-grape – velvet-leaved blueberry	MS			x
RI	river	any		x	x
RO	rock outcrop	any	x	x	
RP	road surface	any	x		
RU	rubble	any	x		
SB	snowberry – balsamroot	IDF			x
SG	hybrid white spruce – soopolallie – grouseberry	MS	x		
SM	saskatoon – Douglas maple	IDF			x
SP	Douglas-fir/western larch – spruce – pinegrass	IDF	x	x	
SS	hybrid white spruce/trembling aspen - sarsaparilla	IDF	x	x	
SW	pasture sage – bluebunch wheatgrass	IDF	x		
	or saskatoon – bluebunch wheatgrass	MS	x		
TA	talus	any	x	x	
UR	urban	any		x	
WB	western larch – birch-leaved spirea	MS			x
WS	western larch – snowberry	IDF			x

[1] biogeoclimatic zone; IDF = Interior Douglas-fir Zone, MS = Montane Spruce Zone

Pasture sage or saskatoon – bluebunch wheatgrass in the grass/forb structural stage is dominated by open grasslands of bluebunch wheatgrass. Antelope-brush – bluebunch wheatgrass in the same structural stage is dominated by openings of bluebunch wheatgrass associated with several other species, primarily antelope-brush, saskatoon, pasture sage, and Kentucky bluegrass. Douglas-fir – Rocky Mountain juniper ecosites selected for by bighorn ewes were primarily in the young and mature forest structural stages. These site series are dominated by open Douglas-fir stands associated with Rocky Mountain juniper, bluebunch wheatgrass, nodding onion, kinnikinnick, and pinegrass.

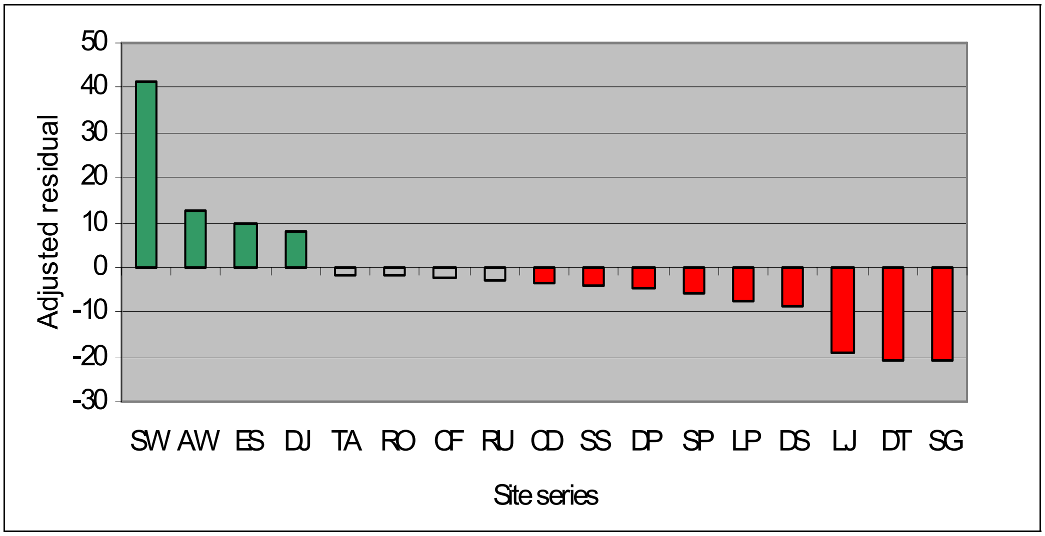

Figure 5. Selection for and against site series in the first decile by bighorn ewes at Columbia Lake as indicated by the adjusted residual statistic.

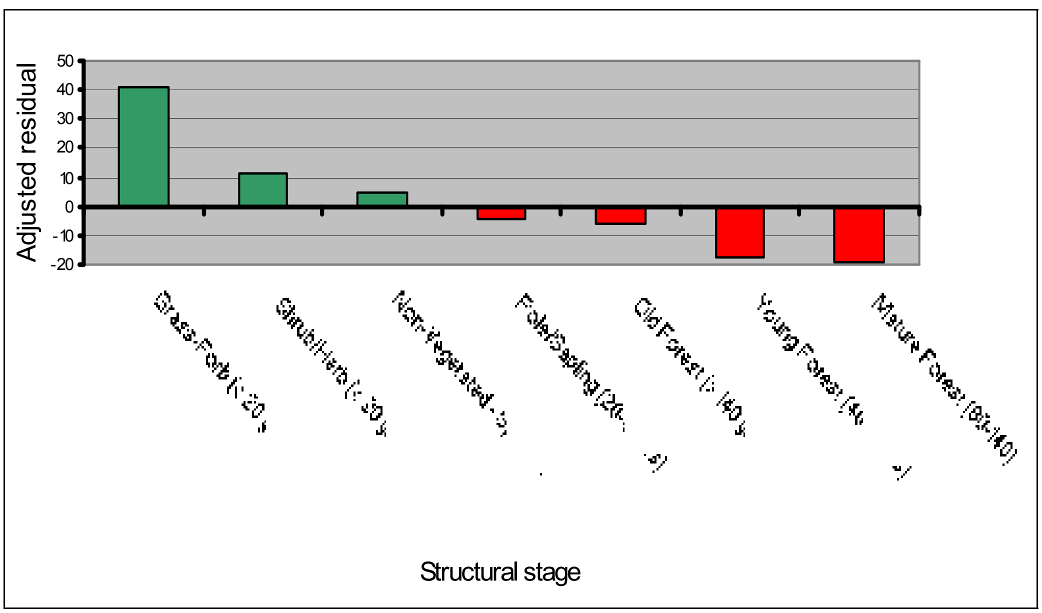

Figure 6. Selection for and against structural stages in the first decile by bighorn ewes at Columbia Lake as indicated by the adjusted residual statistic.

In the second decile, bighorn ewes again selected for pasture sage or saskatoon – bluebunch wheatgrass and Douglas-fir – Rocky Mountain juniper site series, but they were also found more often than expected in areas where rocky outcrops and road surfaces were present (Figure 7). All site series that were avoided in the first decile were also strongly avoided in the second.

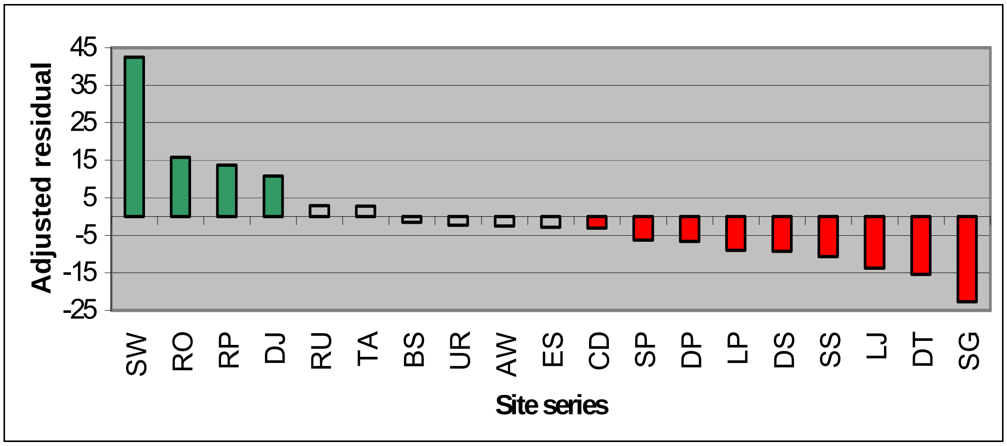

Figure 7. Selection for and against site series in the second decile by bighorn ewes at Columbia Lake as indicated by the adjusted residual statistic.

Grass-forb, non-vegetated/sparsely vegetated, and young forest were strongly selected in the second decile, while old forest, pole sapling, shrub-herb, and mature forest stages were strongly avoided (Figure 8). Vegetation on rocky outcrops accounted for less than 20% of the ground cover and was often dominated by low cover of saskatoon. However, plant cover could be very diverse in these communities depending on the microclimate.

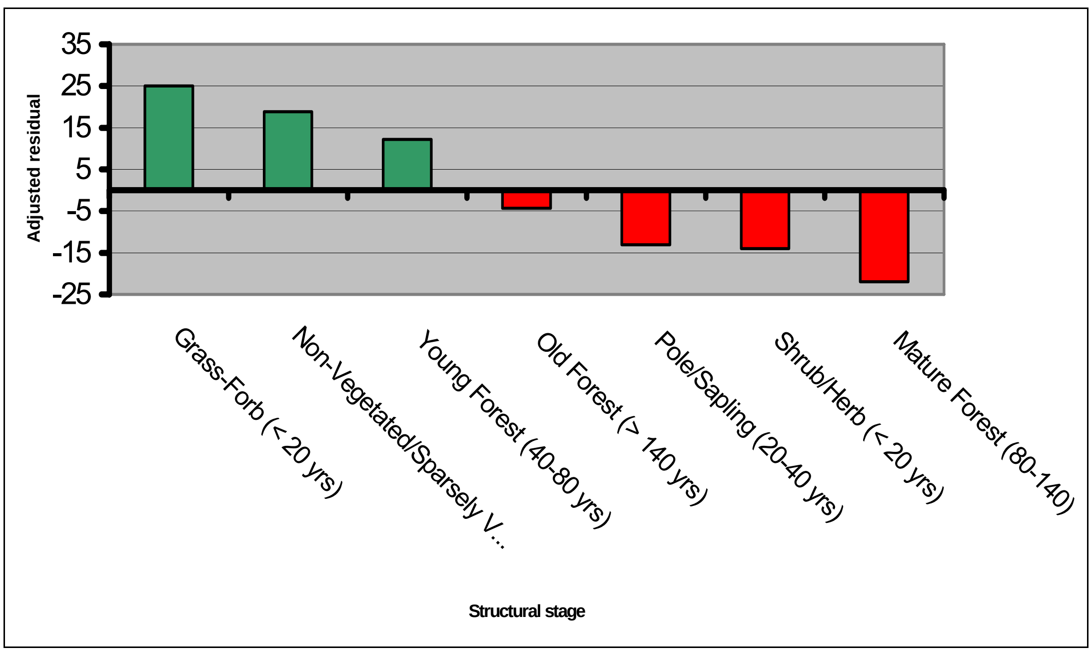

Figure 8. Selection for and against structural stages in the second decile by bighorn ewes at Columbia Lake as indicated by the adjusted residual statistic.

Strongly selected ecosites were distributed at low elevations, primarily on the west side of the 100% MCP cumulative winter range (Figures 9, 10). In particular, ecosites at the south end of the cumulative home range received more use that the same ecosites further north. Ecosites where rocky outcrops occurred in the second decile were most-commonly associated with saskatoon – bluebunch wheatgrass and antelope-brush – bluebunch wheatgrass site series in the first structural stage (Figures 9, 10).

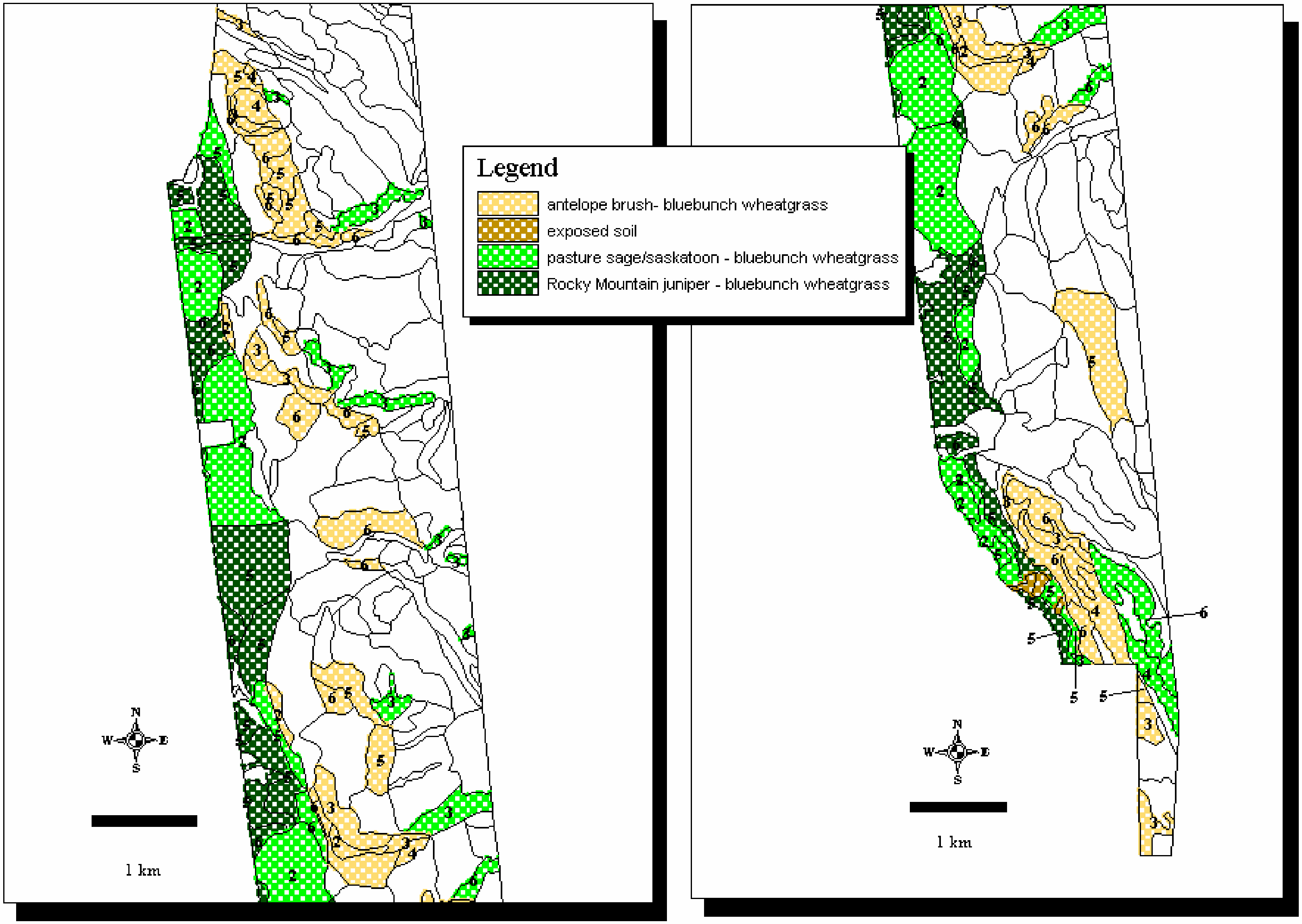

Figure 9. First decile site series strongly selected by bighorn ewes within their cumulative winter range at Columbia Lake. Numbers within each polygon refer to the associated structural stage of the site series.

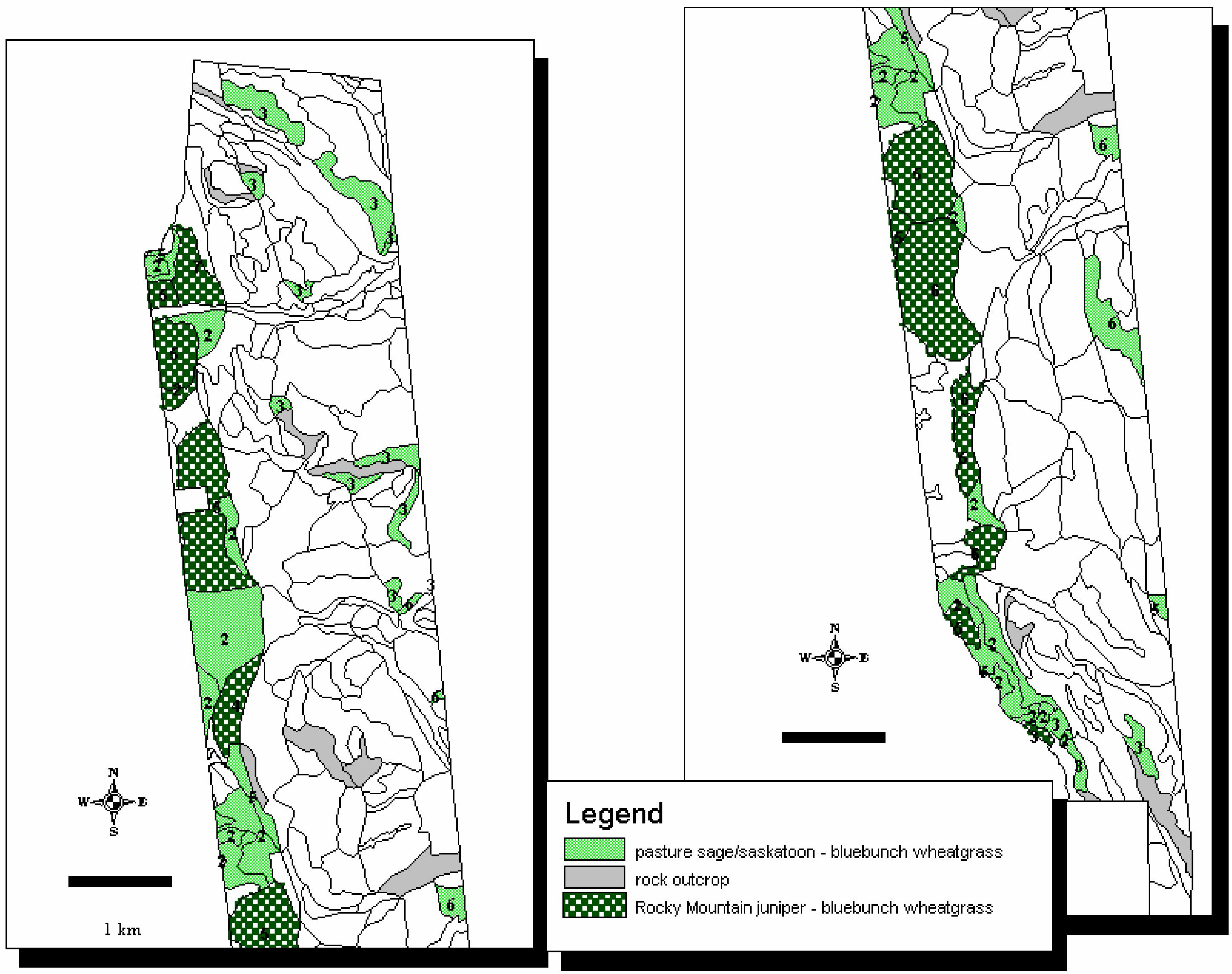

Figure 10. Second decile site series selected by bighorn ewes within their cumulative winter range at Columbia Lake. Numbers within each polygon refer to the associated structural stage of the site series.

<u>Bull River</u>

Antelope-brush – bluebunch wheatgrass, cultivated field and river types were strongly selected by radiocollared bighorn ewes (Figure 11). Site series that they avoided most were Douglas-fir – snowberry – balsamroot, Douglas-fir/lodgepole pine – pinegrass – twinflower, and Douglas-fir/western larch – spruce – pinegrass. There was strong selection for one structural stage, low shrub, at Bull River. Bighorn ewes avoided all structural stages greater than low shrub (Figure 12).

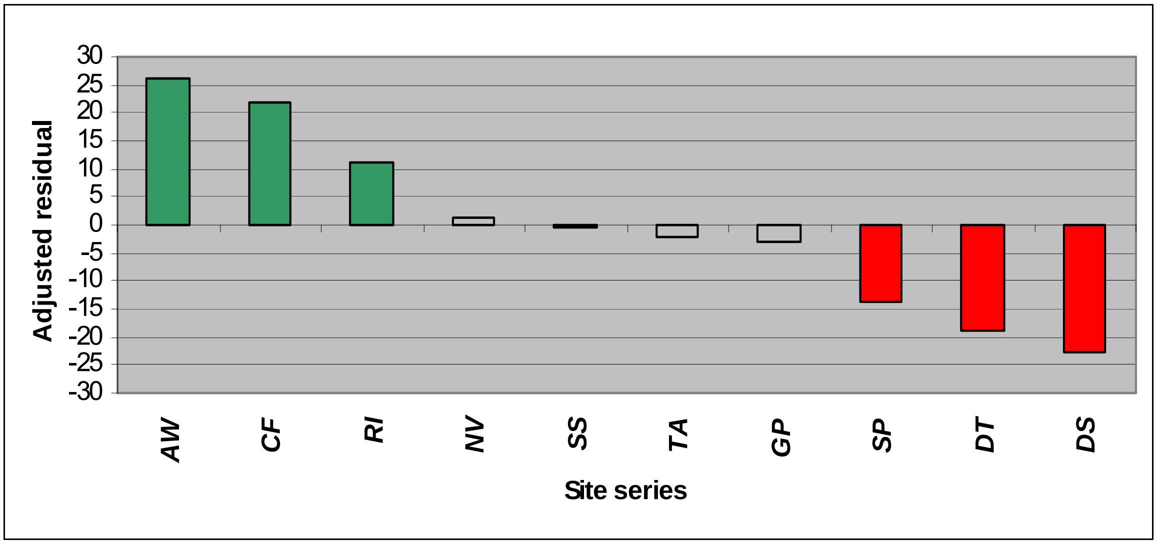

Figure 11. Selection for and against site series in the first decile by bighorn ewes at Bull River as indicated by the adjusted residual statistic.

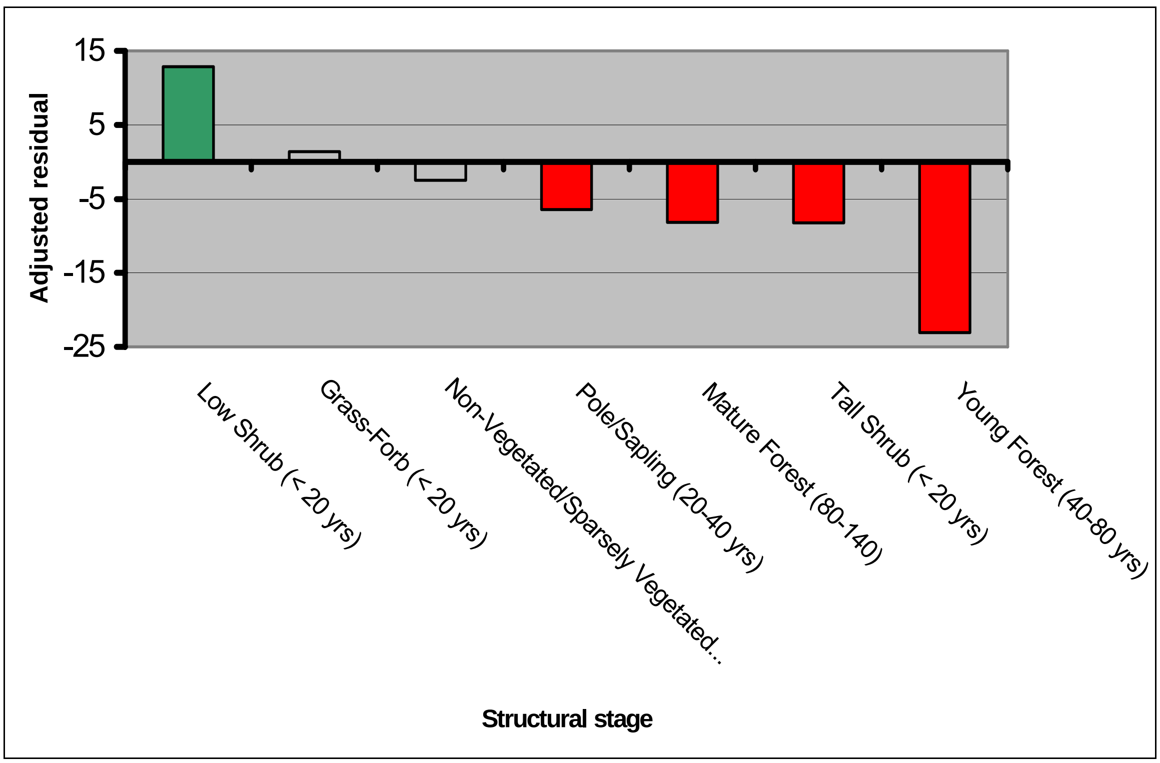

Figure 12. Selection for and against structural stages in the first decile by bighorn ewes at Bull River as indicated by the adjusted residual statistic.

In the second decile, antelope-brush – bluebunch wheatgrass, talus and Douglas-fir/lodgepole pine – pinegrass – twin flower site series were strongly selected (Figure 13). Site series strongly avoided by bighorn ewes were, in increasing order, river, rock outcrop, cultivated field, hybrid white spruce/trembling aspen – sarsaparilla, Douglas-fir/western larch – spruce – pinegrass, and Douglas-fir – snowberry – balsamroot. Within the second decile, the young forest and sparsely vegetated structural stages were strongly selected while the grass/forb, pole sapling, and low shrub structural stages were avoided (Figure 14).

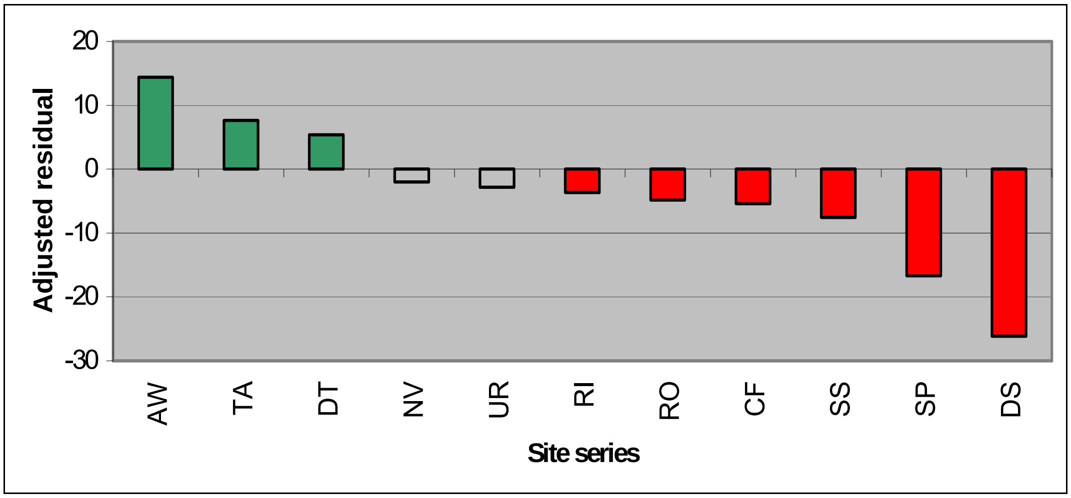

Figure 13. Selection for and against site series in the second decile by bighorn ewes at Bull River as indicated by the adjusted residual statistic.

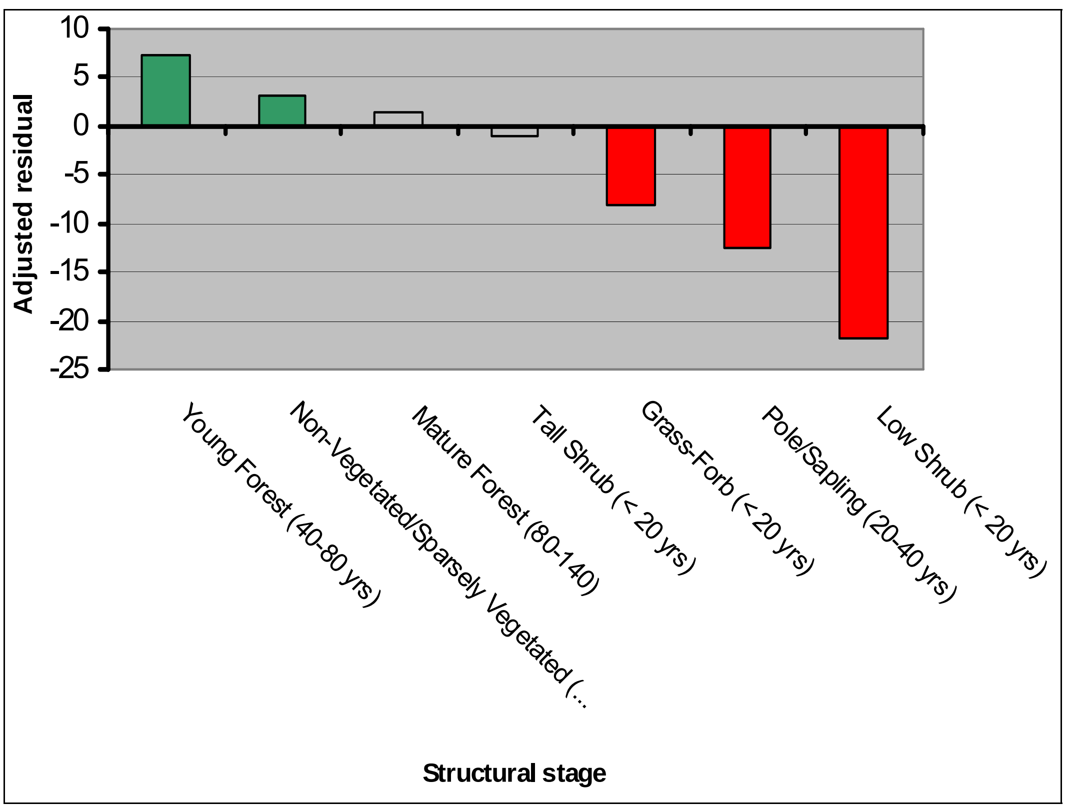

Figure 14. Selection for and against structural stages in the second decile by bighorn ewes at Bull River as indicated by the adjusted residual statistic.

Antelope-brush – bluebunch wheatgrass site series in the low shrub structural stage are dominated by those species in addition to saskatoon. However, Douglas-fir are often associated with the ecosites as well as ponderosa pine, pin cherry, snowberry, junegrass and Canada bluegrass. Most of these sites were found along the north side of the Bull River immediately east of the highway (Figure 15). The only cultivated field within the 100% MCP winter range was located in the same immediate area.

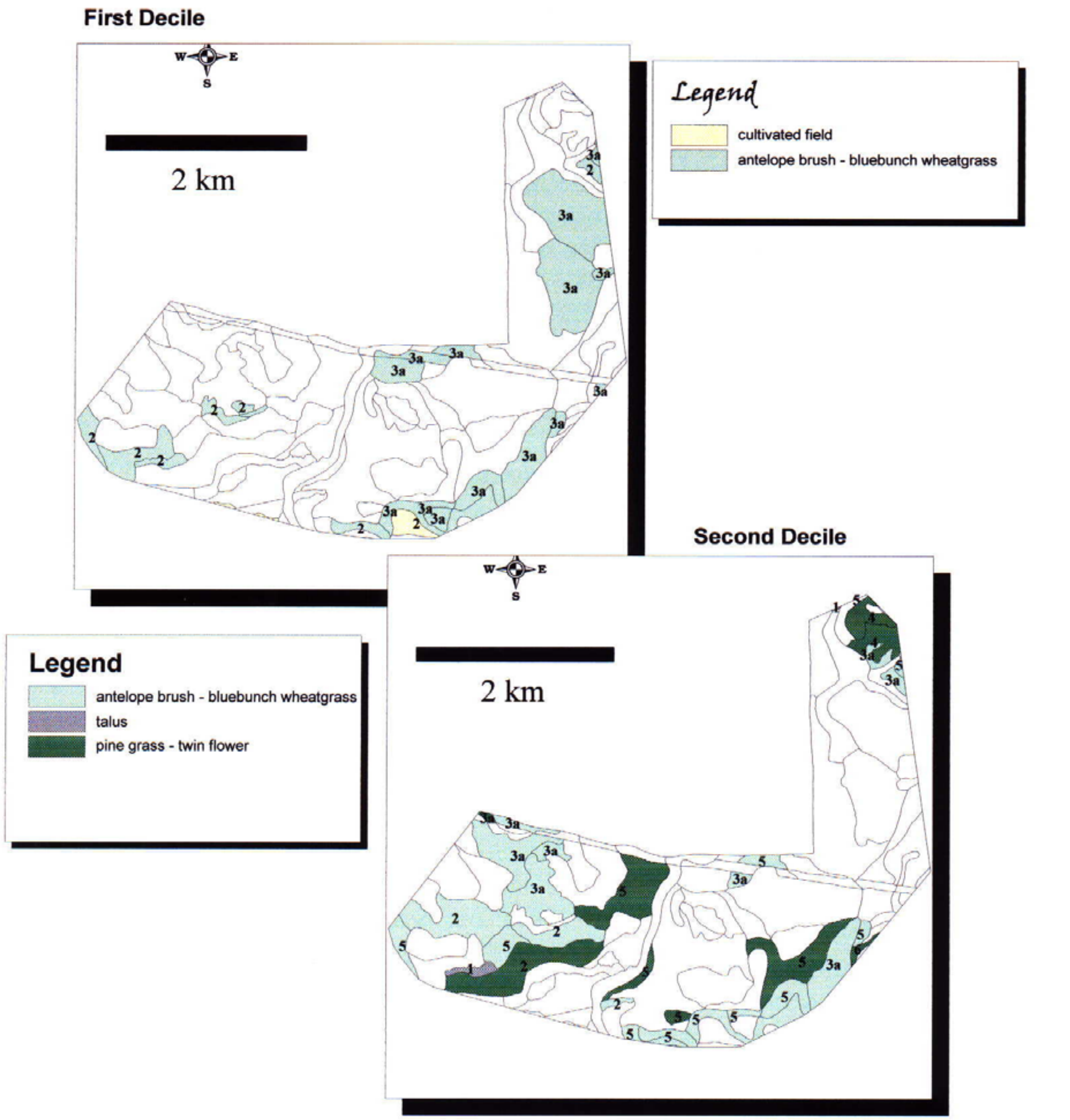

Figure 15. Site series selected by bighorn ewes within their cumulative winter range at Bull River. Numbers within each polygon refer to the associated structural stage of the site series.

Mount Broadwood

Radiocollared ewes strongly selected 4 site series in the first decile at the Mount Broadwood study area and avoided 8 (Figure 16). Abandoned field, western larch – snowberry, Douglas-fir – bluebunch wheatgrass, and non-vegetated site series were used significantly greater than expected. Site series strongly avoided by bighorn ewes were, in increasing order, bulrush-water reed grass, saskatoon - Douglas maple, juniper-pinegrass, talus, grey frayed-cap feathermoss – bluegrass, western larch – birch-leaved spirea, Douglas-fir – pinegrass – stepmoss, tall Oregon grape – velvet-leaved blueberry, Douglas-fir – red-stemmed feathermoss, and bluebunch wheatgrass – Jacob's ladder. No structural stages were strongly selected in the first decile although the shrub/herb and pole sapling structural stages were used more frequently than expected. (Figure 17). Young forest was strongly avoided by radiocollared ewes.

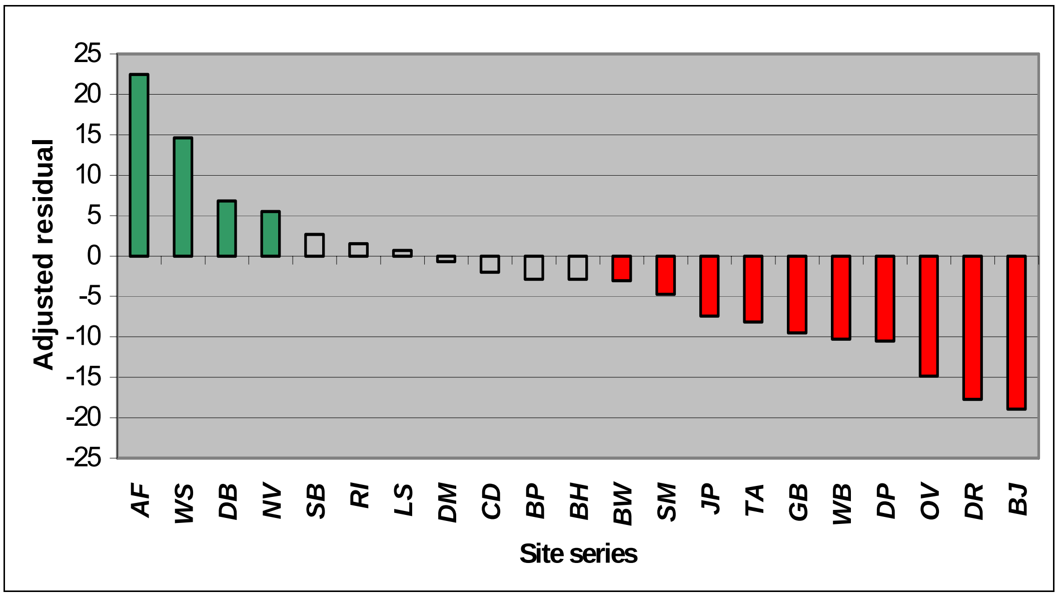

Figure 16. Selection for and against site series in the first decile by bighorn ewes at Mount Broadwood as indicated by the adjusted residual statistic.

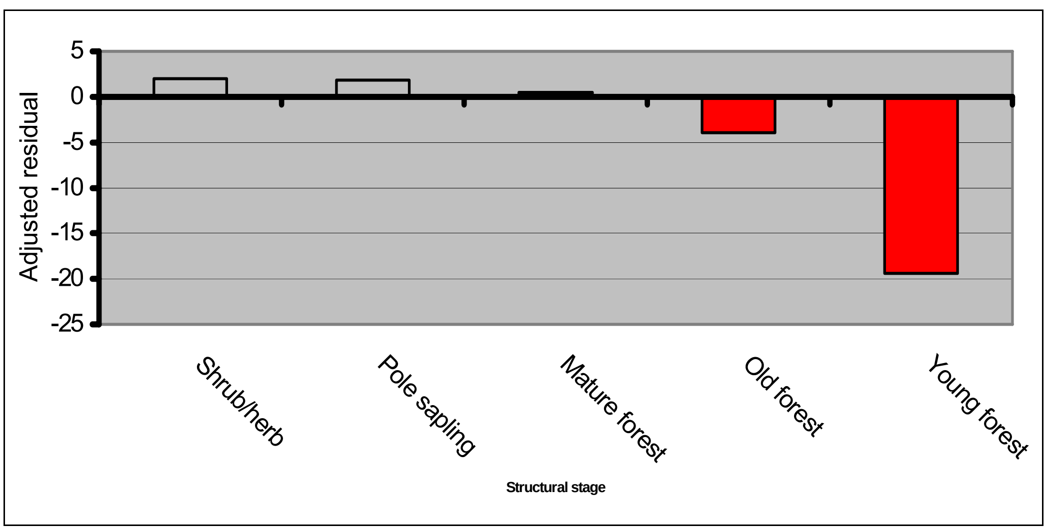

Figure 17. Selection for and against structural stages in the first decile by bighorn ewes at Mount Broadwood as indicated by the adjusted residual statistic.

Within the second decile, Douglas-fir – bluebunch wheatgrass, western larch – snowberry and snowberry – balsamroot were strongly selected (Figure 18). The 8 site series strongly avoided by bighorn ewes were, in increasing order, paper birch – red-osier dogwood, rock outcrop, western larch – birch-leaved spirea, bluegrass – pussytoes, bluebunch wheatgrass - Jacob's ladder, grey frayed-cap feathermoss – bluegrass, Douglas-fir – red-stemmed feathermoss, and tall Oregon grape – velvet-leaved blueberry (Figure 18). Among structural stages, young forest and pole sapling were strongly selected within the second decile, while old growth forest was used significantly less than expected (Figure 19).

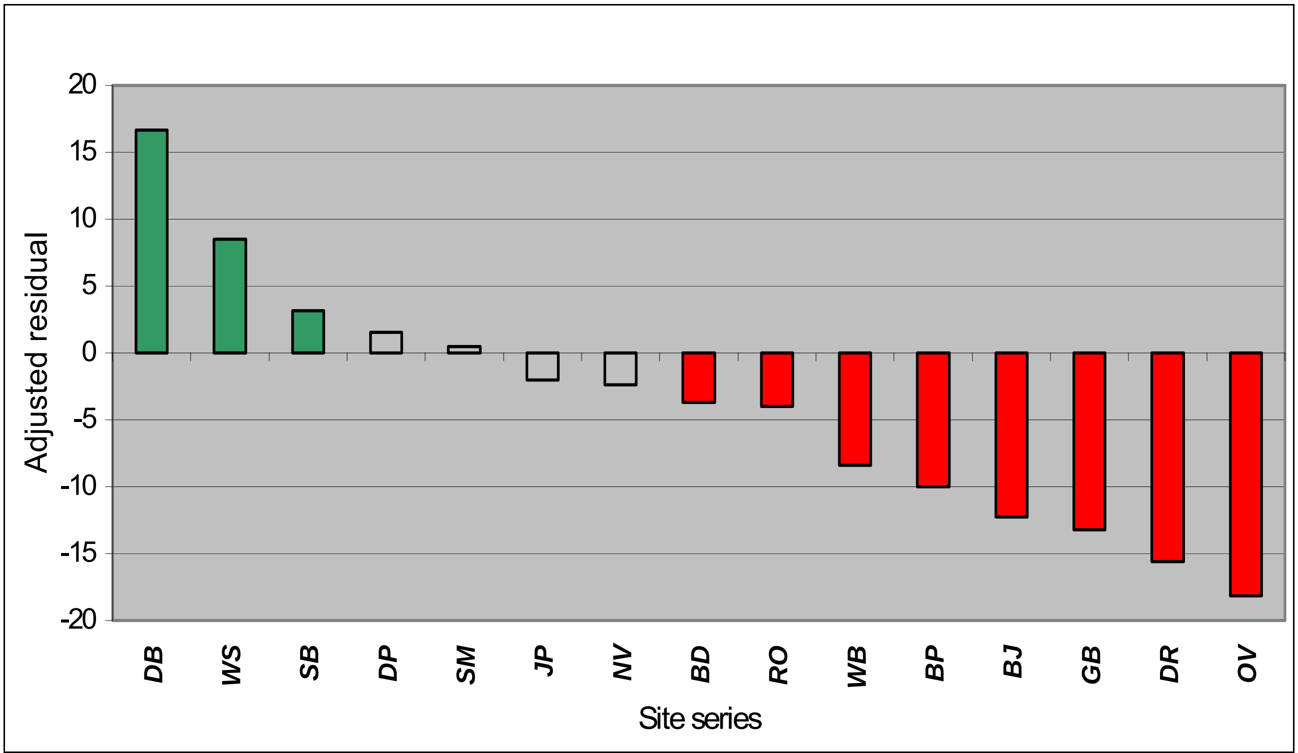

Figure 18. Selection for and against site series in the second decile by bighorn ewes at Mount Broadwood as indicated by the adjusted residual statistic.

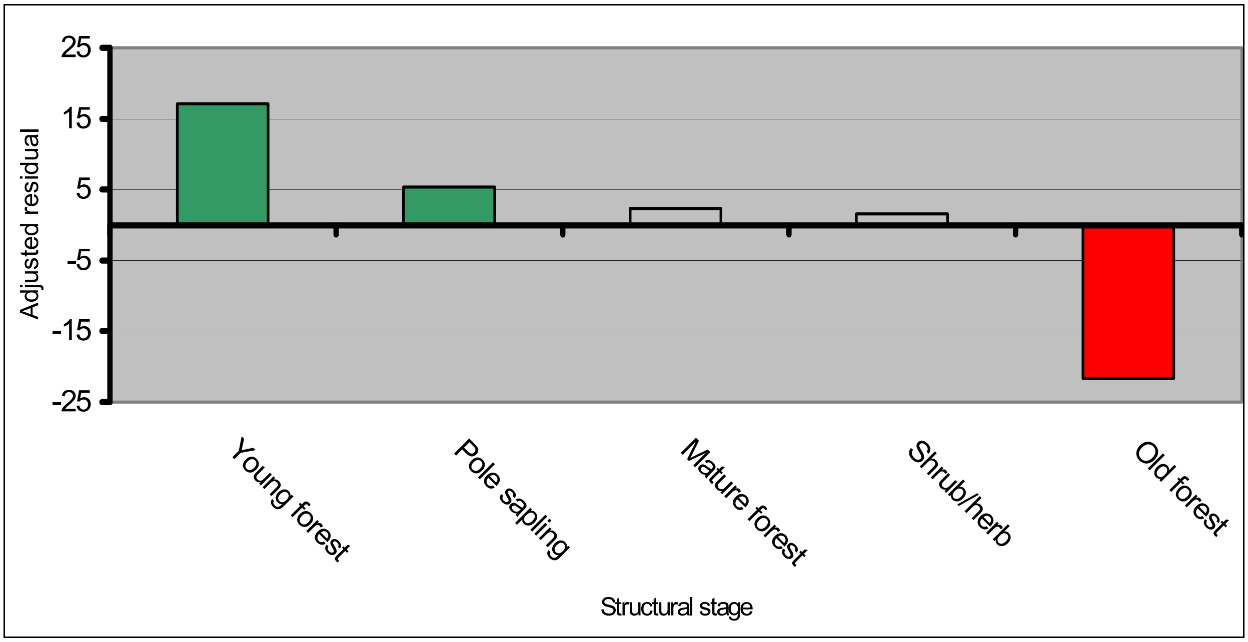

Figure 19. Selection for and against structural stages in the second decile by bighorn ewes at Mount Broadwood as indicated by the adjusted residual statistic.

The most frequently-used of the strongly selected site series were along the Wigwam and Elk Rivers. This was particularly true for the Douglas-fir – bluebunch wheatgrass site series in both structural stages. Although the type was located throughout the southern third of the MCP (Figure 20), it was used by bighorns only in close proximity to the two rivers. The Douglas-fir – bluebunch wheatgrass site series was most frequently associated with the shrub/herb structural stage, particularly in the first decile. This ecosite is dominated by bluebunch wheatgrass grassland. Other grasses that occur include junegrass and other bluegrass species. In the pole sapling and young forest structural stages, it changes from grassland to open Douglas-fir forest with a grassland understory. Western larch – snowberry types in the shrub/herb structural stage consisted primarily of dense stands of snowberry, but with several bighorn forage plants associated with it. Saskatoon, buckbrush, western fescue, and Oregon grape are found here.

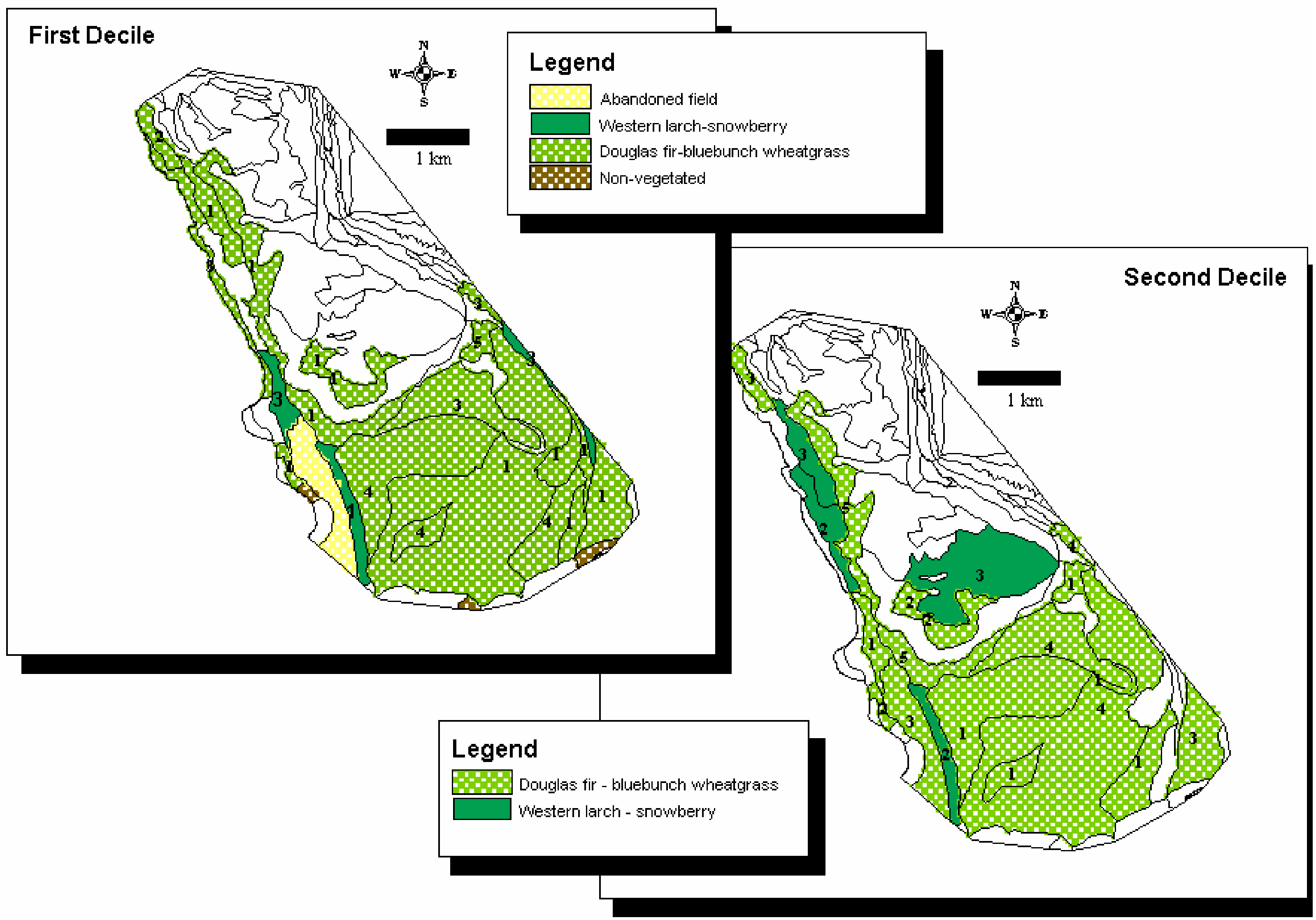

Figure 20. Site series selected by bighorn ewes within their cumulative winter range at Mount Broadwood. Numbers within each polygon refer to the associated structural stage of the site series.

4.2.2 Discriminant Function Analysis - Including all Variables

The discriminant function analysis (DFA) using all variables discriminated well between used and unused habitat within the 100% MCP winter ranges at the 3 study areas. Relatively high Canonical Correlation Coefficients (0.756-0.624), low Wilk's lambda values (0.611-0.428), high Eigenvalues (0.637-1.334), and finally, very good percent classification success (79.9-87.5%) all indicate the strength of the DFA to differentiate between land that was selected by bighorn ewes and those areas that were avoided within the winter ranges (Figure 21). The Bull River and Columbia Lake DFAs were stronger than the Mount Broadwood DFA in all cases.

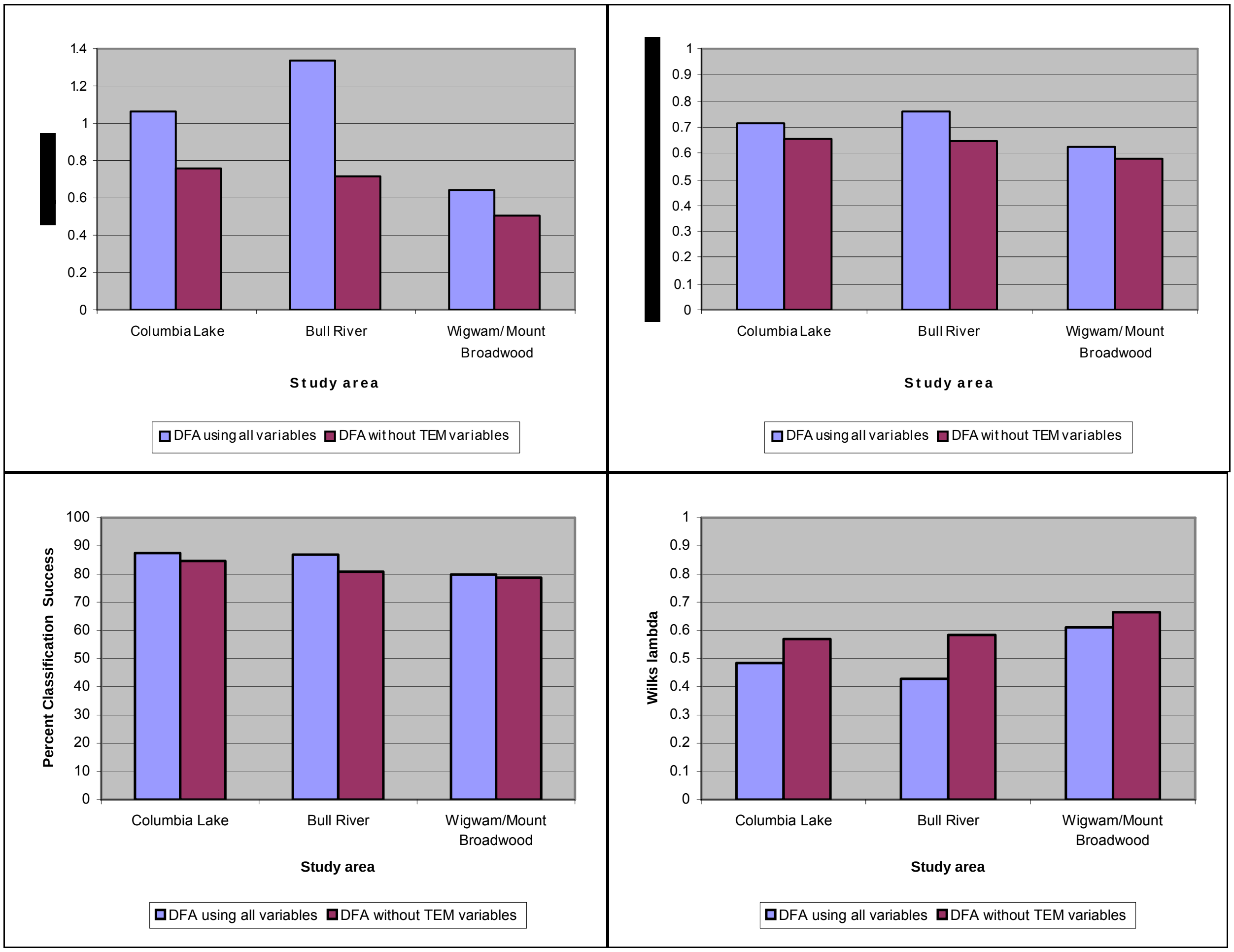

Figure 21. A comparison of Eigenvalues, Canonical Correlation Coefficients, Wilk's Lambda and percent classification success associated with discriminant function analyses conducted with and without TEM variables in 3 bighorn ewe winter ranges in the East Kootenay Trench.

<u>Columbia Lake</u>

Table 5 lists the top 10 variables in the DFA based on the absolute value of the Standardized Canonical Coefficient. The group centroid for selected habitat was 1.79 and for available habitat was –0.59. A positive group centroid for selected habitat and a negative value for available habitat means that for TEM variables, a positive Standardized Canonical Coefficient represents selection for that site series while a negative value indicates avoidance. Among topographical variables, elevation, distance to steep terrain, terrain ruggedness, and southwest aspect were important contributors to the multivariate model. Bighorns selected for lower elevations, land closer to areas of steep terrain (≥30°), increased terrain ruggedness (i.e., land with many changes in slope and aspect), and land facing southwest within the winter home range. Among TEM variables, pasture sage – bluebunch wheatgrass, Douglas-fir – Rocky Mountain juniper, lodgepole pine – juniper – pinegrass, and the hybrid white spruce – soopolallie – grouseberry site series (all in the second decile), were top 10 contributors to the multivariate model. In addition, the antelope-brush – bluebunch wheatgrass site series and structural stage in the first decile were also in the top 10 variables. All site series listed above were used significantly more than expected in the multivariate model. Lower structural stages, the earlier seral stages in succession, were also selected.

Table 5. The top 10 variables contributing to the multivariate model of bighorn ewe winter range at Columbia Lake, based on the Standardized Canonical Coefficient.

Variable	Standard Canonical Coefficient
Elevation	-0.57772962
SW (2nd decile)	0.56016889
Distance to Steep Terrain	-0.494542955
Terrain Ruggedness	0.385756546
DJ (2nd decile)	0.287826381
LJ (2nd decile)	0.284178467
AW (1st decile)	0.280483227
SG (2nd decile)	0.216335916
Structural Stage (1st decile)	-0.214474607
SW Aspect	0.211515879

Table 6 lists the top 10 contributors to the DFA based on the absolute value of the Structure Matrix Coefficient. Bighorn ewes selected for land with lower greenness values and lower structural stages in the first decile. Among site series, pasture sage – bluebunch wheatgrass was selected for in both the first and second deciles, although ecosites in which the site series occurred in the second decile were more important. In addition, both Douglas-fir/lodgepole pine – pinegrass – twinflower in the first decile and hybrid white spruce – soopolallie – grouseberry in the second decile were selected against. In order of importance to the DFA, the following topographical variables were included in the top 10: elevation, distance to steep terrain, terrain ruggedness, and slope.

Table 6. The top 10 variables contributing to the multivariate model of bighorn ewe winter range at Columbia Lake, based on the absolute value of the Structure Matrix.

Variable	Structure Matrix
Greenness	-0.453708596
Structural Stage (1st decile)	-0.433976731
SW (2nd decile)	0.421779929
SW (1st decile)	0.409845719
Elevation	-0.372959397
Distance to Steep Terrain	-0.329099766
Terrain Ruggedness	0.264402046
Slope (degrees)	0.234291628
SG (2nd decile)	-0.210910714
DT (1st decile)	-0.190830669

Bull River

Table 7 lists the top 10 variables based on the absolute value of the Standardized Canonical Coefficient in the DFA. The group centroid for selected habitat was –1.15 and for available habitat was 1.16. A negative group centroid for selected habitat and a positive value for available habitat means that for TEM variables, a negative Standardized Canonical Coefficient represents selection for that site series while a positive value indicates avoidance. Among TEM variables, site series from the second decile, Douglas-fir – snowberry – balsamroot, antelope-brush – bluebunch wheatgrass, and Douglas-fir/western larch – spruce – pinegrass, and the structural stages associated with the second decile were major contributors to the multivariate model. All 3 site series were avoided. Among structural stages, there was selection for higher successional stages in both deciles. Within the first decile site series, Douglas-fir/western larch – spruce – pinegrass, and Douglas-fir/lodgepole pine – pinegrass – twin flower site series were avoided while cultivated field and river were selected. Ewes also selected for lower elevations.

Table 7. The top 10 variables contributing to the multivariate model of bighorn ewe winter range at Bull River, based on the Standardized Canonical Coefficient.

Variable	Standard Canonical Coefficient
DS (2nd decile)	0.857870903
AW (2nd decile)	0.727329998
Structural Stage (2nd decile)	-0.71857415
CF (1st decile)	-0.660457881
SP (2nd decile)	0.589695451
Structural Stage (1st decile)	-0.48337025
SP (1st decile)	0.444812267
RI (1st decile)	-0.436718351
DT (1st decile)	0.354179471
Elevation	0.34281743

Table 8 lists the top 10 contributors to the DFA based on the absolute value of the Structure Matrix Coefficient. Six were TEM variables. Ewes selected for older seral stages within structural stages of the first decile. Douglas-fir – snowberry – balsamroot was avoided in both deciles. Within the first decile, antelope-brush – bluebunch wheatgrass and cultivated field site series were selected for, while Douglas-fir/lodgepole pine – pinegrass – twinflower was avoided. Elevation was the most important topographical variable, with ewes selecting for lower elevations. Increased terrain ruggedness and southwest aspects were also favoured. Ewes also selected for locations with lower greenness values than expected by chance.

Table 8. The top 10 variables contributing to the multivariate model of bighorn ewe winter range at Bull River, based on the absolute value of the Structure Matrix Coefficient.

Variable	Structure Matrix
Elevation	0.469582256
Structural Stage (1st decile)	0.373241456
AW (1st decile)	-0.312120852
DS (2nd decile)	0.310782381
Greenness	0.302115244
DS (1st decile)	0.265133815
CF (1st decile)	-0.25372364
Terrain Ruggedness	-0.245003227
SW Aspect	0.240886313
DT (1st decile)	0.214983509

<u>Mount Broadwood</u>
Table 9 lists the top 10 variables based on the absolute value of the Standardized Canonical Coefficient. The group centroid for selected habitat was 0.688 and for available habitat was -0.926. The 4 most important variables based on the Standard Canonical Coefficient were all topographical. Ewes were found more than expected on south, southwest, and southeast aspects. In addition, they selected for lower elevations and areas closer to steep terrain. Among site series, they selected for Douglas-fir – bluebunch wheatgrass in both the first and second deciles, and abandoned fields in the first decile. The western larch – birch-leaved spirea site series was avoided in the first decile. In addition, ewes selected for lower structural stages in the second decile.

Table 9. The top 10 variables contributing to the multivariate model of bighorn ewe winter range at Bull River, based on the Standardized Canonical Coefficient.

Variable	Standard Canonical Coefficient
Distance to Steep Terrain	-0.553991113
SW Aspect	0.545442475
S Aspect	0.417968399
Elevation	-0.39087221
DB (2nd decile)	0.3631968
AF (1st decile)	0.260629652
SE Aspect	0.258250718
WB (1st decile)	-0.190328801
Structural Stage (2nd decile)	-0.156097238
DB (1st decile)	0.152120853

Table 10 lists the top 10 contributors to the DFA based on the absolute value of the Structure Matrix. Five were topographical variables. Lower elevations, decreased distance to steep terrain, southwest aspects, and increased terrain ruggedness were all selected. Flat terrain was avoided. Abandoned fields and Douglas-fir – bluebunch wheatgrass site series in the first decile were used more than expected, while Douglas-fir – red-stemmed feathermoss was avoided. Tall Oregon-grape – velvet-leaved blueberry was avoided in both deciles.

Table 10. The top 10 variables contributing to the multivariate model of bighorn ewe winter range at Mount Broadwood, based on the absolute value of the Structure Matrix Coefficient.

Variable	Structure Matrix
Elevation	-0.63274313
Distance to Steep Terrain	-0.47709605
SW Aspect	0.43624271
AF (1st decile)	0.271738688
Flat	-0.22783986
OV (2nd decile)	-0.21790325
Terrain Ruggedness	0.214206776
DR (1st decile)	-0.21269764
DB (1st decile)	0.199766732
OV (1st decile)	-0.17728074

4.2.3 Discriminant Function Analysis - Excluding TEM Variables

The discriminant function analysis (DFA) excluding TEM variables discriminated well between used and unused habitat within the 100% MCP winter ranges at the 3 study areas. Relatively high Canonical Correlation Coefficients (0.656-0.579), low Wilk's lambda values (0.664-0.570), high Eigenvalues (0.506-0.756), and good percent classification success (78.8-84.7%) all indicate the strength of the DFA to differentiate between land that were selected for by bighorn ewes and those areas that were avoided within the winter ranges (Figure 21). All 3 DFAs without TEM variables were not as strong as DFAs using all variables in their ability to differentiate used and unused habitat within the 3 winter ranges. As was the case with the DFA using all variables, the Mount Broadwood DFA was the weakest of the 3.

<u>Columbia Lake</u>
Table 11 lists the top 5 variables based on the absolute value of the Standardized Canonical Coefficient. The group centroid for selected habitat was –1.509 and for available habitat was 0.501. Bighorn ewes selected for lower elevations, increased terrain ruggedness, land closer to steep terrain, steeper terrain, and lower greenness values.

Table 11. The top 5 variables contributing to the multivariate model of bighorn ewe winter range at Columbia Lake, based on the absolute value of the Standard Canonical Coefficient.

Variable	Standard Canonical Coefficient
Elevation	0.792750913
Terrain Ruggedness	-0.475472523
Distance to Steep Terrain	0.529848846
Greenness	0.350532946
Slope (degrees)	-0.234421898

The Structural Matrix Coefficient produced a similar picture of the DFA, although the relative importance of the variables changed somewhat (Table 12). Greenness became the most important contributor to the DFA, followed by elevation, distance to steep terrain, terrain ruggedness, and slope.

Table 12. The top 5 variables contributing to the multivariate model of bighorn ewe winter range at Columbia Lake, based on the absolute value of the Structure Matrix Coefficient.

Variable	Structure Matrix
Greenness	0.539141251
Elevation	0.443187098
Distance to Steep Terrain	0.391068763
Terrain Ruggedness	-0.314188559
Slope (degrees)	-0.278408394

<u>Bull River</u>
Table 13 lists the top 5 variables based on the absolute value of the Standardized Canonical Coefficient. The group centroid for selected habitat was –0.841 and for available habitat was 0.848. Bighorn ewes selected for lower elevations, increased terrain ruggedness, steeper slopes, and southwest-facing aspects. However, in contrast to the other 2 study areas, bighorn ewes selected for habitats further from steep terrain than would be expected by chance. Greenness contributed little to the DFA based on the Standardized Canonical Coefficients.

Again, the Structure Matrix Coefficient showed similar relationships among the variables and the distribution of bighorn ewes on their winter ranges (Table 14). Four of the 5 variables included in the top 5 using the Standardized Canonical Coefficient were also in the top 5 when the Structure Matrix Coefficients were examined. Ewes selected for lower elevations, increased distances to steep terrain, decreased greenness values, increased terrain ruggedness and greater than expected use of southwest aspects.

Table 13. The top 5 variables contributing to the multivariate model of bighorn ewe winter range at Bull River, based on the absolute value of the Standard Canonical Coefficient.

Variable	Standard Canonical Coefficient
Elevation	0.510151885
Terrain Ruggedness	-0.360096506
Distance to Steep Terrain	-0.342084877
Slope (degrees)	-0.283070559
SW Aspect	0.260317968

Table 14. The top 5 variables contributing to the multivariate model of bighorn ewe winter range at Bull River, based on the absolute value of the Structure Matrix Coefficient.

Variable	Structure Matrix
Elevation	0.642302497
Distance to Steep Terrain	-0.516955107
Greenness	0.413238306
Terrain Ruggedness	-0.335119529
SW Aspect	0.329488345

Mount Broadwood

Table 15 lists the top 5 variables based on the absolute value of the Standardized Canonical Coefficient. The group centroid for selected habitat was –0.613 and for available habitat was 0.826. Based on the absolute value and sign of the Standard Canonical Coefficient, bighorn ewes selected for south, southeast, and southwest aspects, lower elevations, and areas closer to steep terrain. Landsat imagery was not available for the Mount Broadwood study area so correlations between greenness and bighorn ewe distribution could not be made.

Table 15. The top 5 variables contributing to the multivariate model of bighorn ewe winter range at Mt Broadwood, based on the absolute value of the Standard Canonical Coefficient.

Variable	Standard Canonical Coefficient
SW Aspect	0.674362895
Elevation	-0.600084407
Distance to Steep Terrain	-0.53737405
S Aspects	0.47596382
SE Aspects	0.341068675

The importance of variables changed when the Structure Matrix Coefficients were ordered (Table 16). Two variables included among the top 5 when the Standard Canonical Coefficient was considered were not within the top 5 based on the absolute value of the Structure Matrix Coefficient. Elevation became the most important variable, with SW aspect and distance to steep terrain remaining in the top 5. As was the case in all other models, lower elevations, decreased distances to steep terrain, and greater than expected use of southwest aspects characterized bighorn ewe use of the study area. In addition, avoidance of flat terrain and greater than expected use of steeper slopes were added and S and SE aspects were dropped.

Table 16. The top 5 variables contributing to the multivariate model of bighorn ewe winter range at Mount Broadwood, based on the absolute value of the Structure Matrix Coefficient.

Variable	Structure Matrix
Elevation	-0.71039562
Distance to Steep Terrain	-0.53564697
SW Aspect	0.489779967
Flat	-0.25580118
Slope (degrees)	0.2501185

4.2.4 Comparison of Habitat Selection between Study Areas

General linear modeling was used to examine the similarities and differences in availability and use of habitat between the 3 study areas. Topographical variables were contrasted between Columbia Lake, Bull River, and Mount Broadwood to test whether habitat availability and use were significantly different. TEM variables could not be used because classification of site series and structural stages were not consistent across the 3 study areas. Significant differences were found between all 3 study areas, both in the types of habitat available and in the use of habitat by the radiocollared bighorn ewes. However, trends in use by radiocollared ewes were almost all in the same direction in the 3 study areas. In all 3 study areas, bighorns used lower elevations (Figure 22). Lower greenness values were selected for in Columbia Lake and Bull River (Figure 23). The greenness layer was not available for the Mount Broadwood study area. Among slope variables, sheep selected for steeper slopes as well as for areas with greater terrain ruggedness (Figures 24, 25). The only exception to similar use trends across the 3 study areas was with the variable, distance to steep terrain. At Columbia Lake and Mount Broadwood, ewes were closer to steep terrain than would be expected by chance (Figure 26). However, at Bull River, the opposite was true. The definition of steep terrain was land >30^{o} slope. The 100% MCP winter range at Bull River did not contain steep terrain, producing this result. The lack of escape terrain may be related to the proximity of that herd to the of Bull River townsite (possibly leading to lower predator numbers) or because the degree of grazing pressure there (Chapter 5) necessitates movement to less secure areas for foraging.

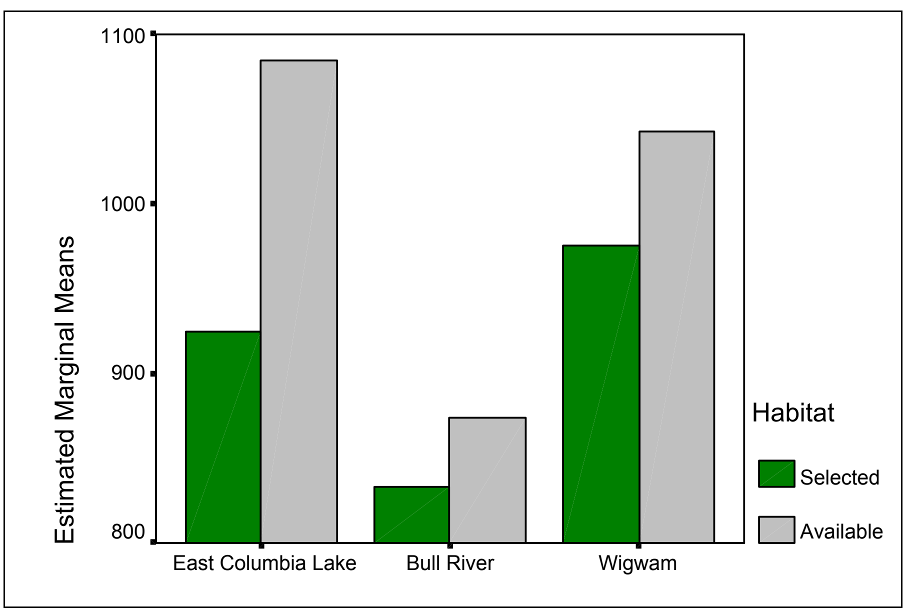

Figure 22. Estimated marginal means of elevation across 3 bighorn ewe winter ranges in the East Kootenay Trench (Wigwam = Mount Broadwood).

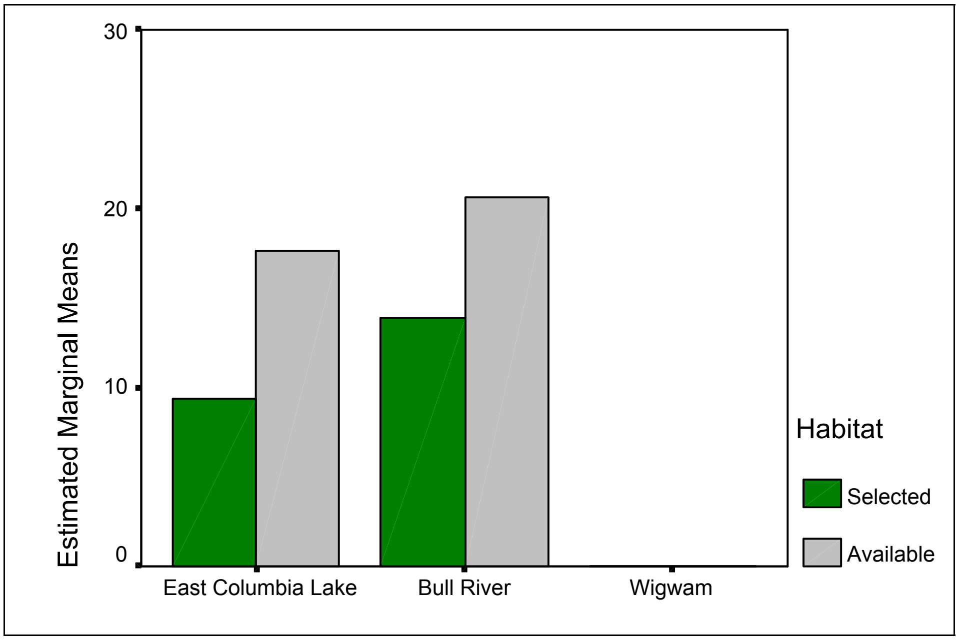

Figure 23. Estimated marginal means of greenness across 3 bighorn ewe winter ranges in the East Kootenay Trench (Wigwam = Mount Broadwood).

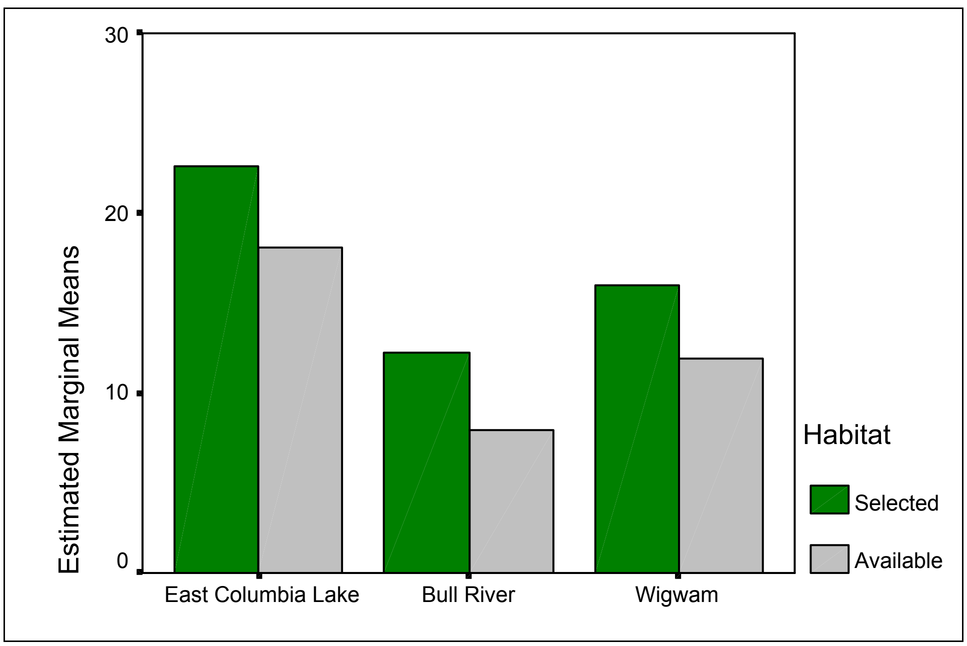

Figure 24. Estimated marginal means of slope across 3 bighorn ewe winter ranges in the East Kootenay Trench (Wigwam = Mount Broadwood).

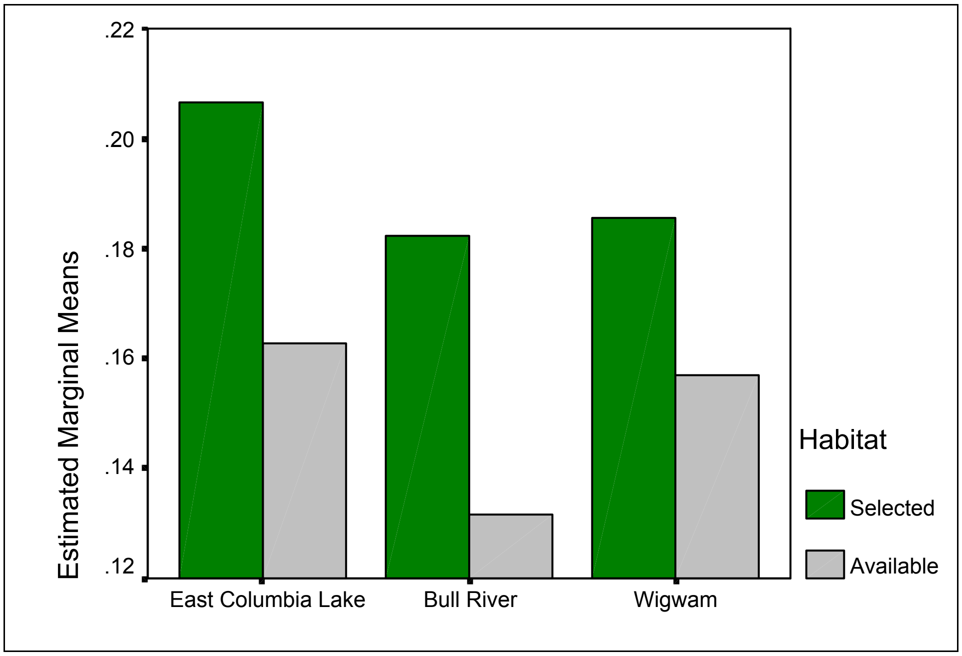

Figure 25. Estimated marginal means of terrain ruggedness across 3 bighorn ewe winter ranges in the East Kootenay Trench (Wigwam = Mount Broadwood).

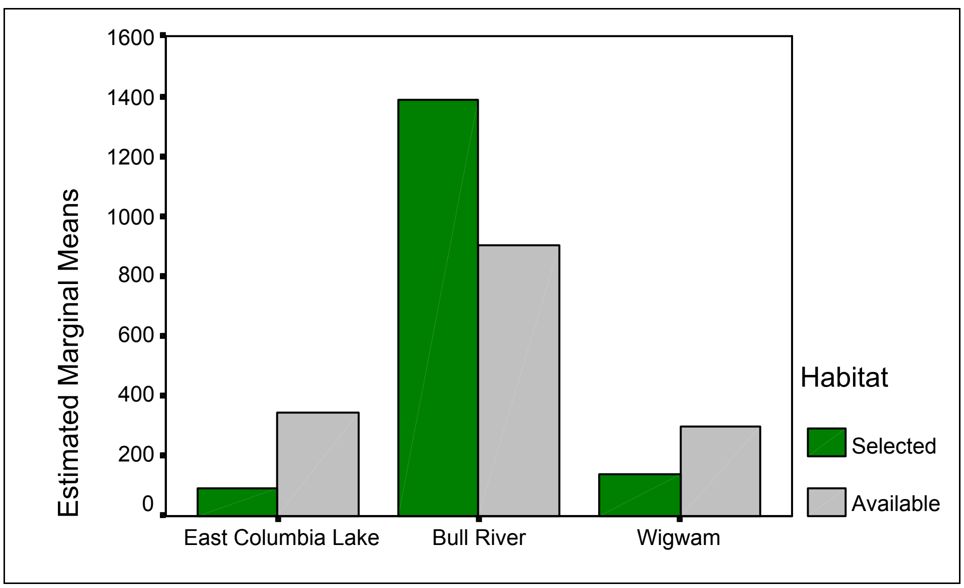

Figure 26. Estimated marginal means of distance to steep terrain across 3 bighorn ewe winter ranges in the East Kootenay Trench (Wigwam = Mount Broadwood).

5.0 Discussion

Radiocollared bighorn ewes used habitat in a predictable fashion in all 3 study areas. Results from the different univariate and multivariate analyses of the bighorn ewe radiotelemetry data showed strong correlations between ewe distribution and several habitat types that provided life requisites: forage, security, and thermal cover. Over all 3 study areas, bluebunch wheatgrass site series were selected for, typically in the earlier seral stages such as grass/forb and shrub/herb. Selection for these within the second decile (the second most abundant site series within an ecosite) was sometimes directed toward older structural stages in which open stands of Douglas-fir occurred with understories of bluebunch wheatgrass. In addition, the attraction to artificial opening was evident at 2 of the 3 study areas. Abandoned fields at Bull River and Mount Broadwood were strongly selected in the first decile. All site series strongly selected by bighorn ewes contained forage in the form of grasses, herbs, and/or shrubs. This emphasizes the generalist foraging strategy of bighorn sheep. They are capable of digesting a wide variety of plant species and many different forage species contribute to their diet.

Site series in the second decile were an important part of bighorn ewe habitat selection. The DFA using all variables demonstrated this; site series in the second decile were contributors to the multivariate model in all 3 study areas. In some cases (e.g., Columbia Lake), a bluebunch wheatgrass site series from the second decile was ranked higher in importance to the model than the same site series in the first decile. These site series may be smaller inclusions of preferred habitat in a matrix of less suitable habitat. Crosstabulations of use versus availability showed the importance of escape terrain in the second decile at Bull River and Columbia Lake. Rock outcrops were strongly selected for at Columbia Lake while at Bull River, talus was strongly selected in the second decile.

In several cases, strong selection for site series was documented that did not appear to make sense ecologically. River site series appeared in several instances as did road surface. This is a consequence of the sampling procedure wherein each radiolocation was buffered with a 100 m radius circle and the areas within the buffered circles were randomly sampled. For radiolocations that were within 100 m of a river or a road surface, it was possible to have selection for these site series even though it is unlikely that these site series were used very much or at all, as in the case of the river site series. The proximity of sheep to those site series may relate to the use of road salt (road) and steep, south-facing terrain (river).

A greenness band derived from Landsat 5 TM satellite images appears to be well-correlated with ewe winter range use in the East Kootenay Trench (Figure 27). Radiocollared bighorn ewes strongly selected lower greenness values than would be expected by chance within the two 100% MCP winter ranges where the layer was available. The variable ranked first and fifth in the DFA using all variables, and fourth and third in the DFA without TEM variables based on the Structural Matrix Coefficients at Columbia Lake and Bull River, respectively. Lower greenness values correspond well with grasslands (i.e., younger structural stages) that were selected by bighorn ewes.

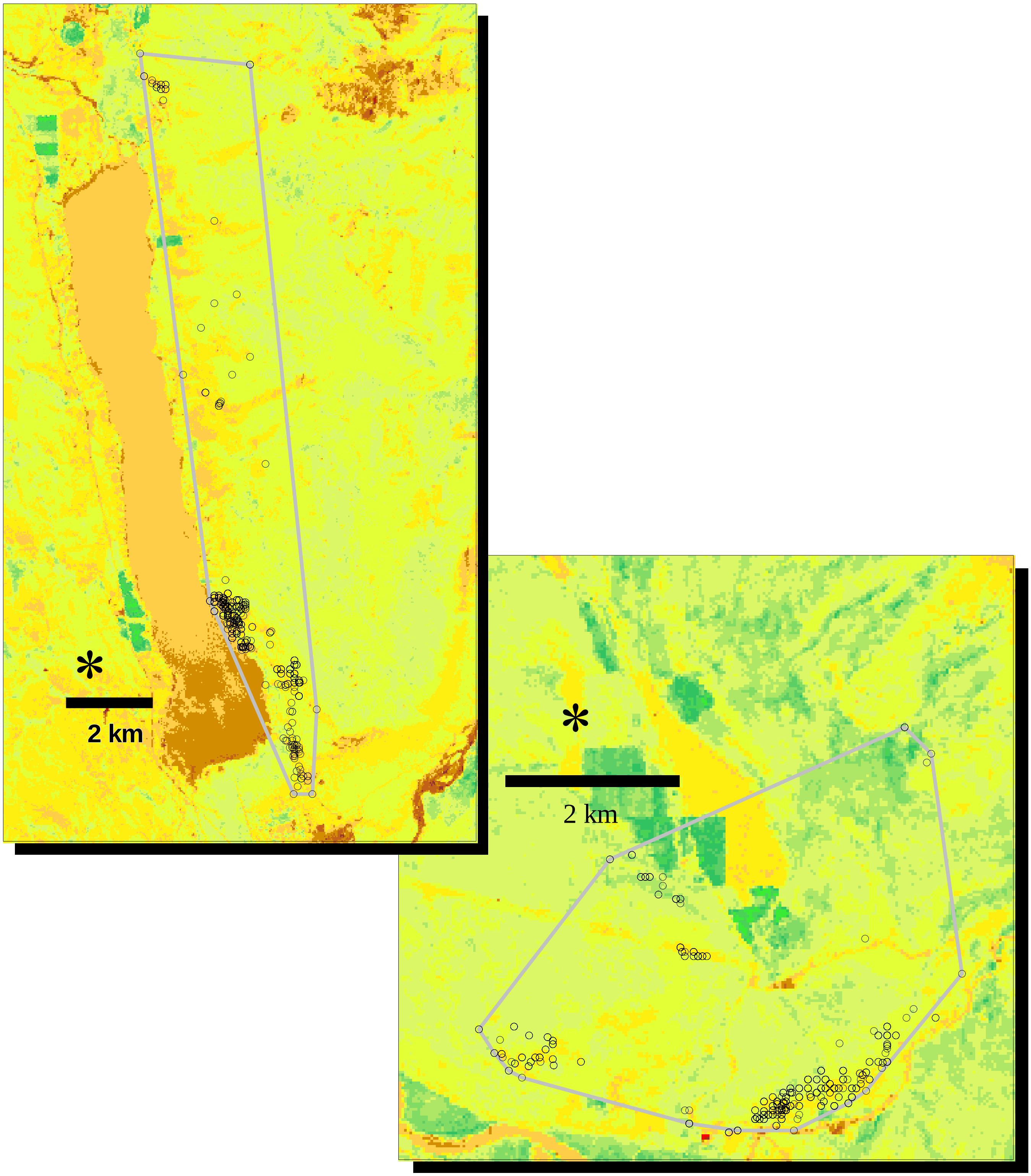

Figure 27. Greenness values derived from Landsat 5 TM satellite images at Columbia Lake and Bull River in relation to radiolocations of bighorn ewes during winter.

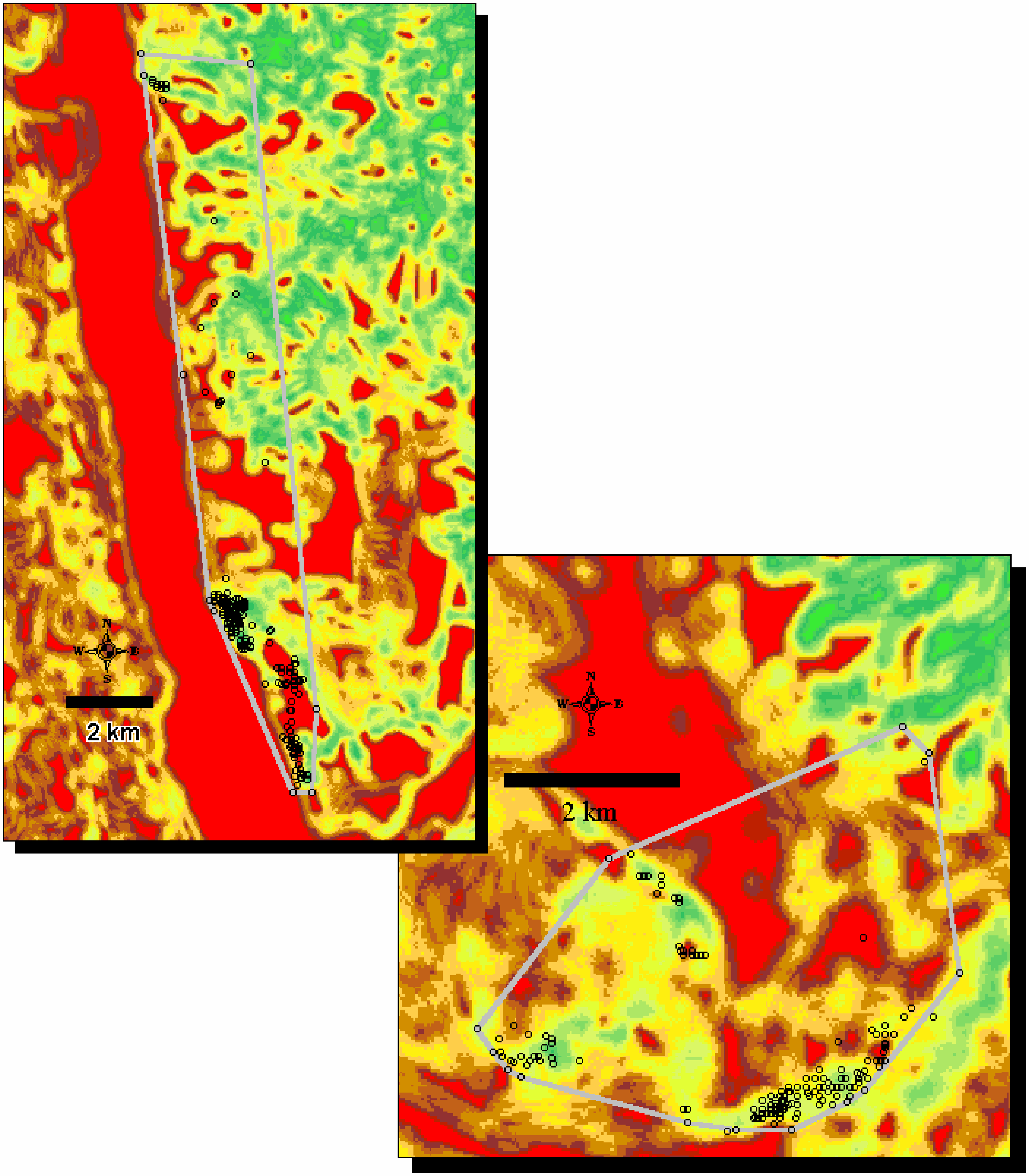

Figure 28. Terrain ruggedness values derived from digital elevation models at Columbia Lake and Bull River in relation to radiolocations of bighorn ewes during winter (red→ brown→yellow→green denotes increasing terrain ruggedness).

The reduced strength of the DFAs for the Mount Broadwood study area relative to the other 2 study areas (Figure 21) is likely due to the lack of a greenness layer in those analyses.

Topographical variables demonstrated the importance of terrain attributes to bighorn ewe habitat selection. Within the DFAs, these variables were significant contributors to the models. Elevation, and bighorns' selection for lower elevations within their winter ranges, was ranked among the top 10 variables in the DFA using all variables in all study areas, and in 2 cases, it was ranked first. In DFAs conducted without TEM variables, elevation ranked first or second among all variables. Lower elevations within the winter ranges likely have less snow accumulation through the winter than higher elevations making for easier foraging by bighorns. Steep terrain, distance to steep terrain, and terrain ruggedness all provide some measure of ewe habitat selection for security. These attributes appear to correlate well with escape terrain. In most DFAs, at least one of these variables was a significant contributor to the model. Increased terrain ruggedness, increased slope, and decreased distance to steep terrain characterized ewe habitat selection (e.g. Figure 28). Aspect, another topographical variable, was another frequent contributor to the DFAs. In particular, southerly aspects tended to be strongly selected. Southerly aspects have greater exposure to solar radiation in the winter and as such accumulate less snow. In the same manner as lower elevations, southerly aspects are more efficient feeding sites since bighorns have to dig less to gain access to forage.

The topographical variable, distance to steep terrain, provided the only case in which trends in habitat selection were not consistent across the 3 study areas. At Columbia Lake and Mount Broadwood, ewes strongly selected areas closer to steep terrain than would be expected by chance. However, the inverse was true at Bull River. Steep terrain was identified as land with a slope in excess of 30^{o}. The 100% MCP cumulative winter range at Bull River enclosed very little land identified as steep terrain using this criterion with the result that bighorn habitat use within the MCP did not follow the trend in the other 2 study areas.

This analysis emphasizes some of the strengths and weaknesses of using TEM as a tool to examine bighorn sheep habitat relationships. The TEM variables showed strong correlations with bighorn sheep habitat use. By identifying site series and structural stages that are strongly selected as well as those strongly avoided by bighorn ewes, habitat manipulations can be specifically targeted to increase the ability of the winter range to support sheep. In particular, ecosites with preferred site series (e.g., a bluebunch wheatgrass type) but occurring in structural stages that are avoided by bighorns can be targeted for habitat enhancement. These sites could be manipulated to bring them back to an earlier seral stage (i.e., a lower structural stage), one that is preferred by sheep. These management prescriptions can be very specific so that only those ecosites that are occurring in proximity to ecosites that are heavily used by bighorns are manipulated. This should increase the likelihood that habitat enhancement sites will be discovered quickly by bighorns on the winter range.

A weakness of the TEM data is its limited areal extent. Even though sheep populations at the 3 study areas are currently low relative to historic numbers, the 100% MCP winter range in each study area extended beyond the boundaries of the TEM area. Telemetry data of ewes outside the TEM boundaries couldn't be used. Similarly, the results of the habitat selection analysis can only be applied to areas with TEM data in place. Bighorn winter ranges without TEM data cannot benefit from the analysis.

The topographical and satellite image based variables do not suffer from this problem. They are available across the landscape and relationships developed in the 3 study areas can be applied throughout low elevation sheep range on the east side of the Trench. In addition, although the DFAs which excluded the TEM variables were weaker than DFAs which used all available variables, they were not significantly weaker. Differences in classification success ranged from 1.1% at Mount Broadwood to 6.0% at Bull River. Since the DFAs which did not incorporate the TEM variables used fewer variables that are more widely available and yet did not have significantly lower classification success, they are the preferred model from an regional perspective. However, TEM provides additional detailed ecosite data that are beneficial for habitat enhancement planning.

6.0 Literature Cited

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Chapter 4: Regional Habitat Model

30 September 2006

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Summary

Discriminant function analysis methods were used to create a regional habitat model. "Greenness" values obtained from satellite imagery and non-biotic landscape attributes were compared between random locations within bighorn ewe winter ranges and random locations within an area defined as potentially available to sheep along the western edge of the Rocky Mountains and eastern edge of the Rocky Mountain Trench. The 5 main predictive variables in the model were elevation (negative), distance to slope >20° (negative), terrain ruggedness (positive), greenness score (negative) and early-winter solar irradiance (positive). Portrayed as a map, the model indicated habitat to be heavily concentrated along the toe of the Rocky Mountains, but to also extend outward into the Trench and upward into major tributary valleys where there is little of no winter sheep occupancy. It is likely that this apparent overestimation of sheep habitat was due to the model's inability to capture influences covering broader areas and longer time scales, such as the ephemeral nature of non-forested habitat in tributaries, and the effect of small patch size. Imperfect correlations between key ecological requirements and model variables (such as deeper snowpacks in tributary valleys than at similar elevations in the Trench) likely also played a role. The model serves as a layer in identifying areas contributing to range carrying capacity (Chapter 6).

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Acknowledgements

J. Wierzchowski, Geomar Consulting, Terrace, spent several days sorting through archived material to locate and reconstruct some of the old files needed to complete this analysis. M. Worgan, Mountainlife Enterprises, Brisco, translated, georeferenced and classified GIS files to make presentation of the habitat maps possible.

1.0 Introduction

Micro-habitat modeling was conducted for each of the herds having radiocollared sheep, as described in Chapter 3. While those 3 herd-specific models provided generally similar results, each was fit specifically to a single group of sheep and was based on a limited number of collared ewes. In addition, the variety of habitats available from which ewes were able to make selection choices was somewhat limited within the range of any one herd. Thus, while herd-specific models have the advantage of illustrating unique local patterns of habitat selection, there is a risk that they are “over-fit” to a specific herd or even to the small sample of ewes from which telemetry data was drawn so may have limited applicability to the broader region. Also, not all of the variables used in micro-habitat modeling were available outside of bighorn sheep winter ranges, or even for the entire area within some of the ranges. Therefore, a regional habitat model was also developed for the entire area encompassing the 3 herds, with the intent that it would be:

- exclusive of TEM variables (which can be of highly localized availability);
- based on a larger sample of ewes and therefore include a greater range of habitat selection patterns;
- more generic; and
- potentially applicable to all herds along the eastern margin of the southern Rocky Mountain Trench.

2.0 Methods

To determine habitat use, a minimum convex polygon (MCP) cumulative winter home range was first defined for each of the Columbia Lake, Bull River and Mount Broadwood herds, using only ground-based telemetry locations (Figure 1). In a GIS environment, habitat attributes were extracted for a random selection of 2038 points within these MCP polygons to define “used habitat”. With the exception of the greenness score, all variables were non-biotic (Table 1). “Available habitat” was considered to be all land on the eastern edge of the Rocky Mountain

Trench and the westernmost ranges of the Rocky Mountains adjacent to the herds studied, i.e. encompassing the Brisco, Stanford, Hughes, Lizard, Galton and eastern portion of the MacDonald ranges (Figure 1). Within this area, habitat attributes were extracted for 5497 random locations.

Table 1. Attributes extracted for the use and availability dataset in the regional habitat model.

<table>
<tr><th>Variable</th><th>Source</th></tr>
<tr><td>elevation (m a.s.l.)
slope (°)
aspect (8 primary directions and flat)
terrain ruggedness (based on variability in gradient and aspect)
distance to steep terrain (slope > 30º)
distance to steep terrain (slope > 20º)</td><td>Digital elevation model (DEM)</td></tr>
<tr><td>greenness score (a measure of biomass)</td><td>tassel cap transformation of the Landsat Thematic Mapper spectral channels</td></tr>
<tr><td>density of gravel and dirt roads (km/km^2)</td><td>Terrain Resource Information Mapping (TRIM)</td></tr>
<tr><td>average early-winter solar irradiance (Dec-Feb)</td><td rowspan="2">calculated monthly; solar elevation and azimuth calculated between 10:30 and 17:00 then irradiance determined as:
I = (A + B*N/n)*{S*cos(solar incidence angle)}
where
I = irradiance
A = 0.29*cos(latitude)
B = proportion of exoatmospheric radiation transmitted on shortest atmospheric path (assumed to be 0.5)
N/n = relative duration of solar irradiance (assumed to be 1 for selected hours)
S = solar constant
solar incidence angle is a function of solar elevation, solar azimuth, azimuth of slope, and slope angle</td></tr>
<tr><td>average late-winter solar irradiance (Mar-Apr)</td></tr>
</table>

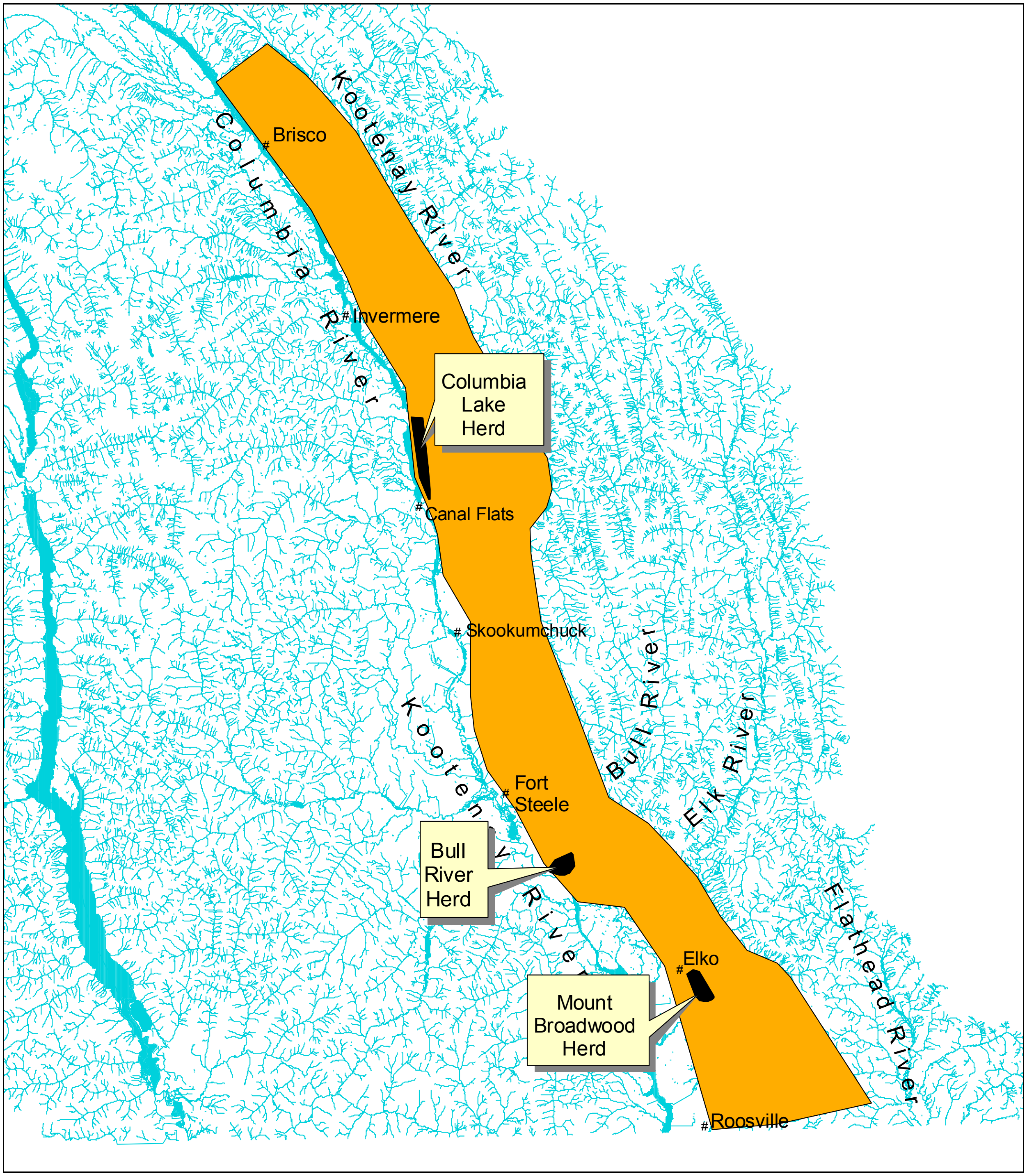

Figure 1. Location of winter composite minimum convex polygon home ranges for radiocollared ewes at 3 East Kootenay winter ranges (black, from which the "used" habitat sample was drawn) in relation to the area from which the "available" sample was drawn (orange).

For model building we used Discriminant Function Analysis (DFA) contrasting "use" versus "availability". We used the Mahalanobis distances criterion in the stepwise method for variables' entry and removal. We judged the relative contribution of the variables by analyzing the order in which the variables were entered/removed, combined with the analysis of the structure matrix and the magnitude of the standardized canonical function coefficients. We estimated the overall power of the models by scrutinizing the Eigenvalues, Wilk's Lambdas, Canonical Correlation Coefficients, and the percentage of correctly classified cases. Classification success was evaluated by first applying the discriminant function to each point used in developing the model to determine the predicted group membership (available or used) of each point, then comparing these predictions to the locations' actual membership. We then generated the most parsimonious multivariate model by using the 5 variables indicated by the above analyses to be the most important.

The very strong contribution of elevation to the model may have masked the influence of other variables, so we repeated the discriminant function analysis without the elevation variable.

On the univariate level, we used T-tests and non-parametric tests to determine whether the observed differences between the "use" and "availability" were statistically significant.

We developed a winter sheep habitat model by calculating, for each of the 3.8 million pixels within the study area, the Mahalanobis distances to the "used" and "available" group centroids and therefore the probability of group membership. We then generated a continuous group membership surface representing the probability of each pixel being "used" habitat (assumed to correlate to habitat quality)[7]. The map was clipped to portray regional habitat probability values only within the area where the models were developed.

To determine whether habitat selection patterns evident from aerial telemetry data matched results obtained through ground telemetry, we determined median group membership probability values for each of the aerial and ground telemetry datasets. Aerial locations were limited to those below 1455 m elevation, the highest elevation recorded for ground-based locations. To explain differences between the fit of the two datasets to the model we compared the two distributions on all variables used in the model, with the exception of aspect (strongly correlated to solar irradiance) and road density. A discriminant function analysis was then performed on the aerial-location dataset.

3.0 Results[8]

3.1 Models Using Ground-Based Telemetry Data

Based on the order of variable entry into the discriminant function model (elevation → distance to slope >20° → greenness score → terrain ruggedness → early winter solar irradiance), "F to remove" statistics within the 5-variable model (elevation > distance to slope >20° > terrain

[7] Initially this was done for the full model, the model with elevation excluded (to illustrate the effect of variables masked by the strong influence of elevation), and a third model that represented the arithmetic average of the other two. This was done for exploratory purposes. Because the elevation-included model most closely represented the data, it is the most representative of sheep habitat value and is the model used for further analysis (Chapter 6).

[8] Many of the results were misplaced between the time of analysis (2001) and time of writing (2006). Portions of this section that provide statements of results without supporting data or statistics are based on an outline written in 2001 indicating that such results were in fact observed and were statistically significant, but those sections of the analysis are no longer available.

ruggedness > greenness > early winter solar irradiance), standardized canonical coefficients (Table 2) and structure matrix values (Table 3), the most parsimonious multivariate model used the following 5 variables (in descending order of importance):

- elevation
- distance to slope > 20º
- terrain ruggedness
- greenness score
- average early-winter solar irradiance

Table 2. Standardized canonical coefficients of discriminant function.

Variable	Coefficient
Elevation	0.871
Greenness score	0.278
Terrain ruggedness	-0.314
Distance to slope > 20º	0.629
Average early-winter solar irradiance	-0.236

Table 3. Structure matrix values of discriminant function.

Variable	Coefficient
Elevation	0.533
Greenness score	0.422
Average early-winter solar irradiance	-0.379
Distance to slope > 20º	0.376
Terrain ruggedness	-0.297

The DFA discriminated well between used and available habitat, with a canonical correlation coefficient of 0.629, a Wilks' lambda of 0.604, an Eigenvalue of 0.656 and median and mean classification success of 84.0% and 82.1%, respectively (Table 4).

Table 4. Classification success of discriminant function (correctly classified cases highlighted).

	Actual Group Membership	Predicted Group Membership		Total
		Selected	Available	
Count	Used	1793	245	2038
	Available	1100	4397	5497
%	Used	88.0	12.0	100.0
	Available	20.0	80.0	100.0

When we repeated the DFA without the elevation variable, we found that the univariate correlation with the DFA remained the same but the multivariate contribution (standardized coefficients) pointed to greenness as the most important variable (variables listed in descending order of importance):

- greenness score
- distance to slope > 20º
- average early-winter solar irradiance
- terrain ruggedness

T-tests and non-parametric tests used to determine whether the observed differences between "use" and "availability" were statistically significant confirmed that this was the case for both models. The map created using the ground-telemetry habitat model (elevation variable included) indicates the distribution of quality habitat along the base of the Rocky Mountains in the Rocky Mountain Trench, and in major tributary valleys to it (Figure 2). Figures 3 to 6 portray detailed views of the model at each of the 3 winter ranges from which radiotelemetry data was drawn, and for the Premier Lake winter range where radiocollared sheep were monitored more recently as part of another project (Chapter 6).

3.2 Analysis of Aircraft-Based Telemetry Data

We found the ground locations to fit the model very well[9] (median value of 85% probability). The aerial locations, however, showed little agreement with the model (mean value of 39% probability, with close to 14% of the locations falling within 0% probability zone). The distributions of aerial-telemetry and ground-telemetry data with respect to model values differed for all but two of the variables (Table 5). Ground-based observations characterized sheep as selecting for more sunny locations, lower elevations, lower greenness scores, more rugged terrain, and the areas closer to moderately steep terrain.

Table 5. Univariate habitat values of ground-based and aircraft-based telemetry fixes (shaded values do not differ at $\alpha = 0.05$).

Variable	Ground-based Telemetry Data (mean & 95% C.I.)		Aircraft-based Telemetry Data (mean & 95% C.I.)	
Early-winter solar irradiance	0.501	(0.492-0.510)	0.457	(0.435-0.480)
Late-winter solar irradiance	0.724	(0.716-0.732)	0.678	(0.657-0.699)
Elevation (m)	940	(935-944)	1070	(1053-1088)
Greenness score	17.3	(17.0-17.6)	19.7	(18.8-20.6)
Terrain ruggedness	0.252	(0.249-0.256)	0.227	(0.215-0.239)
Slope (°)	16.7	(16.2-17.1)	17.7	(16.5-18.8)
Distance to slope > 20º (m)	88	(84-93)	146	(121-171)
Distance to slope > 30º (m)	494	(462-526)	443	(380-506)

The DFA performed on the aerial locations showed that the strength of the contrast between the "used" and "available" was much reduced in comparison to the ground-telemetry dataset, with a canonical correlation coefficient of 0.180, a Wilks' lambda of 0.968, an Eigenvalue of 0.034 and median and mean classification success of 66.4% and 67.1%, respectively. However, the direction of the differences was maintained between the two datasets. Both aerial and ground locations confirm that sheep tend to select more sunny areas, in rugged terrain, close to steep slopes, and in the areas of lower greenness scores.

[9] This is a somewhat biased measure since the same points were used to develop the home ranges.

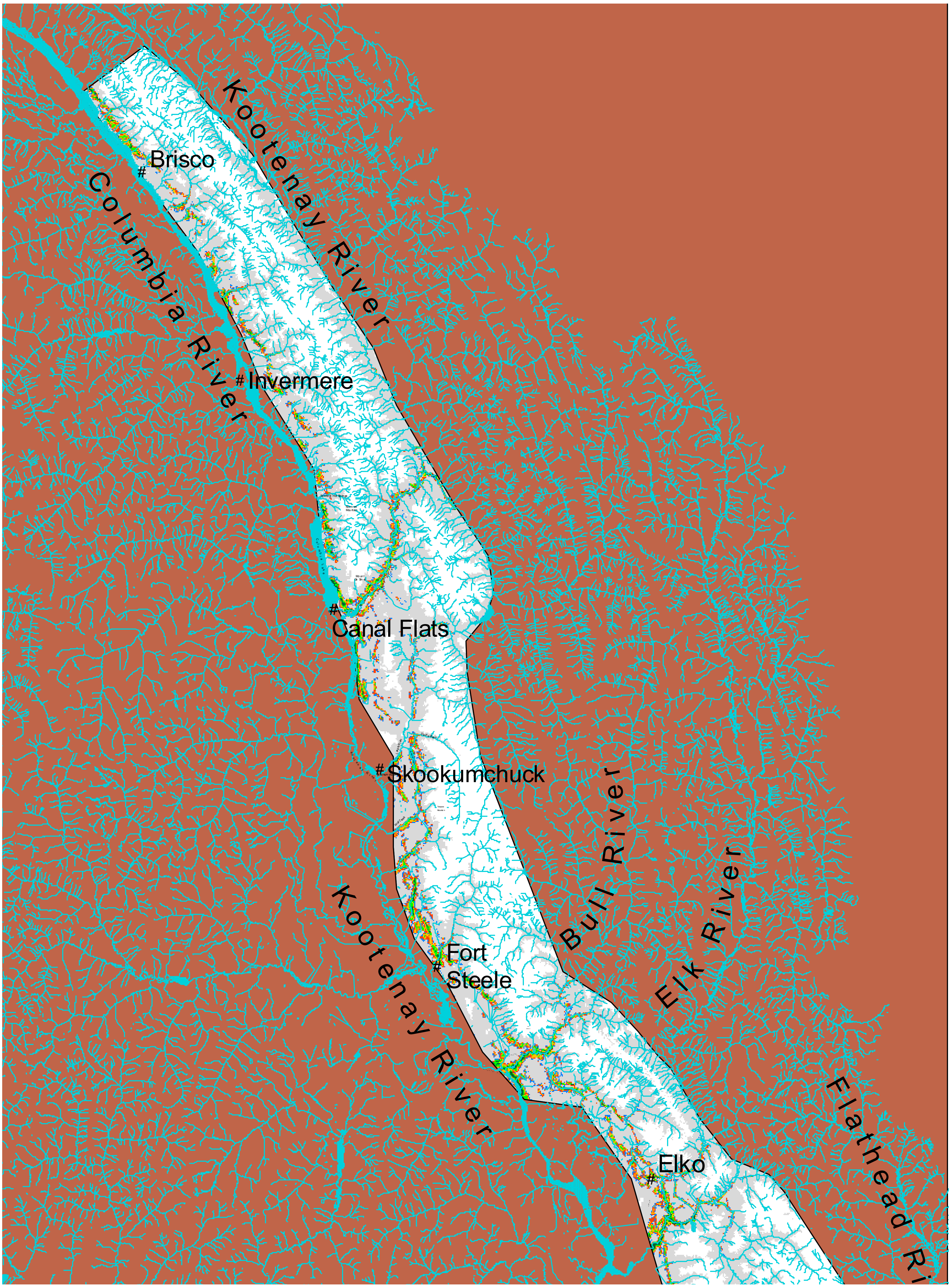

Figure 2. Regional bighorn ewe winter habitat model probability surface. Habitat of decreasing predicted value in 7 classes from dark green through light green, yellow, orange, blue and grey and white. The latter 2 classes can be considered non-habitat.

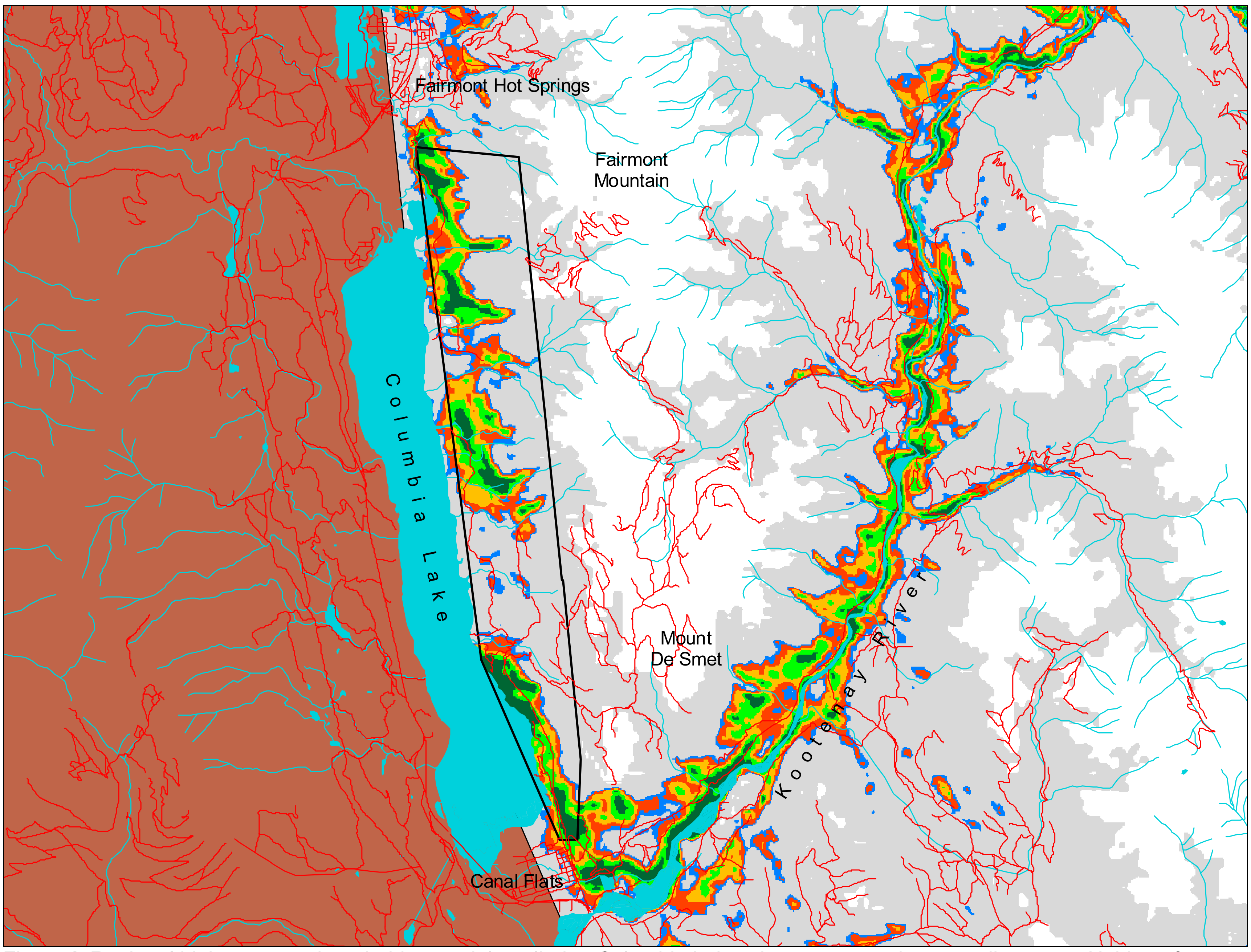

Figure 3. Regional bighorn ewe winter habitat model applied to Columbia Lake winter range and surrounding area. Habitat of decreasing predicted value in 7 classes from dark green through light green, yellow, orange, blue and grey and white. The latter 2 classes can be considered non-habitat. Black line is composite winter home range of radiocollared ewes.

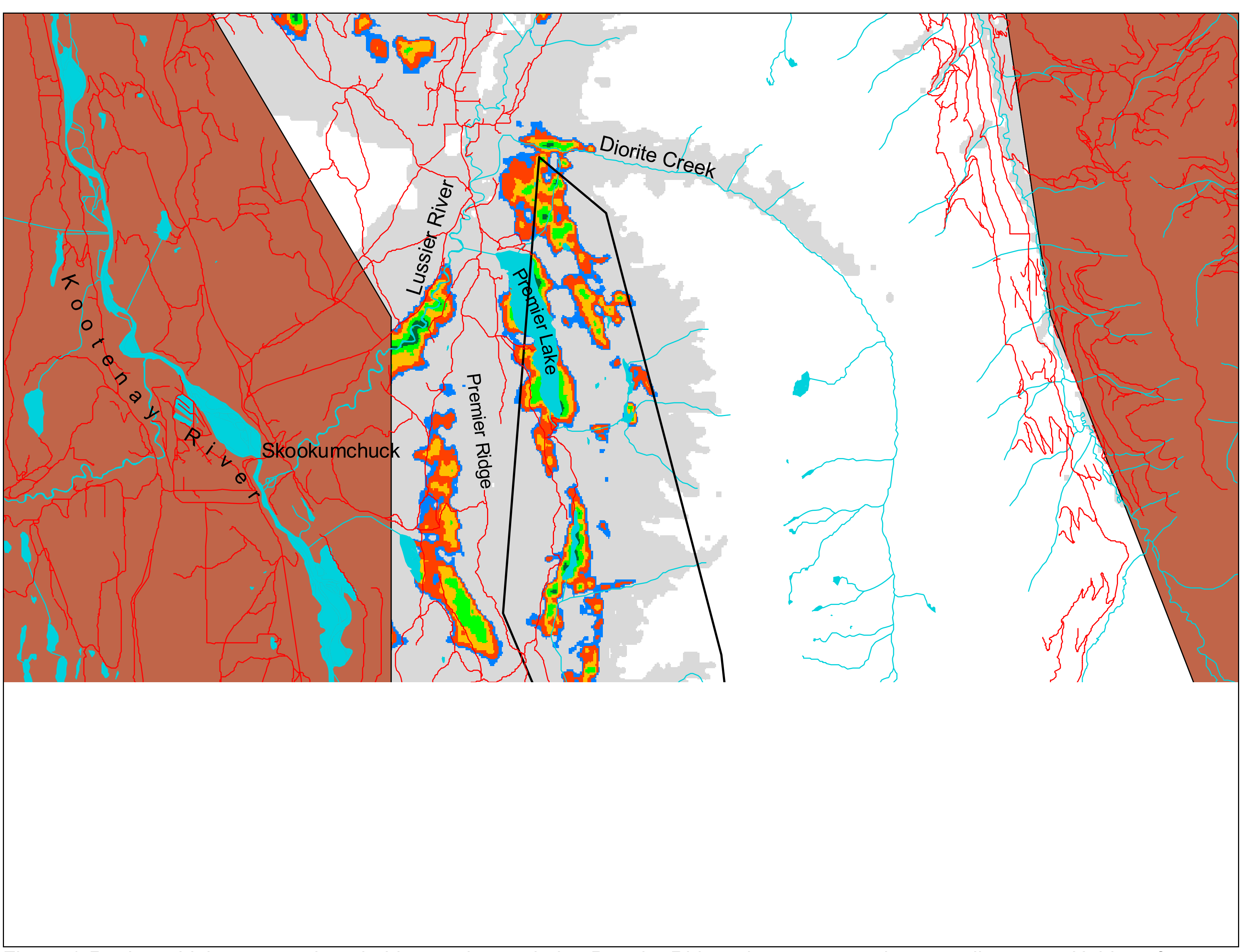

Figure 4. Regional bighorn ewe winter habitat model applied to Premier Ridge winter range and surrounding area. Habitat of decreasing predicted value in 7 classes from dark green through light green, yellow, orange, blue and grey and white. The latter 2 classes can be considered non-habitat. Black line is composite winter home range of radiocollared ewes (telemetry data courtesy L. Ingham, Fish and Wildlife Compensation Program, BC Hydro, Invermere; see Chapter 6).

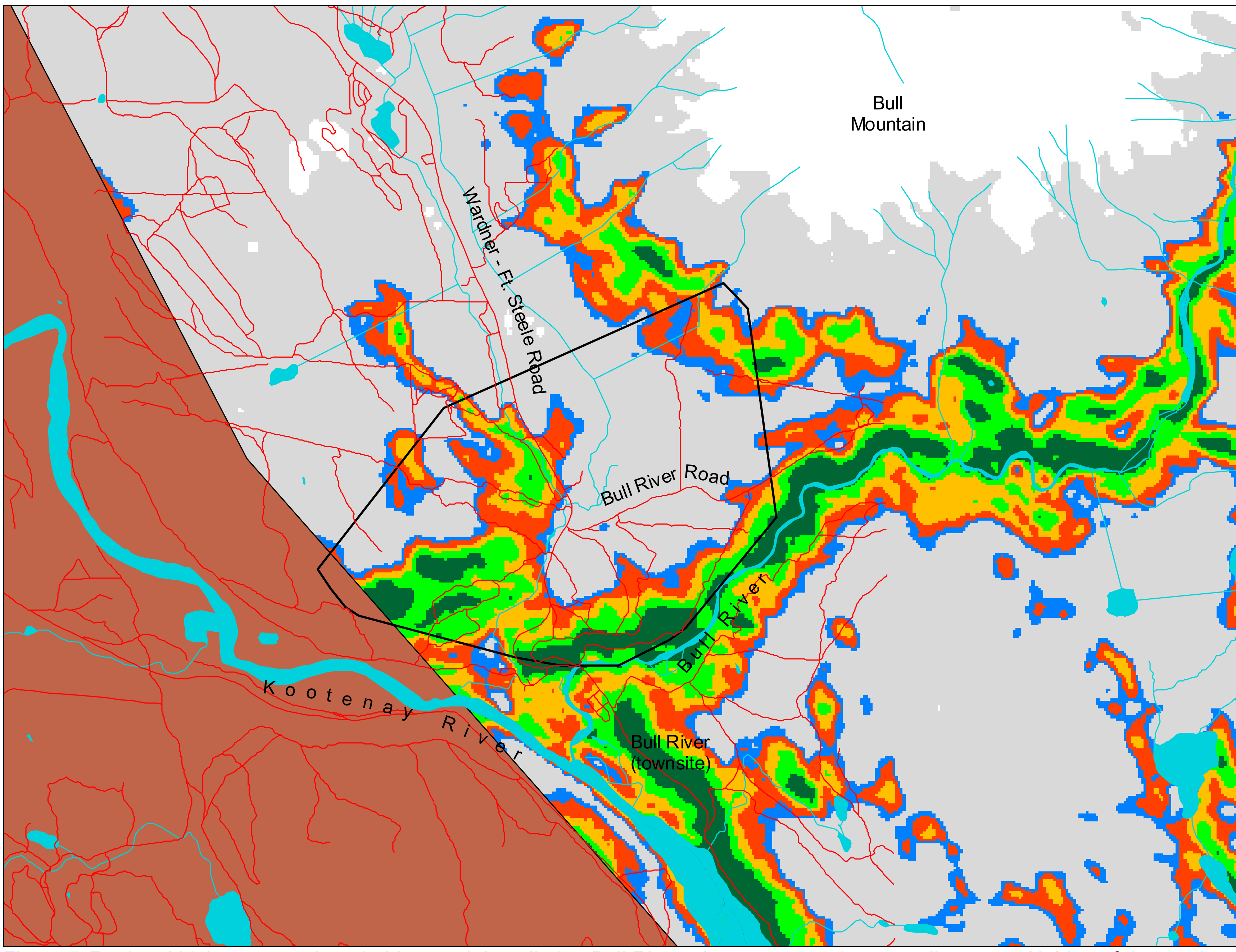

Figure 5. Regional bighorn ewe winter habitat model applied to Bull River winter range and surrounding area. Habitat of decreasing predicted value in 7 classes from dark green through light green, yellow, orange, blue and grey and white. The latter 2 classes can be considered non-habitat. Black line is composite winter home range of radiocollared ewes.

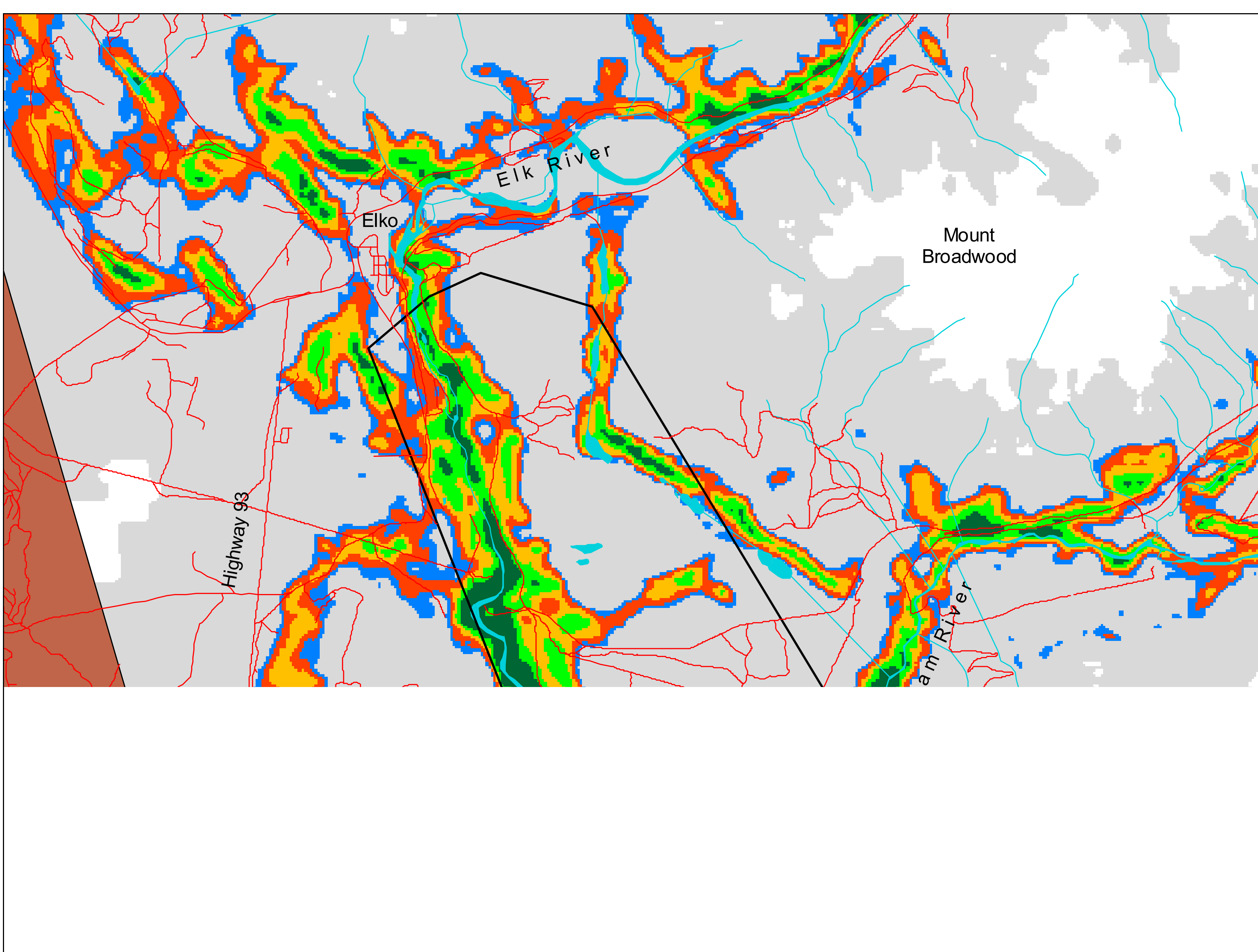

Figure 6. Regional bighorn ewe winter habitat model applied to Mount Broadwood winter range and surrounding area. Habitat of decreasing predicted value in 7 classes from dark green through light green, yellow, orange, blue and grey and white. The latter 2 classes can be considered non-habitat. Black line is composite winter home range of radiocollared ewes.

4.0 Discussion

Because the model based on aerial telemetry was not as strong as the ground-telemetry model but showed the direction of differences between used and available habitat to be similar to that of the ground model, the aerial model is of little value for management purposes. Instead, the original model based on ground telemetry is the appropriate tool.

Each of the 5 main contributing variables in the model had an obvious relationship with bighorn sheep winter ecology. Based on structure matrix values (whose coefficients inversely reflect the relationship with sheep habitat), the overriding value of elevation no doubt relates to the fact that low elevations have low snowfall, warm temperatures, and open habitats that provide both forage and long sight lines. Low greenness scores are associated with non-forested and often rocky locations, typical of sites that provide both escape terrain and grass forage. Solar irradiance is an important factor in maintaining low snow depths. Selection for proximity to slopes of > 20° is consistent with the need for escape terrain adjacent to foraging areas. Terrain ruggedness reflects both the presence of escape terrain and decreasing snow loads.

It is important to note that this model does not address factors that potentially limit bighorn sheep distribution at broader scales. For example, habitat is shown to extend well up into tributaries of the Trench in locations where there is little if any bighorn sheep winter activity. Similarly, while the maps have been clipped to portray the model only within the polygon used to define “available” land for model development, the unmasked model does portray sheep habitat well out into the Trench, away from the face of the Rockies. The lack of sheep occupancy of these areas likely represents the deeper snowpacks and decreased permanence of non-forested sites in the tributary valleys; the amount of intervening land without escape terrain, the lack of exposed bedrock and possibly competition with other ungulates in the middle of the Trench; and the generally limited patch size in both locations. Historic predation or hunting pressure in either of those locations may also have created lasting effects on the current distribution of sheep. Factors that act on longer time scales or broader geographic scales than those used in developing the model may therefore results in the portrayal of some habitat where it does not truly exist. The model is of greatest utility when limited to predicting the occurrence of current habitats along the eastern edge of the Trench.

Chapter 5. Range Conditions and Use

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B. Weerstra photo

Summary

Range sampling occurred at each of the 4 winter ranges, focusing on areas shown by telemetry, habitat analysis and anecdotal information to be most heavily used by bighorn sheep. Research activities included:

- describing plant communities (species present, percent cover, site characteristics), including those affected by introduced weeds and agronomic species;
- describing the short-term influence of a prescribed burn;
- using range reference areas to compare ungrazed exclosures to areas available for grazing (Columbia Lake and Mount Broadwood) or to compare an area having wildlife grazing only to an area with wildlife and cattle grazing (Bull River);
- measuring production of grasses, forbs and shrubs;
- measuring the winter utilization of grasses, forbs and shrubs and, at Bull River, the summer utilization by cattle;
- determining the plant species most abundant in scat as a measure of winter diet; and
- measuring the nutritional composition of forage plants.

Within the portion of sheep habitat measured, 6 grassland or grass-shrubland communities were identified at Columbia Lake, along with 6 at Premier Ridge, 10 at Bull River and 13 at Mount Broadwood. At Columbia Lake, common native grasses were needle-and-thread grass, bluebunch wheatgrass and Junegrass, with the exotic cheatgrass common on some sites. Fescues were notably absent within the areas investigated. Prairie sagewort and white pussytoes were 2 of the most common forbs. Premier Lake communities were strongly dominated by bluebunch wheatgrass, with considerably less cover of Junegrass, rough fescue and other native grasses. Two non-native grass species, cheatgrass and Canada bluegrass, were common on some sites. Forb and shrub composition was variable, but spreading dogbane and antelope-brush were consistently common. On the Bull River winter range, Canada bluegrass and at least 1 species of introduced brome (cheatgrass, Japanese brome, smooth brome) dominated at most sites. Native grass composition was diverse, but the needlegrasses (needle-and-thread grass, spreading needlegrass, Columbia needlegrass) were collectively most common. The rare grass, little bluestem, dominated on 1 site. Forb composition was dominated by introduced species, particularly black medic and sulphur cinquefoil, with the diversity and coverage of weeds of considerable concern. A variety of native shrubs occurred, though antelope-brush was the most widespread. At Mount Broadwood, native grasses were typically more common than exotics, but in some areas exotics did dominate. The native component was largely fescues (mainly rough fescue and Idaho fescue), bluebunch wheatgrass and, in some areas, pinegrass or poverty oatgrass, though with a considerable diversity of other species. Cover of introduced and potentially introduced grasses was mostly common timothy, Canada bluegrass and Kentucky bluegrass. The forb layer was notably weedy on about half of the sites studied, with common St. John's-wort, sulphur cinquefoil, spotted knapweed and various clovers being common. Native forb composition was more diverse than in other study areas. Common snowberry was the most abundant and widespread shrub.

Comparisons of exclosures to areas outside of them suggested that range condition was better at Columbia Lake than at Mount Broadwood, although conditions were quite variable within each of those winter ranges. The comparison of sites with and without cattle grazing at Bull River indicated a considerable effect of livestock on the native plant community.

Sheep diets from January through April at Columbia Lake, Bull River and Mount Broadwood were strongly dominated by grasses, particularly needlegrasses, wheatgrasses and fescues. Mount Broadwood scats were the only ones with a large shrub component, consisting mainly of creeping Oregon-grape. Forbs, particularly prairie sagewort, had moderately high occurrence in the diet at Columbia Lake. Nutrient levels were almost universally deficient in comparison to maintenance diets for domestic sheep. While there was some use of the few species with better levels of protein, energy or micronutrients, such as creeping Oregon-grape, willow and possibly white pussytoes, the predominant diet of grasses generally had lowest apparent nutritional value. This may reflect differing nutritional requirements of domestic versus bighorn sheep, a shift by bighorns to a “maintenance” mode in winter, the effect of unpalatable compounds in some plants of otherwise high nutritional value, or simply the lack of availability of better forage within environments that provide sheep with the necessary escape terrain or other requirements. A better understanding of nutrition would require knowledge of summer foraging and mineral licks.

Forage production was measured across community types at each winter range. Grass production increased from north to south, being double at Mount Broadwood compared to Columbia Lake. However, the greater abundance of little-used agronomic or weedy grasses at the southern sites negated some of this difference. There was also far more variability in production among sites at the southern winter ranges. Utilization was particularly variable among sites within each winter range, with values often approaching nil in some communities while others were heavily used. Averaging across plant communities, grass utilization was greatest at Columbia Lake and Bull River (including both cattle and wildlife grazing at Bull River), and lower at Premier Ridge. Mean utilization levels were even lower at Mount Broadwood, but the predominance of weeds may have influenced grazing effort there. Production and utilization data were used in part to develop carrying capacity estimates (Chapter 6).

One of the major findings was the diversity and high ground cover of exotic plant species. This included both weeds and agronomics. Even where the situation was less severe, at Columbia Lake and Premier Ridge, cheatgrass and several weedy forbs were well established, and there were nearby seed sources for more aggressive species. At Bull River and Mount Broadwood, exotic grasses (particularly Canada bluegrass and cheatgrass) had supplanted natives on many sites, and weedy or agronomic forbs such as sulphur cinquefoil, common St. John’s-wort, spotted knapweed, black medic, sweet clover, great mullein and oxeye daisy commonly dominated forb composition. Such species not only are indicative of past impacts to the native ranges, they typically expand to cause both declines in the value of preferred native forages and reduced site stability.

Short-term monitoring of vegetation responses to prescribed fire at Bull River were equivocal. There was no evidence of the suppression of sulphur cinquefoil, and in fact this species may have benefited. Future habitat restoration work, whether based on mechanical removal, fire, or both, must include planning to prevent the further expansion of weeds on bighorn winter ranges.

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Acknowledgements

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1.0 Introduction

This chapter covers one of the goals identified in Chapter 1, namely to determine the range characteristics, quality, and trends for habitats that are seasonally selected by sheep, with emphasis on preferred plant species. Within this, the specific objectives were to:

1. Characterize plant communities occurring at the 4 winter ranges, limiting investigations to Terrestrial Ecosystem Mapping (TEM) site series indicated by micro-habitat modeling (Chapter 3) to be preferred by bighorn sheep.
2. Determine forage production and forage quality within these communities.
3. Determine the degree of forage utilization over winter by wild ungulates including bighorn sheep, and (where applicable) during summer by cattle.
4. Report on other factors relevant to bighorn sheep forage quality at the 4 winter ranges, such as weed presence and the effects of burns.

The ultimate objective was to determine whether there was enough range of sufficient quality to continue supporting bighorn sheep and other herbivores in the 4 study areas. Fundamental to this goal is the concept of the “safe-use factor”. According to most range management guidelines, summer utilization by livestock or wild ungulates should not exceed 50% in order to leave 25% of the forage for winter wildlife use and 25% for carry-over (a requirement for plant regrowth, seed production, winter insulation and erosion control). However, evidence from the East Kootenay suggests that range quality declines unless about 50% carry-over is maintained, meaning that utilization by wild ungulates (mainly during winter in the Trench) and summer livestock utilization should collectively not exceed 50% (D. Smith, Ministry of Agriculture and Lands, Cranbrook, pers. comm.). How the 50% use is allocated between livestock and wildlife is largely a management, not scientific, question. However, total annual utilization of East Kootenay rangelands exceeding 50% of production potentially results in declining range quality.

2.0 Methods

2.1 Range Assessment

2.1.1 Study Design Considerations

Range evaluations began in 1998, within the preferred winter habitat (TEM) types determined through micro-habitat modeling (Chapter 3). The project’s terms of reference called for the assessment of range condition using paired 15-m x 30-m plots consisting of a series of transects at each sampling location, as has been done in previous studies (Demarchi 1967; Stelfox et al. 1985, Davidson 1991). By using similar methods, data collected in this study could be compared to the results of earlier studies, and long-term trends could be identified. One plot would be a fenced exclosure designed to exclude ungulates. The second plot would be located nearby in an area of similar site and vegetative characteristics, but would be open to grazing. However, in response to concerns expressed by the Ministry of Forests (MOF) with regard to the construction of new range exclosures and questions regarding the terms of reference, a meeting was held with MOF and Ministry of Environment, Lands and Parks (MOELP) officials and the project consultants to discuss the methods. The 15-m x 30-m exclosures were considered too small to properly evaluate range use, resulting in "edge effects" within the entire exclosure, so there was opposition to building new exclosures of this size. It was decided that if an existing 15-m x 30-m exclosure was in key bighorn sheep winter range, and if it was in good repair, an attempt would be made to relocate the existing transects within and outside the exclosure and follow previous methodology, but no new 15-m x 30-m exclosures would be built. New, larger exclosures (minimum of 1 ha) conforming to MOF's current Range Reference Area Program (RRAP; Erickson 2000) methodology would only be constructed if the proposed location was determined by the Regional Range Ecologist for MOF be useful to that program.

The TEM map units (polygons) indicated by micro-habitat modeling to be preferred by bighorn sheep each contained up to 3 plant communities. It was agreed that 30-m transects (hereafter "preferred-habitat transects") would be placed to sample a variety of the plant community types. Thus, it was intended that at each study site there would be:

- a series of 30-m transects to sample preferred habitats, with a series of microplots established on each transect;
- for each of these transects, a nearby forage production cage for fall and spring clipping to determine forage availability prior to and after winter use; and
- where possible, 1 or more pairs of plots per study area to monitor long-term effects of grazing, consisting of 5 transects per plot with 1 plot inside and 1 plot just outside an exclosure (hereafter "range reference areas"). Range reference area transects outside the exclosure would be in addition to, and independent of, the preferred-habitat transects.

2.1.2 Preferred-Habitat Transects

In the Columbia Lake and Bull River study areas, preferred-habitat transects were located within the TEM units identified through micro-habitat modeling as being key winter habitat. The precise location of the initial transects was based on air photo interpretation and site examinations in order to place them at sites within the vegetation communities that were perceived to be representative. Since no radiotelemetry data had been collected in the Premier Ridge and Mount Broadwood study areas, Bill Warkentin and Anna Fontana of MOELP and Mario Rocca of EKWA indicated the perceived bighorn sheep winter ranges by providing maps or providing advice in the field.

According to the project terms of reference, the habitat selection analysis results for Bull River were to be extrapolated to Mount Broadwood. However, following the initial vegetation survey work at Mount Broadwood, it was concluded that the species composition of the vegetation communities there did not match those of the antelope-brush-bluebunch wheatgrass (AW) ecosystem unit of the Bull River study area. No antelope-brush[10] was noted in the bighorn

[10] Common names are reported in the text of this report; scientific names are included only in tables or where referencing species not found in the study areas. Appendix 5-1 provides a master list of species known to occur in the study areas, including scientific names. All scientific and common names reported

sheep winter range at Mount Broadwood, and dominant grasses varied from non-native species such as common timothy and Canada bluegrass, to native species such as Idaho fescue, bluebunch wheatgrass, poverty oatgrass and pinegrass. Many forb and shrub species were noted that did not occur at Bull River. Since extrapolation of habitat preferences from Bull River was questionable, radiotelemetry work began in the Mount Broadwood study area in 1999 to obtain site-specific habitat selection data.

The following methodology was established by MOF (district level) for the establishment and reading of transects for range management. It was used for the preferred-habitat transects.

- A minimum of 2 transects per distinct community type is required.
- A transect is placed in the most representative part of the polygon.
- Transects located on slopes are established parallel to slope contours.
- A transect is 30 m long with 15 0.1-m^2 microplots (20 cm x 50 cm in size) placed at 2-m intervals along the right-hand side of the transect to sample graminoids and forbs. At each transect, 2 10-m x 10-m macroplots are used to record the shrub cover (<2.5 m in height). These macroplots are at either end of the transect and straddle it equally on both sides. One 20-m x 20-m macroplot located at the centre of the 30-m transect and straddling it is used to estimate the canopy cover of trees and tall shrubs (>3 m in height). Trees and shrubs are recorded only once in the average percent cover column to the nearest 5%.
- Cover estimates for all other species are recorded to the nearest 1% between 1 and 15%, and to the nearest 5% between 20 and 100%. Cover estimates are recorded at each microplot on the range inventory form. The plant species is recorded using a 7-letter code composed of the first 4 letters of the genus and first 3 letters of the species. If the species is unknown it is marked on the plot sheet (with a unique code), collected, and later identified. If possible, all plants should have a species name. All other components of the vegetation inventory data sheet must be completed.

The preferred-habitat transects locations were noted (Appendix 5-2) so that they could be relocated and re-read in future years. Thus, they constitute a series of permanent monitoring plots to detect changes in the vegetation over time, in addition to providing current data to define vegetation communities selected by sheep.

2.1.3 Range Reference Area Plots

As noted below, existing exclosures were used at 2 sites, a simulated exclosure (fenced private land) was used at a third site, and no range reference data were collected at the fourth site. Methods for establishment and monitoring followed the July, 1998 version of the Range Reference Area vegetation monitoring procedures for the Nelson forest region (available in slightly modified form as Gayton 2001), except as noted below. Various sizes of microplots were used along range reference area transects during previous sampling in the study areas. Davidson (1991) indicated that he used 0.5-m^2 microplots in 1987, but that 0.25-m^2 microplots were used in 1984, and 0.1-m^2 plots were used in 1966. Mr. Davidson recalled, however, that his microplots were 0.5 m x 0.5 m (P. Davidson, formerly Ministry of Environment, Lands and Parks, Cranbrook, pers. comm.), which equals 0.25 m^2. Poulton and Tisdale (1961) recommended a 1-ft x 2-ft plot (30 cm x 60 cm) or 0.18 m^2. For this assessment, a 0.25-m^2 plot frame was used for existing exclosures at Columbia Lake and Mount Broadwood, as specified in the terms of reference. A 0.1-m^2 plot frame was used for the new range reference area at Bull River (see below).

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here follow the useage in "E-Flora BC", an electronic database of the departments of Geography and Botany at the University of British Columbia (http://www.eflora.bc.ca/) as of 1 December 2006.

In the Columbia Lake study area, the existing exclosure below the radio tower (Appendix 5-2) was suitable for this project, but the vegetation community in which it was located was not large enough to allow expansion of the exclosure to 1 ha. The wire on the east side of the exclosure had been cut some time in the past, allowing grazing to take place inside the exclosure. EKWA volunteers repaired the fence in 1998. The 5 original 15-m transects were relocated within the exclosure but the original transects outside the exclosure could not be found. The original transects were on a flat area to the southeast of the exclosure. An area fitting this description had previously been scraped clear of snow to establish temporary corrals for the capture of 10 ewes for radiocollaring. It is possible that any pegs were destroyed in the process. To the west of the exclosure, the vegetation community and site parameters were most similar to the area inside the exclosure, so 5 new transects were established there to complete the paired design.

The existing exclosures in the Premier Ridge study area were not in key bighorn sheep winter habitat so were not used. The Regional Range Ecologist did not believe that building a new exclosure here would meet the objectives of the RRAP.

The 2 existing exclosures at the Bull River study area were unsuitable since they were in areas not currently used by bighorn sheep. However, a fenced area on private land (owned by the Armstrongs) was virtually ungrazed by livestock, in contrast to very heavy livestock grazing on public land (Whitetail Pasture). Bighorn sheep grazed on both sides of the fence. Permission was obtained from the landowner to use the private land for comparison with the public land, rather than building an exclosure. Five 60-m transects were established parallel to the fence on each side (the plot on public land simulating the area outside an exclosure, the plot on private land simulating the area inside an exclosure; Appendix 5-2). Transects were established 13 m, 19 m, 25 m, 29 m and 35 m from the fence. The zero point was located on the west side of a bird house for swallows at the base of the metal post. The transects were read from east to west. The 10 sampling locations along each transect were predetermined in the guidelines. Sampling was conducted using a 0.1-m^2 Daubenmire frame placed on the right-hand (upslope) side of the tape.

The existing exclosure on Wigwam Flats (Appendix 5-2) in the Mount Broadwood study area was suitable for use in this project. Fence repairs were completed in 1998. The Regional Range Ecologist decided against expanding this exclosure to 1 ha. Prior to the 1998 assessment, the transect markers had to be located and replaced, as many of the wooden stakes had rotted and fallen over. The 5 original 15-m transects were relocated within the exclosure and most of the original transects outside the exclosure were found. They were remarked as best as possible.

In summary, range reference area sampling:

- did not occur at Premier Ridge;
- made use of repaired existing exclosures at Columbia Lake and Wigwam Flats that were smaller than RRAP standards (5 15-m transects within exclosures, and 5 15-m transects outside exclosures at each study site); and
- opportunistically used a nearly ungrazed parcel of private land at Bull River to similate an exclosure, which was then compared to grazed Crown land using 5 60-m transects on each parcel. Transect size and configuration matched RRAP standards, although no permanent structure was built.

2.1.4 Forage Production and Utilization

Production cages were placed in association with most of the preferred-habitat transects and range reference areas to exclude grazing. Transects that were not associated with a production cage were either in a vegetation community that was already represented by one, or the transect was established too late in the 3-year study to permit forage production assessment.

Production clippings were conducted in late September to determine if there was any difference in production inside and outside the cage or exclosure due to summer grazing, and to represent the amount of forage available going into the winter. Summer and fall livestock grazing occurred only at the Bull River study area. There was no perceptible difference in production inside versus outside the production cages at the other 3 study areas and no evidence of grazing, suggesting that grazing by wildlife did not occur or was negligible. Therefore fall clipping was conducted only outside the cage at the Columbia Lake, Premier Ridge and Mount Broadwood sites. An area of 1 m^2 was clipped. Since grazing had occurred in the Bull River study area, fall clipping was conducted inside and outside the cages, and each cage was moved to a new location in the vicinity of the associated preferred-habitat transect or the range reference area.

Clipping was conducted again in mid-April both inside and outside the cages at all study areas in order to assess forage use by bighorn sheep (or other wild ungulates) over the fall, winter and early spring. At this time there was little new plant growth. The only exception to this schedule was in spring 2000, when Bull River cages BR-07 and BR-08 were clipped on March 24 prior to a controlled burn. Vegetation matter was clipped within a 1-m^2 area inside the cage, representing the forage that was available for the fall-winter-spring season, and in 1 m^2 outside the cage, representing the forage that remained after grazing over this period. Following each clipping, the cage was moved to a new location in the vicinity of the associated transect or the range reference area.

Grass, forbs and shrubs were clipped and bagged separately. It was not possible to accurately separate grass and forbs in the field during the spring due to the deterioration of the plants, so they were later sorted more accurately in the lab. Fresh green spring growth was removed at that time, since it would not have been available over the winter.

The cages at BR-01, 04, 10 and 11 at the Bull River study area were moved at some time during each of the summers of 1999 and 2000 without the study team's knowledge, so that the vegetation beneath was not protected from grazing. Therefore, for the fall clippings in those years, a 1-m^2 area that had received the least amount of grazing in the vicinity of each cage was clipped to represent a state approaching the ungrazed condition, recognizing that this would underestimate the true amount of summer grazing.

Forage production samples were oven dried at 60°C for approximately 24 hours, then weighed to the nearest 0.1 g. For each of the defined community types, the production data collected over the 3 years were pooled (e.g. for a community represented by 3 sites and clipped over 3 years, 9 samples would be combined to give a single production figure for that community type). Utilization data collected for 2 years were pooled in the same manner. In some instances, only 1 site represented the community type. The production data were presented as kg/ha for the grass, forb and (if present) shrub components. The utilization data (difference between production in cage and outside cage) were presented as percent use. Minimum, maximum and mean production and utilization values were determined.

To place forage production values in the context of precipitation during the growing season, precipitation data were obtained (April 1 - October 31) from 3 meteorological stations located near the study areas. Data covered the 3 years in which forage production was recorded, and the long-term average.

2.1.5 Range Sampling Schedule

The delay in the 1998 summer field program, caused by reassessing the methods, precluded a complete assessment of plant species composition of the vegetation communities within the 4 study areas that year. The optimal period for vegetation assessment in this region ends approximately mid-July, when dry conditions cause plant senescence (D. Smith, Ministry of Agriculture and Lands, Cranbrook, pers. comm.). However, as many transects as possible were established. Preferred-habitat transect and range reference area exclosure locations were pin-pricked on colour copies of air photos and the positions were recorded using a hand-held Global Positioning System (GPS) unit (Appendix 5-2, Figure 1). Most cages were put in place. Based on a preliminary, subjective vegetation community analysis, some of the community types appeared to be represented by only 1 transect. Therefore, additional transects were established from mid-June to early July, 1999, to create at least 2 transects per community type. Over the 3 years (1998-2000), the following range-sampling schedule was followed.

Columbia Lake
Eight preferred-habitat transects were established in 1998, and a production cage was associated with each. An additional 3 transects without cages were established in mid- to late June, 1999 to provide second representatives of 3 of the community types sampled. Clipping occurred at the production cages and the exclosure in September, 1998 and at the production cages only in mid-April, 1999, late September, 1999 and in April, 2000.

Premier Ridge
Two preferred-habitat transects were established in 1998 and a production cage was placed in association with each. An additional 6 production cages were placed in other vegetation communities. Transects associated with these cages were established in mid- to late June, 1999, along with an additional 5 transects to more fully represent the various plant community types. Clipping occurred at the 8 original production cages in September, 1998 and mid-April, 1999. Production cages were set up at the 5 new sites in the fall of 1999 and clipping was conducted at all 13 sites then, as well as in April, 2000.

Bull River
Nine preferred-habitat transects were established in 1998. One production cage was associated with each transect with the exception that 2 of the transects were positioned on terraces. These were associated with 2 cages each, placed in areas that differed in the dominant grass species. A twelfth cage was placed on public land in the vicinity of the simulated exclosure.

Clipping occurred inside and outside the 12 production cages in September, 1998 and mid-April, 1999. An additional 4 preferred-habitat transects were established in mid-June, 1999 to provide second representatives of 4 of the community types sampled. Two of these were associated with the second cages on the terraces. Clipping occurred at the original 12 production cage sites in late September, 1999 and in April, 2000. After conferring with the radiotelemetry technician, 2 more transects (BR-14, BR-15) were established in July, 2000 in areas that were frequented by bighorn sheep west of Wardner-Fort Steele Road, above an old quarry site (I. Teske, Ministry of Environment, Cranbrook, pers. comm.).

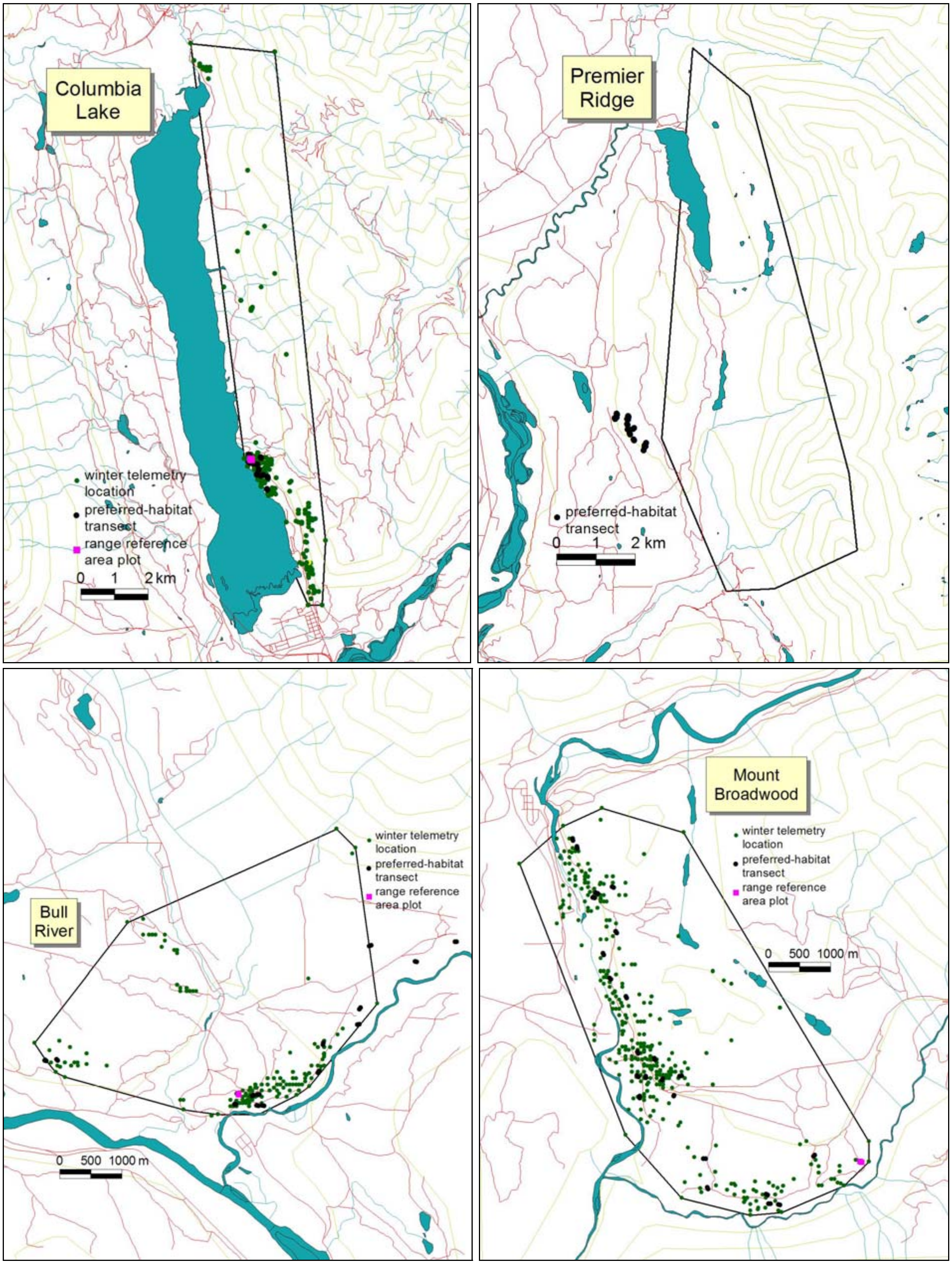

Figure 1. Range sampling locations in relation to composite winter home ranges (polygon with black outline) of collared ewes. See also Appendix 5-2.

In the spring of 1998, a controlled burn was conducted by the Columbia Basin Fish and Wildlife Compensation Program on some of the south- and southwest-facing slopes in the Bull River study area. Preferred-habitat transects BR-02 and BR-03 were established in these areas shortly after the burn (summer 1998) then re-read in 1999 and 2000 to monitor potential changes. A second controlled burn was conducted in March of 2000. It affected BR-07 and BR-08. The 1998 data from these sites provided information prior to the burn. These transects were reread in 2000 to obtain information on plant species cover and composition immediately following the burn. Thus, data for BR-02 and BR-03 showed plant composition during the summer immediately following the spring burn and for 2 subsequent years, while the data for BR-07 and BR-08 indicated plant composition prior to the burn and in the summer immediately following the spring burn.

Mount Broadwood

Twelve cages were placed in preferred habitats and 1 cage was placed near the exclosure during 1998, with clipping in September, 1998 and mid-April, 1999. In late June and early July, 1999, transects were established near 10 of these cages; telemetry data collected the previous winter indicated that the other 2 cages were not in prime winter range. An additional 9 transects were also established during 1999, based on the results of the habitat selection analysis. Production cages were set up at these 9 new sites in late September, 1999, with clipping conducted at all 19 preferred-habitat sites and the exclosure then and in April, 2000. To provide 2 samples of each plant community type, 4 more preferred-habitat transects were established in July, 2000.

2.1.6 Vegetation Data Analysis

Microplot data from each preferred-habitat transect were averaged over the transect to provide the average cover of each plant species. These data were subjected to ordination (detrended correspondence analysis), cluster analysis and two-way indicator species analysis (TWINSPAN) to assist in the identification of plant community types. The site groupings from each analysis were subjectively assessed based on plant species composition and dominance, and physical site characteristics (e.g. aspect, slope) to determine the most appropriate allocation of a site to a specific community type.

Transects and range reference areas were assigned range condition ratings. Range condition is an indicator of a site's vegetation, productivity and land stability. The range condition rating was determined by totalling the percent prominence values[11] of desirable forage species. Desirable species for native vegetation are defined as all graminoids and legumes. For tame pasture, they are considered to be all forage plants seeded on the sites (Robertson and Adams 1990). For the purpose of this study, percentage values were converted to 11 discrete categories (Table 1).

[11] % species composition = % of plots in which that species occurred
species prominence = (square root of % species composition) x average % cover of that species
% species prominence value = (species prominence value / sum of species prominence values for all vascular plants) x 100
range condition = sum of % species prominence values for all desirable forage species

Table 1. Range condition categories, adapted from Wroe et al. (1988).

Range Condition Category	Total Percent Prominence Values of Desirable Forage Species
Excellent	>85
Low Excellent	>75 - 85
High Good	>65 - 75
Good	>55 - 65
Low Good	>50 - 55
High Fair	>40 - 50
Fair	>30 - 40
Low Fair	>25 - 30
High Poor	>15 - 25
Poor	>5 - 15
Low Poor	≤5

2.2 Forage Assessment

2.2.1 Forage Species Determination

Bighorn sheep scat was collected to determine the relative occurrence of forage plants in the diet at each study area. For each herd, up to 30 samples per month were collected from groups of sheep that included radiocollared ewes. Each of these samples included 10-20 pellets that had been deposited while the group was being observed, to confirm the origin of samples. At Columbia Lake, scat was collected during February, March, April, May and December of 1997 and January, February, March, April and May of 1998. At Bull River, samples were obtained during February, March, April, May and December of 1997 and January, February, March and April of 1998. At Mount Broadwood, samples were collected during January, February, March and April of 1999. Premier Ridge was not sampled. Samples were placed in paper bags and air-dried, then shipped to T. Foppe, Composition Analysis Laboratory, Colorado State University, Fort Collins, Colorado for analysis. Results were reported as percent scat (by weight) consisting of each species (or in some cases genus, family or higher taxonomic level). Mean composition across months was calculated, with each month weighted evenly regardlless of the number of samples per month. This was done for all months, then for January through April only, because no samples were available for December or May from the Mount Broadwood study area. Minimum and maximum monthly values for each species or species group were also noted.

2.2.2 Forage Chemical Analysis

To assess the chemical composition of forage species, they were collected at the beginning and end of the period in which bighorn sheep pellets were collected (December and April) at each of the study areas in which radiotelemetry occurred. The species collected were to be based on the results of scat analysis indicating the main forage plants (Section 2.2.1). However, when initial forage collections were made in mid-December, 1999 at the Columbia Lake and Bull River study areas, analyses for sheep pellets collected from these areas the previous December were not yet available. Therefore, a variety of potential forage species were collected at this time. Partial scat analysis data were available by mid-April, 2000 when the spring forage collections were made at the Columbia Lake, Bull River and Mount Broadwood study areas. Due to the scat analyses being incomplete, some forage species not identified in the scat analyses were collected.

We were unable to collect enough of certain species for chemical analysis due to their low herbage production, low relative frequency or difficulty finding or identifying them under the late season and snowy conditions. Some species identified in the pellets were not collected because they did not occur in the study area, although some may have occurred in adjacent areas. Some plants identified from the pellets were classified only to genus or family. In these cases, as many representatives of the group as possible were collected.

When species occurred in a variety of topographical situations within a study area, samples were collected within each, assuming that the species nutritive value might differ with moisture regime, exposure and substrate. Forage species were clipped using hand shears or picked approximately 2 – 3 cm above ground level. Herbage material was collected from a variety of plants within each site. Samples were placed in paper bags, using 1 bag per species, per topographical location, and filling the bag as full as possible up to approximately 0.5 l of packed herbage material. These bags were stored in a cool, dry area prior to shipment for chemical analyses.

Chemical analyses were performed by Norwest Labs in Lethbridge, Alberta. Tests included crude protein, neutral detergent insoluble nitrogen, acid detergent fibre, neutral detergent fibre, total digestible nutrients, digestible energy, calcium, phosphorus, potassium, magnesium, sodium and sulphur. The total digestible nutrient value equates to *in vitro* dry matter digestibility.

3.0 Results

3.1 Plant Community Types

The plant community types identified in the data analyses are described below. A descriptive summary of the vegetation is provided, along with a summary page per community type that includes the average percent cover of the dominant species, environmental characteristics, and forage production and utilization. Transect numbers corresponding to each plant community description can be cross-referenced from the community descriptions (below) and the maps in Appendix 5-2. Appendices 5-3 to 5-6 contain more complete lists of species present in the Columbia Lake, Bull River and Mount Broadwood study areas.

The level of sampling in this study was adequate for the purposes outlined in the terms of reference, i.e. sampling grasslands and in some cases open forests that occurred within the ecosystem units identified in the habitat selection analysis. However, not all of the vegetation types within the study areas were fully assessed to determine forage production. For instance, rough fescue appeared to be an important forage species at Columbia Lake according to the scat analysis, but it was not present in any of the vegetation communities sampled. It was found in adjacent Douglas-fir forests.

3.1.1 Columbia Lake Study Area

The transects were located within the Pasture Sage-Bluebunch Wheatgrass (SW) ecosystem unit on sites of varying slope and predominantly west to southwest aspect. Vegetation communities were dominated by needle-and-thread grass, Junegrass, bluebunch wheatgrass and/or western bluegrass, or combinations of any of the above. Cheatgrass had invaded several of the communities, becoming a dominant or co-dominant grass. It was determined that 6 plant community types were represented by the 11 preferred-habitat transects and the paired range reference transects (associated with the exclosure).

Some of the types (e.g. Type 3, 4 and 5) closely resembled each other except for the presence or cover value of specific plant species and the landscape position. Type 3 (bluebunch wheatgrass–needle-and-thread grass–Junegrass/prairie sagewort/common rabbit-brush community) had a high cover of needle-and-thread grass and occurred on shallowly sloped knolls and moderately steep westerly slopes. Type 4 (bluebunch wheatgrass–Junegrass–cheatgrass/prairie sagewort–shaggy fleabane community) was sparsely vegetated, having a lower cover of needle-and-thread grass with an increase in cover of cheatgrass, and occurred on exposed west-southwest-facing upland slopes. Type 5 (bluebunch wheatgrass–Junegrass/prairie sagewort/common rabbit-brush community) also had a lower cover of needle-and-thread grass compared to Type 3, with higher cover of cheatgrass and common rabbit-brush, and was located on steep upland slopes near cliff terrain.

The other 3 types were found on level to shallowly sloping terrain. Type 1 (needle-and-thread grass/thread-leaved fleabane–prairie sagewort–Columbia bladderpod/common rabbit-brush community) exemplified good range condition with litter accumulation. With higher forage utilization, needle-and-thread grass and thread-leaved fleabane are displaced by Junegrass and white pussytoes, as displayed in Type 2 (Junegrass–needle-and-thread grass–western bluegrass/white pussytoes–bastard toadflax/common rabbit-brush community). Open areas within or at the margins of Douglas-fir forest were comprised of Type 6 (bluebunch wheatgrass–Junegrass/compact selaginella community), where the dominance of the 2 grass species varied. These types are described on the following pages, using average cover values for the species. Not all species listed, especially those with lower cover values, were present at all sites.

Columbia Lake Type 1

Needle-and-thread grass / thread-leaved fleabane – prairie sagewort – Columbia bladderpod / common rabbitbrush
(*Hesperostipa comata / Erigeron filifolius – Artemisia frigida – Lesquerella douglasii / Ericameria nauseosus*)

(N=2; site CL-01, range reference area) This community type occurred on level areas to shallow west-southwest-facing slopes. With restricted grazing, abundant litter accumulation can occur. However, with the past grazing intensity from bighorn sheep, litter was generally lacking. The soil surface is held together by moss and lichen species. Although the exclosure fence was down for an undetermined period of time, the area inside it had probably been subject to less grazing pressure and had slightly greater grass cover, a greater proportion of Junegrass, and less forb cover than CL-01 and the range reference transects outside the exclosure. The species composition suggested that this type was in excellent condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Needle-and-thread grass (*Hesperostipa comata*)	30.8
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	0.9
Junegrass (*Koeleria macrantha*)	0.5
Western bluegrass (*Pascopyrum smithii*)	0.5
FORBS	
Thread-leaved fleabane (*Erigeron filifolius*)	3.1
Prairie sagewort (*Artemisia frigida*)	2.7
Columbia bladderpod (*Lesquerella douglasii*)	2.2
Yellow gromwell (*Lithospermum incisum*)	0.5
Bastard toadflax (*Comandra umbellata*)	0.5
Tarragon (*Artemisia dracunculus*)	0.5
Yellow salsify (*Tragopogon dubius*)	0.2
White pussytoes (*Antennaria microphylla*)	0.2
SHRUBS	
Common rabbit-brush (*Ericameria nauseosus*)	2.9
LITTER	18.7
SOIL/ROCK	31.7
MOSS/LICHEN	41.8

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: submesic

ELEVATION: 909 m

SOIL DRAINAGE: rapid

SLOPE (%): 0 - 21

ASPECT: none - 242º

FORAGE PRODUCTION (kg/ha)

N=4 (Min/Max/Mean)
Grass: 465 / 765 / 628
Forbs: 23 / 159 / 68
Shrubs: 31 / 199 / 85

WINTER FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)
Grass: 26.1 / 57.1 / 41.6
Forbs: 75.0 / 95.2 / 85.1
Shrubs: 0.0 / 45.7 / 22.9

Columbia Lake Type 2

Junegrass – needle-and-thread grass – western bluegrass / white pussytoes – bastard toadflax / common rabbitbrush
(*Koeleria macrantha – Hesperostipa comata – Pascopyrum smithii / Antennaria microphylla – Comandra umbellata – Ericameria nauseosus*)

N=2; sites CL-02, CL-10) This community type occurred on level terraces above Columbia Lake. The dominant grass was either Junegrass or needle-and-thread grass. This type was more heavily utilized by bighorn sheep. Due to the past grazing intensity, the more desirable species had been reduced in cover, being replaced by increaser species. Litter accumulation was lacking. The soil surface was held together by moss and lichen. The forb composition was more diverse at CL-02. The species composition suggested that this type was in low-good condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Junegrass (*Koeleria macrantha*)	14.6
Needle-and-thread grass (*Hesperostipa comata*)	14.1
Western bluegrass (*Pascopyrum smithii*)	2.3
FORBS	
White pussytoes (*Antennaria microphylla*)	4.5
Bastard toadflax (*Comandra umbellata*)	3.6
Prairie sagewort (*Artemisia frigida*)	2.7
Columbia bladderpod (*Lesquerella douglasii*)	0.8
Common dandelion (*Taraxacum officinale*)	0.6
Western blue flax (*Linum lewisii*)	0.4
Nodding onion (*Allium cernuum*)	0.2
Lemonweed (*Lithospermum ruderale*)	0.2
SHRUBS	
Common rabbit-brush (*Ericameria nauseosus*)	3.4
LITTER	20.6
SOIL/ROCK	39.0
MOSS/LICHEN	12.1

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: submesic

ELEVATION: 842 - 890 m

SOIL DRAINAGE: rapid

SLOPE (%): level

ASPECT: none

FORAGE PRODUCTION(kg/ha)

N=2 (Min/Max/Mean)

Grass:	266 / 451 / 358
Forbs:	97 / 101 / 99
Shrubs:	31 / 301 / 166

WINTER FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)

Grass:	75.9 / 86.3 / 81.1
Forbs:	87.7 / 89.5 / 88.6
Shrubs:	55.0 / 55.0 / 55.0

Columbia Lake Type 3

Bluebunch wheatgrass – needle-and-thread grass – Junegrass / prairie sagewort / common rabbitbrush
(*Pseudoroegneria spicata – Hesperostipa comata – Koeleria macrantha / Artemisia frigida / Ericameria nauseosus*)

(N=2; sites CL-03, CL04) This community type occurred on shallowly sloped exposed bedrock knolls and moderately steep westerly slopes. The knoll site was more heavily utilized by elk and sheep, whereas the steeper slope was primarily used by bighorn sheep. Both sites were exposed to wind and solar radiation. Soil was thin and poor with very little litter, reflecting poor growing conditions. Junegrass was co-dominant along CL-04 and was common along CL-03. Sandberg's bluegrass, large-fruited desert-parsley and nodding onion were frequent along CL-04. Cheatgrass was a minor component of the community at CL-03, along with several weedy forbs. The species composition of these sites suggested that this type was in excellent condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	17.8
Needle-and-thread grass (*Hesperostipa comata*	10.3
Junegrass (*Koeleria macrantha*)	6.4
Sandberg's bluegrass (*Poa secunda*)	0.6
Indian ricegrass (*Achnatherum hymenoides*)	0.1
FORBS	
Prairie sagewort (*Artemisia frigida*)	3.5
Columbia bladderpod (*Lesquerella douglasii*)	2.1
White pussytoes (*Antennaria microphylla*)	0.9
Bastard toadflax (*Comandra umbellata*)	0.8
Little gray aster (*Aster falcatus*)	0.6
Large-fruited desert-parsley (Lomatium macrocarpum)	0.4
Nodding onion (*Allium cernuum*)	0.2
Holboell's rockcress (*Arabis holboellii*)	0.2
Shaggy fleabane (*Erigeron pumilus*)	0.2
SHRUBS	
Common rabbit-brush (*Ericameria nauseosus*)	1.5
LITTER	12.0
SOIL/ROCK	59.2
MOSS/LICHEN	12.5

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: xeric

ELEVATION: 884 - 985 m

SOIL DRAINAGE: rapid

SLOPE (%): 12 - 58

ASPECT: 240º - 260º

FORAGE PRODUCTION(kg/ha)

N=4 (Min/Max/Mean)

Grass:	411 / 655 / 491
Forbs:	39 / 131 / 68
Shrubs:	41 / 291 / 119

WINTER FORAGE UTILIZATION (%)

N=4 (Min/Max/Mean)

Grass:	22.4 / 66.1 / 45.6
Forbs:	0.0 / 100.0 / 46.2
Shrubs:	0.0 / 100.0 / 35.6

Columbia Lake Type 4

Bluebunch wheatgrass – Junegrass – cheatgrass / prairie sagewort – shaggy fleablane (*Pseudoroegneria spicata – Koeleria macrantha – Bromus tectorum / Artemisia frigida – Erigeron pumilus*)

(N=2; sites CL-05, CL-08) This community type occurred on exposed west-southwest-facing upland slopes that are sparsely vegetated. Bands of exposed bedrock were evident throughout. Soil was thin and poor with very little litter accumulation. Winter utilization of grasses was moderate to high. There was an abundance of pellets throughout. The species composition suggested that this type was in high-fair condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	4.2
Cheatgrass (*Bromus tectorum*)	2.0
Junegrass (*Koeleria macrantha*)	1.9
Needle-and-thread grass (*Hesperostipa comata*)	1.4
Sandberg's bluegrass (*Poa secunda*)	0.5
Canada bluegrass (*Poa compressa*)	0.2
FORBS	
Prairie sagewort (*Artemisia frigida*)	4.5
Shaggy fleabane (*Erigeron pumilus*)	1.0
Columbia bladderpod (*Lesquerella douglasii*)	0.7
Great mullein (*Verbascum thapsus*)	0.5
White pussytoes (*Antennaria microphylla*)	0.3
Pennsylvanian cinquefoil (*Potentilla pensylvanica*)	0.3
Holboell's rockcress (*Arabis holboellii*)	0.3
Bristly stickseed (*Lappula squarrosa*)	0.3
Cut-leaved daisy (*Erigeron compositus*)	0.2
SHRUBS	
Common rabbit-brush (*Ericameria nauseosus*)	0.2
LITTER	7.6
SOIL/ROCK	67.6
MOSS/LICHEN	2.5

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: xeric

ELEVATION: 898 - 940 m

SOIL DRAINAGE: rapid

SLOPE (%): 32 - 41

ASPECT: 241º - 257º

FORAGE PRODUCTION(kg/ha)

N=4 (Min/Max/Mean)

Grass:	284 / 906 / 573
Forbs:	44 / 111 / 69
Shrubs:	0 / 2 / 1

WINTER FORAGE UTILIZATION (%)

N=4 (Min/Max/Mean)

Grass:	34.1 / 83.1 / 54.4
Forbs:	33.3 / 88.2 / 58.4
Shrubs:	none in sampling plots

Columbia Lake Type 5

Bluebunch wheatgrass – Junegrass – cheatgrass / prairie sagewort / common rabbitbrush (*Pseudoroegneria spicata – Koeleria macrantha – Bromus tectorum / Artemisia frigida – Ericameria nauseosus)*

(N=2; sites CL-07, CL-09) This community type occurred on exposed, steep upland slopes near cliff terrain. It differed from the bluebunch wheatgrass - needle-and-thread grass - Junegrass/prairie sagewort/common rabbit-brush community type (Type 3) by having low cover of needle-and-thread grass. It was also more sparsely vegetated with a very high cover of exposed rock (bedrock and talus) and soil (over 80%). Soil is non-existent to thin and poor, restricting growing conditions. There was very little litter accumulation. Winter utilization of bluebunch wheatgrass was at 50%, whereas use of other grasses was near 100%. Spotted knapweed (*Centaurea biebersteinii*) was common on the slope and crest above CL-07. The species composition suggested that this type was in good condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	9.4
Cheatgrass (*Bromus tectorum*)	3.1
Junegrass (*Koeleria macrantha*)	3.0
Sandberg's bluegrass (*Poa secunda*)	1.4
Needle-and-thread grass (*Hesperostipa comata*)	0.6
Canada bluegrass (*Poa compressa*)	0.2
FORBS	
Prairie sagewort (*Artemisia frigida*)	3.5
White pussytoes (*Antennaria microphylla*)	0.8
Stickseed (*Lappula* sp.)	0.4
Black medic (*Medicago lupulina*)	0.3
Shaggy fleabane (*Erigeron pumilus*)	0.2
Nodding onion (*Allium cernuum*)	0.2
Lamb's-quarters (*Chenopodium album*)	0.2
Columbia bladderpod (*Lesquerella douglasii*)	0.2
SHRUBS	
Common rabbit-brush (*Ericameria nauseosus*)	5.5
LITTER	12.2
SOIL/ROCK	58.6
MOSS/LICHEN	4.9

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: xeric

ELEVATION: 946 - 987 m

SOIL DRAINAGE: rapid

SLOPE (%): 38 - 53

ASPECT: 223º to 270º

FORAGE PRODUCTION(kg/ha)

N=2 (Min/Max/Mean)

Grass:	639 / 1038 / 839
Forbs:	185 / 186 / 186
Shrubs:	101 / 136 / 119

WINTER FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)

Grass:	84.2 / 92.2 / 88.2
Forbs:	66.7 / 100.0 / 83.4
Shrubs:	not present in all sampling plots

Columbia Lake Type 6

Bluebunch wheatgrass – Junegrass / compact selaginella
(*Pseudoroegneria spicata – Koeleria macrantha / Selaginella densa*)

(N=2; sites CL-06, CL-11) This community type occurs as open areas within or at the margins of Douglas-fir forest. Slope was minimal from level to 2%. The dominant grass was either bluebunch wheatgrass or Junegrass. There was low forage production with little litter accumulation. There were occasional pellet groups. Cheatgrass was a minor component of the community, and spotted knapweed was at 1% cover at CL-11. The species composition suggested that this type was in good condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	7.6
Junegrass (*Koeleria macrantha*)	5.6
Sandberg's bluegrass (*Poa secunda*)	0.3
FORBS	
Compact selaginella (*Selaginella densa*)	2.0
White pussytoes (*Antennaria microphylla*)	1.0
Yarrow (*Achillea millefolium*)	1.0
Spikelike goldenrod (*Solidago spathulata*)	1.0
Cut-leaved daisy (*Erigeron compositus*)	0.8
Long-leaved fleabane (*Erigeron corymbosus*)	0.6
Cut-leaved anemone (*Anemone multifida*)	0.5
Golden-aster (*Heterotheca villosa*)	0.4
Woolly groundsel (*Senecio canus*)	0.4
Common dandelion (*Taraxacum officinale*)	0.4
Little gray aster (*Aster falcatus*)	0.3
Slender hawksbeard (*Crepis atribarba*)	0.2
Spikelike goldenrod (*Solidago spathulata*)	0.2
LITTER	35.2
SOIL/ROCK	26.1
MOSS/LICHEN	34.5

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: sub-xeric to mesic

ELEVATION: sampled at 851 m

SOIL DRAINAGE: moderate

SLOPE (%): 0 - 2

ASPECT: variable

FORAGE PRODUCTION(kg/ha)

N=2 (Min/Max/Mean)
Grass: 235 / 276 / 256
Forbs: 18 / 35 / 26
Shrubs: none

WINTER FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)
Grass: 0.0 / 41.2 / 20.6
Forbs: 42.9 / 95.0 / 69.0
Shrubs: not present in all sampling plots

3.1.2 Premier Ridge Study Area

The terrain of the preferred sheep habitat on Premier Ridge was primarily a series of linear bedrock outcrops and small cliffs along the lower southwest portion of the ridge. It was comprised of a complex series of drainages with numerous aspects of varying slopes. The substrate also varied, with areas of glacial till, talus and fluvial deposits. The terrain was generally open grassland and shrubland complexes interspersed with open mature Douglas-fir and ponderosa pine forest. The percent cover and composition of the ground cover was an expression of moisture and temperature regimes.

The vegetation communities in the Premier Ridge study area were highly variable in terms of plant species dominance. Six different plant community types were defined based on the 13 transects. The majority of transects were located within the Antelope-brush-Bluebunch Wheatgrass (AW) ecosystem unit. Transect PR-06 was located in the Snowberry-Balsamroot (DS) ecosystem unit. Bluebunch wheatgrass was a dominant grass along the transects. Cheatgrass and Canada bluegrass (non-native species) had invaded most sites. The community types are described below, using average cover values for the species. Not all species listed, especially those with lower cover values, were present at all sites.

According to the Terms of Reference, the results of the habitat selection analysis for Columbia Lake were to be extrapolated to the other northern study area, i.e., Premier Ridge. However, based on the vegetation community analysis, it would appear that the Bull River study area was more comparable vegetatively to the Premier Ridge study area.

Premier Ridge Type 1

Spreading dogbane / bluebunch wheatgrass - Junegrass / antelope-brush – saskatoon (*Apocynum androsaemifolium* / *Pseudoroegneria spicata* – *Koeleria macrantha* / *Purshia tridentata* – *Amelanchier alnifolia*)

(N=2; sites PR-08, PR-09) This community type occurred as mixed grassland-shrubland on mid-slopes amongst bedrock outcrops with southwesterly aspects. It appeared to be a degraded bluebunch wheatgrass/antelope-brush community. There was moderate to heavy utilization of all plants, except the bluebunch wheatgrass which appeared lightly utilized, with an abundance of old litter. Rough fescue (*Festuca campestris*) and Junegrass were heavily grazed and could be eliminated by the present grazing pressure. The abundance of spreading dogbane suggested this type was in a regressive state. There were extensive sheep pellet groups throughout, with occasional elk pellets on lower portions of the slope. The species composition suggested that this type was in high-poor condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	15.0
Junegrass (*Koeleria macrantha*)	2.5
Rough fescue (*Festuca campestris*)	1.5
Canada bluegrass (*Poa compressa*)	0.7
Cheatgrass (*Bromus tectorum*)	0.3
Columbian needlegrass (*Achnatherum nelsonii*)	0.2
Sedge (*Carex* sp.)	0.2
FORBS	
Spreading dogbane (*Apocynum androsaemifolium*)	23.0
Arrowleaf balsamroot (*Balsamorhiza sagittata*)	3.2
Yellow salsify (*Tragopogon dubius*)	1.4
Yarrow (*Achillea millefolium*)	0.9
Bastard toadflax (*Comandra umbellata*)	0.7
Wild strawberry (*Fragaria virginiana*)	0.5
White pussytoes (*Antennaria microphylla*)	0.4
Groundsel (*Senecio* sp.)	0.2
SHRUBS	
Antelope-brush (*Purshia tridentata*)	11.3
Saskatoon (*Amelanchier alnifolia*)	8.9
Choke cherry (*Prunus virginiana*)	2.6
Prairie rose (*Rosa woodsii*)	0.2
LITTER	47.1
SOIL/ROCK	49.8
MOSS/LICHEN	0.0

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 956 - 1098 m

SOIL DRAINAGE: moderate

SLOPE (%): 32 - 49

ASPECT: 208º - 248º

FORAGE PRODUCTION (kg/ha)

N=3 (Min/Max/Mean)

Grass:	369 / 1226 / 748
Forbs:	39 / 277 / 163
Shrubs:	0 / 98 / 67

WINTER FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)

Grass:	68.5 / 72.2 / 70.4
Forbs:	30.0 / 90.4 / 60.2
Shrubs:	none in sampling plots

Premier Ridge Type 2

Bluebunch wheatgrass - Junegrass / antelope-brush – common snowberry – saskatoon / golden-aster
(*Pseudoroegneria spicata – Koeleria macrantha* / *Purshia tridentata – Symphoricarpos albus – Amelanchier alnifolia* / *Heterotheca villosa*)

(N=3; sites PR-02, PR-05, PR-12) This community type occurred as mixed grassland-shrubland on upper slopes. In drier areas, an antelope-brush/bluebunch wheatgrass association predominated. In drainage areas and moist sites, a saskatoon-choke cherry/bluebunch wheatgrass association predominated. There were both elk and sheep pellet groups throughout, with a concentration of elk pellets on lower portions of the slope and open grassland below. There was moderate to heavy utilization of all plants except the bluebunch wheatgrass, which appeared not to be utilized. An abundance of old litter was associated with each bluebunch wheatgrass plant. Spreading dogbane was present at only PR-02, where it dominated the forb layer. The species composition suggested that this type was in low-good condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	20.5
Junegrass (*Koeleria macrantha*)	1.6
Cheatgrass (*Bromus tectorum*)	0.5
Canada bluegrass (*Poa compressa*)	0.3
FORBS	
Spreading dogbane (*Apocynum androsaemifolium*)	3.0
Golden-aster (*Heterotheca villosa*)	0.9
Wavy-leaved thistle (*Cirsium undulatum*)	0.6
Great mullein (*Verbascum thapsus*)	0.4
Shaggy fleabane (*Erigeron pumilus*)	0.3
Yarrow (*Achillea millefolium*)	0.2
SHRUBS	
Antelope-brush (*Purshia tridentata*)	7.9
Common snowberry (*Symphoricarpos albus*)	2.5
Saskatoon (*Amelanchier alnifolia*)	1.4
Prairie rose (*Rosa woodsii*)	1.0
LITTER	28.8
SOIL/ROCK	63.5
MOSS/LICHEN	3.4

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: xeric

ELEVATION: 980 - 1136 m

SOIL DRAINAGE: rapid

SLOPE (%): 42 - 61

ASPECT: 180º - 224º

FORAGE PRODUCTION (kg/ha)

N=5 (Min/Max/Mean)

Grass:	266 / 582 / 479
Forbs:	5 / 88 / 41
Shrubs:	0 / 225 / 110

WINTER FORAGE UTILIZATION (%)

N=4 (Min/Max/Mean)

Grass:	0.0 / 65.1 / 33.5
Forbs:	0.0 / 87.5 / 53.6
Shrubs:	none in sampling plots

Premier Ridge Type 3

Bluebunch wheatgrass - cheatgrass - Canada bluegrass / antelope-brush
(*Pseudoroegneria spicata - Bromus tectorum - Poa compressa / Purshia tridentata*)

(N=1; site PR-13) This community type occurred on the crest of a bedrock outcrop and consisted of mixed grassland - shrubland. It was similar to Type 1, except that it occurred on level to undulating terrain with 0 to 4% slope. There was higher grass cover with less shrub and spreading dogbane cover. Although rough fescue was more abundant, cheatgrass and Canada bluegrass were present, which degraded the condition of the site. There was an abundance of sheep pellet groups. Utilization was low, with the occasional bluebunch wheatgrass plant lightly grazed. There was an abundance of old litter. The species composition suggested that this type was in fair condition.

PLANT COMPOSITION	CANOPY COVER (%)
GRAMINOIDS	
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	12.1
Cheatgrass (*Bromus tectorum*)	10.3
Canada bluegrass (*Poa compressa*)	6.5
Rough fescue (*Festuca campestris*)	2.1
Junegrass (*Koeleria macrantha*)	1.1
Pinegrass (*Calamagrostis rubescens*)	1.0
FORBS	
Groundsel (*Senecio* sp.)	3.0
White pussytoes (*Antennaria microphylla*)	1.5
Spreading dogbane (*Apocynum androsaemifolium*)	1.1
Compact selaginella (*Selaginella densa*)	1.0
Yarrow (*Achillea millefolium*)	0.9
Hawkweed (*Hieracium* sp.)	0.7
Arrowleaf balsamroot (*Balsamorhiza sagittata*)	0.3
SHRUBS	
Antelope-brush (*Purshia tridentata*)	5.1
LITTER	59.5
SOIL/ROCK	24.7
MOSS/LICHEN	0.0

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 103m

SOIL DRAINAGE: moderate

SLOPE (%): 0 - 4

ASPECT: variable

FORAGE PRODUCTION (kg/ha)

N=1 (Min/Max/Mean)

	Min	Max	Mean
Grass:	596	596	596
Forbs:	65	65	65
Shrubs:	2	2	2

WINTER FORAGE UTILIZATION (%)

N=0 (Min/Max/Mean)
Grass: no clip plot
Forbs:
Shrubs:

Premier Ridge Type 4

Bluebunch wheatgrass - Canada bluegrass / antelope-brush – saskatoon
(*Pseudoroegneria spicata - Poa compressa / Purshia tridentata - Amelanchier alnifolia*)

(N=1; site PR-06) This community type occurred on the crest of a bedrock outcrop and consisted of mixed grassland- shrubland. There was an abundance of old litter which was a result of low forage use. The bluebunch wheatgrass appeared not to be utilized. Sheep pellet groups were occasional. The species composition suggested that this type was in low-excellent condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	34.6
Canada bluegrass (*Poa compressa*)	3.2
Junegrass (*Koeleria macrantha*)	1.1
Cheatgrass (*Bromus tectorum*)	0.8
FORBS	
Yarrow (*Achillea millefolium*)	1.5
White pussytoes (*Antennaria microphylla*)	0.7
Wild strawberry (*Fragaria virginiana*)	0.2
SHRUBS	
Antelope-brush (*Purshia tridentata*)	9.1
Saskatoon (*Amelanchier alnifolia*)	2.3
Prairie rose (*Rosa woodsii*)	1.3
LITTER	59.1
SOIL/ROCK	15.7
MOSS/LICHEN	12.1

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: sub-xeric

ELEVATION: 1081 m

SOIL DRAINAGE: moderate

SLOPE (%): 0 - 2

ASPECT: 230º

FORAGE PRODUCTION (kg/ha)

N=2 (Min/Max/Mean)

Grass:	737 / 855 / 796
Forbs:	10 / 43 / 27
Shrubs:	0 / 17 / 9

WINTER FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)

Grass:	0.0 / 3.4 / 1.7
Forbs:	0.0 / 44.4 / 22.2
Shrubs:	none in sampling sites

Premier Ridge Type 5

Bluebunch wheatgrass - Canada bluegrass - Columbian needlegrass / white pussytoes / saskatoon - antelope-brush
(*Pseudoroegneria spicata - Poa compressa - Achnatherum nelsonii / Antennaria microphylla / Amelanchier alnifolia - Purshia tridentata*)

(N=3; sites PR-03, PR-07, PR-11) This community type occurred on a variety of terrain ranging from level upland to northeast-facing upper slopes to a lower west-facing slope with a grassland-shrubland complex. Another dominant species in this grassland-shrubland complex was kinnikinnick. Spreading dogbane was present only at PR-07, where it was common. Some other grasses and forbs were common at certain of the 3 sites but not others. There was an abundance of elk and sheep pellet groups throughout. Utilization was low on the northeast-facing upper slope with an abundance of old litter, and was light to moderate at the other 2 sites. The species composition suggests that this type was in low-fair condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	8.2
Canada bluegrass (*Poa compressa*)	7.0
Columbian needlegrass (*Achnatherum nelsonii*)	4.7
Junegrass (*Koeleria macrantha*)	1.7
Bluegrass (*Poa* sp.)	1.2
Spreading needlegrass (*Achnatherum richardsonii*)	0.3
Needle-and-thread grass (*Hesperostipa comata*)	0.2
FORBS	
White pussytoes (*Antennaria microphylla*)	4.0
Timber milk-vetch (*Astragalus miser*)	2.7
Yarrow (*Achillea millefolium*)	1.7
Paintbrush (*Castilleja* sp.)	1.3
Golden-aster (*Heterotheca villosa*)	1.1
Menzie's campion (*Silene menziesii*)	1.1
Tufted phlox (*Phlox caespitosa*)	1.0
Spreading dogbane (*Apocynum androsaemifolium*)	0.9
Scouler's hawkweed (*Hieracium scouleri*)	0.9
Lemonweed (*Lithospermum ruderale*)	0.8
Smooth aster (*Aster laevis*)	0.6
Yellow salsify (*Tragopogon dubius*)	0.4
Arrowleaf balsamroot (*Balsamorhiza sagittata*)	0.3
Common dandelion (*Taraxacum officinale*)	0.3
Nodding onion (*Allium cernuum*)	0.3
Locoweed (*Oxytropis* sp.)	0.3
SHRUBS	
Kinnikinnick (*Arctostaphylos uva-ursi*)	3.9
Saskatoon (*Amelanchier alnifolia*)	3.0
Antelope-brush (*Purshia tridentata*)	2.5
Birch-leaved spiraea (*Spiraea betulifolia*)	1.7

LITTER	50.3
SOIL/ROCK	19.7
MOSS/LICHEN	16.8

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: sub-xeric to mesic

ELEVATION: 952 - 1088 m

SOIL DRAINAGE: moderate

SLOPE (%): 5 - 21

ASPECT: 90º - 224º

FORAGE PRODUCTION (kg/ha)

N=5 (Min/Max/Mean)
Grass: 336 / 736 / 593
Forbs: 93 / 226 / 152
Shrubs: 0 / 643 / 174

WINTER FORAGE UTILIZATION (%)

N=5 (Min/Max/Mean)
Grass: 39.5 / 77.1 / 38.1
Forbs: 29.6 / 85.5 / 44.8
Shrubs: 50.9 / 50.9 / 50.9
(not present in some sampling plots)

Premier Ridge Type 6

Common snowberry - antelope-brush - saskatoon / bluebunch wheatgrass - cheatgrass / golden-aster
(*Symphoricarpos albus - Purshia tridentata - Amelanchier alnifolia / Pseudoroegneria spicata - Bromus tectorum / Heterotheca villosa*)

(N=3; sites PR-01, PR-04, PR-10) This community type occurred as mixed shrubland on talus substrate on lower to mid-slopes beneath rocky outcrops. On drier knolls, an antelope-brush/bluebunch wheatgrass association predominated. In depression areas and moist sites, a saskatoon/Junegrass association predominated. Both elk and sheep pellet groups occurred throughout. There was moderate to heavy utilization. The species composition suggested that this type was in high-poor condition.

PLANT COMPOSITION	CANOPY COVER (%)
GRAMINOIDS	
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	8.6
Cheatgrass (*Bromus tectorum*)	3.1
Canada bluegrass (*Poa compressa*)	2.7
Junegrass (*Koeleria macrantha*)	1.4
Sedge (*Carex* sp.)	0.3
FORBS	
Golden-aster (*Heterotheca villosa*)	3.0
Spreading dogbane (*Apocynum androsaemifolium*)	1.5
Yarrow (*Achillea millefolium*)	1.3
Yellow salsify (*Tragopogon dubius*)	1.3
Wavy-leaved thistle (*Cirsium undulatum*)	0.9
Lemonweed (*Lithospermum ruderale*)	0.6
Thyme-leaved sandwort (*Arenaria serpyllifolia*)	0.5
Bastard toadflax (*Comandra umbellata*)	0.4
Pale alyssum (*Alyssum alyssoides*)	0.3
Great mullein (*Verbascum thapsus*)	0.3
Tufted phlox (*Phlox caespitosa*)	0.3
White pussytoes (*Antennaria microphylla*)	0.2
Common dandelion (*Taraxacum officinale*)	0.2
SHRUBS	
Common snowberry (*Symphoricarpos albus*)	14.9
Antelope-brush (*Purshia tridentata*)	13.3
Saskatoon (*Amelanchier alnifolia*)	11.4
Prairie rose (*Rosa woodsii*)	2.4
Choke cherry (*Prunus virginiana*)	0.4
LITTER	38.8
SOIL/ROCK	56.2
MOSS/LICHEN	0.5

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: sub-xeric to mesic

ELEVATION: 986 - 1036 m

SOIL DRAINAGE: moderate

SLOPE (%): 38 - 58

ASPECT: 244º - 248º

FORAGE PRODUCTION (kg/ha)

N=5 (Min/Max/Mean)
Grass: 291 / 805 / 526
Forbs: 10 / 78 / 52
Shrubs: 37 / 487 / 272

WINTER FORAGE UTILIZATION (%)

N=5 (Min/Max/Mean)
Grass: 13.8 / 84.6 / 53.8
Forbs: 0.0 / 91.7 / 42.8
Shrubs 0.0 / 65.4 / 32.7
(not present in some sampling plots)

3.1.3 Bull River Study Area

The majority of preferred-habitat transects were placed east of Wardner-Fort Steele Road within the Antelope-brush-Bluebunch Wheatgrass (AW) ecosystem unit. Two were placed in the Cultivated Field (CF) ecosystem unit on a level terrace beside Bull River. It was dominated by smooth brome, Canada bluegrass, black medic and common dandelion. A moist drainage area through the west-central portion of this area was dominated by tufted vetch. A terraced site within the AW ecosystem unit was dominated by spreading needlegrass and slender wheatgrass, while yet another was dominated by Canada bluegrass and black medic. The remaining sites tended to have southerly aspects and steep slopes. Canada bluegrass, bluebunch wheatgrass and needle-and-thread grass were dominants or co-dominants. Cheatgrass and sulphur cinquefoil, 2 non-native weedy species, had invaded several of the communities, becoming dominant or co-dominant species. Shrubs, such as antelope-brush, saskatoon and common snowberry were often common.

In the area identified as a critical wintering area west of Wardner – Fort Steele Road, 2 transects representing different vegetation communities were established, also in the AW ecosystem unit.

It was determined that 10 plant community types were represented by the 15 preferred-habitat transects and the range reference area transects. Some of these may have once been the same type, but due to grazing disturbance and the invasion of non-native weeds and agronomic species, the plant species composition had shifted. The community types are described below, using average cover values for the species. Not all species listed, especially those with lower cover values, were present at all sites.

The transects of the rangeland reference area, established on either side of the fence between Whitetail Pasture and the Armstrong's property, represented a rare community type dominated by little bluestem, needle-and-thread grass, cheatgrass and bluebunch wheatgrass. Little bluestem is a rare grass species in British Columbia. Like BR-05 and BR-13, this site was located on the slope above the first terrace above the river. The abundance of cheatgrass as well as sweet-clover and pale alyssum, and the common occurrence of other weeds, indicated that this site had also been disturbed in the past. The non-native species dominated in Whitetail Pasture while the native species dominated on the portion of the slope belonging to the Armstrongs. Common native species included prairie sagewort, yellow gromwell, sand dropseed and antelope-brush. This community was named the needle-and-thread grass - cheatgrass - little bluestem/prairie sagewort - sweet-clover/antelope-brush community type.

Sulphur cinquefoil is an aggressive non-native weed. Its cover was extremely high at BR-02 and BR-03 (Community Type 4), especially immediately following the controlled burn at these sites. Other weed species of concern, that are were not dominant but have the potential to expand in area and diminish range quality, included spotted knapweed and common hound's-tongue.

Bull River Type 1

Canada bluegrass - smooth brome / black medic - common dandelion
(*Poa compressa* - *Bromus inermis* / *Medicago lupulina* - *Taraxacum officinale*)

(N=2; sites BR-01, BR-10) This community type occurred on an old fluvial floodplain terrace and represented the CF ecosystem unit. It was comprised almost entirely of agronomic, non-native species. Although it apparently had not been cultivated, the dominance of tame forage species suggested that it might have been seeded in the past. This area was treated with fertilizer in early May, 2000. The area received heavy use by both cattle and bighorn sheep. Sulphur cinquefoil was a minor component of the community at BR-01. Spotted knapweed was also present on the terrace. If the site was in a natural state, this type would have been considered to be in low-poor condition. However, if it had been seeded to tame forage, then it would be in high-good condition. The production and summer utilization figures were not accurate due to the production cages being moved sometime during each of the summers of 1999 and 2000. Use of BR-10 (bluegrass-dominated) was close to 100% both years, whereas use of BR-01 (brome-dominated) was likely over 50%.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Canada bluegrass (*Poa compressa*)	33.4
Smooth brome (*Bromus inermis*)	14.0
Quackgrass (*Elymus repens*)	2.1
Sedge (*Carex* sp.)	1.2
Slender wheatgrass (*Elymus trachycaulus*)	1.1
FORBS	
Black medic (*Medicago lupulina*)	18.1
Common dandelion (*Taraxacum officinale*)	6.2
Yellow salsify (*Tragopogon dubius*)	1.6
Alfalfa (*Medicago sativa*)	1.0
Tufted vetch (*Vicia cracca*)	1.0
Thyme-leaved sandwort (*Arenaria serpyllifolia*)	0.5
LITTER	93.8
SOIL/ROCK	3.1
MOSS/LICHEN	2.0

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 764 - 768 m

SOIL DRAINAGE: moderate to well

SLOPE (%): undulating micro-relief on level terrace

ASPECT: variable

FORAGE PRODUCTION (kg/ha)

N=6 (Min/Max/Mean)
Grass: >: 1030 / 3143 / 1932
Forbs: >: 1 / 381 / 141
Shrubs: none

WINTER FORAGE UTILIZATION (%)

N=4 (Min/Max/Mean)
Grass: 1.2 / 84.1 / 44.5
Forbs: 0.0 / 99.5 / 38.7
Shrubs: none

SUMMER CATTLE FORAGE UTILIZATION (%)

N=4 (Min/Max/Mean)
Grass: >: 23.7 / 97.0 / 60.2
Forbs: >: 0.0 / 100.0 / 61.0
Shrubs: none

Bull River Type 2

Canada bluegrass - spreading needlegrass - bluebunch wheatgrass / black medic / antelope-brush (*Poa compressa - Achnatherum richardsonii - Pseudoroegneria spicata / Medicago lupulina / Purshia tridentata*)

(N=2; sites BR-04, BR-11) This community type occurred on a glaciofluvial terrace and consisted of a grassland- shrubland complex. It was characterized by a mixture of native and non-native species. The abundance of tame forage species suggested that it might have been seeded in the past or had been altered through heavy grazing. The saskatoon in the area received heavy browsing. Sulphur cinquefoil was present but at low cover. An unknown forb, appearing only as a rosette of hairy leaves, was common at BR-04. The area received heavy use by both cattle and bighorn sheep. This community type was in poor range condition. The production and summer utilization figures are not accurate due to the production cages being moved sometime during each of the summers of 1999 and 2000. Use of BR-11 was close to 100% in both years, where less than a 2 cm stubble height remained once the cattle were moved off for the year. Use of BR-04 was likely over 50%, based on an ocular estimate of annual forage production amongst the shrub cover, where the forage was more protected from grazing.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Canada bluegrass (*Poa compressa*)	32.2
Spreading needlegrass (*Achnatherum richardsonii*)	3.2
Western bluegrass (*Pascopyrum smithii*)	2.5
FORBS	
Black medic (*Medicago lupulina*)	5.6
Spikelike goldenrod (*Solidago spathulata*)	2.8
Tufted phlox (*Phlox caespitosa*)	2.6
Unknown	1.4
Smooth daisy (*Erigeron glabellus*)	0.9
Sulphur cinquefoil (*Potentilla recta*)	0.5
Common dandelion (*Taraxacum officinale*)	0.5
Shaggy fleabane (*Erigeron pumilus*)	0.4
Yarrow (*Achillea millefolium*)	0.3
Menzie's campion (*Silene menziesii*)	0.2
SHRUBS	
Antelope-brush (*Purshia tridentata*)	6.1
Saskatoon (*Amelanchier alnifolia*)	3.3
Kinnikinnick (*Arctostaphylos uva-ursi*)	0.4
LITTER	80.5
SOIL/ROCK	0.5
MOSS/LICHEN	18.1

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 783 m

SOIL DRAINAGE: moderate to well

SLOPE (%): level terrace

ASPECT: none

FORAGE PRODUCTION (kg/ha)

N=6 (Min/Max/Mean)
Grass: >: 541 / 1426 / 981
Forbs: >: 0 / 288 / 71
Shrubs: 0 / 526 / 126

WINTER FORAGE UTILIZATION (%)

N=4 (Min/Max/Mean)
Grass: 0.0 / 80.2 / 50.7
Forbs: 45.2 / 73.3 / 53.9
Shrubs: 80.0 / 80.0 / 80.0
(not present in some sampling plots)

SUMMER CATTLE FORAGE UTILIZATION (%)

N=4 (Min/Max/Mean)
Grass: >: 35.5 / 71.1 / 55.1
Forbs: >: 0.0 / 62.5 / 28.0
Shrubs: 0.0 / 71.7 / 23.9

Bull River Type 3

Spreading needlegrass - Canada bluegrass - rough fescue / sulphur cinquefoil - wild bergamot / saskatoon - antelope-brush
(*Achnatherum richardsonii - Poa compressa - Festuca campestris / Potentilla recta - Monarda fistulosa / Amelanchier alnifolia - Purshia tridentata*)

(N=2; sites BR-06, BR-12) This community type occurred on a level glaciofluvial river terrace and was comprised of an open mixed grassland-shrubland complex interspersed with mature Douglas-fir trees. The weedy tall hawkweed (*Hieracium piloselloides*) was co-dominant only at BR-12. The area received light to moderate use by cattle and occasional use by bighorn sheep. Litter accumulation was relatively good compared to other types but was patchy, suggesting higher use in some localized areas. This type was in high-fair to low-good range condition.

PLANT COMPOSITION	CANOPY COVER (%)
GRAMINOIDS	
Spreading needlegrass (*Achnatherum richardsonii*)	15.1
Canada bluegrass (*Poa compressa*)	6.0
Rough fescue (*Festuca campestris*)	3.8
Idaho fescue (*Festuca idahoensis*)	2.1
Slender wheatgrass (*Elymus trachycaulus*)	1.8
Junegrass (*Koeleria macrantha*)	0.7
Sedge (*Carex* sp.)	0.5
FORBS	
Sulphur cinquefoil (*Potentilla recta*)	6.5
Wild bergamot (*Monarda fistulosa*)	4.7
Tall hawkweed (*Hieracium piloselloides*)	3.2
Early blue violet (*Viola adunca*)	1.6
Orange arnica (*Arnica fulgens*)	1.7
Great mullein (*Verbascum thapsus*)	1.3
Shaggy fleabane (*Erigeron pumilus*)	1.0
Yarrow (*Achillea millefolium*)	0.8
Black medic (*Medicago lupulina*)	0.6
Cut-leaved anemone (*Anemone multifida*)	0.4
White pussytoes (*Antennaria microphylla*)	0.3
SHRUBS	
Saskatoon (*Amelanchier alnifolia*)	9.6
Antelope-brush (*Purshia tridentata*)	3.3
Kinnikinnick (*Arctostaphylos uva-ursi*)	1.3
Common snowberry (*Symphoricarpos albus*)	0.6
LITTER	87.8
SOIL/ROCK	3.3
MOSS/LICHEN	1.3

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 852 - 857 m

SOIL DRAINAGE: well

SLOPE (%): level

ASPECT: none

FORAGE PRODUCTION (kg/ha)

N=3 (Min/Max/Mean)

Grass:	634 / 809 / 748
Forbs:	42 / 139 / 92
Shrubs:	219 / 751 / 445

WINTER FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)

Grass:	0.0 / 1.8 / 0.9
Forbs:	0.0 / 17.6 / 8.8
Shrubs:	0.0 / 0.0 / 0.0

SUMMER CATTLE FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)

Grass:	29.5 / 65.1 / 47.3
Forbs:	0.0 / 12.9 / 6.5
Shrubs:	0.0 / 0.0 / 0.0

Bull River Type 4

Canada bluegrass - bluebunch wheatgrass - Junegrass / sulphur cinquefoil / antelope-brush - western snowberry
(*Poa compressa - Pseudoroegneria spicata - Koeleria macrantha / Potentilla recta / Purshia tridentata - Symphoricarpos occidentalis*)

(N=2; sites BR-02, BR-03) This community type occurred on southeast-facing slopes above Bull River and consisted of a grassland-shrubland complex. The abundance of non-native weedy species suggested that this type had been altered through heavy grazing. BR-02 and BR-03 were subjected to a controlled burn in the spring of 1998, which may be related to the high cover of sulphur cinquefoil. The abundance of this species was of great concern. Associated invader species included great mullein and black medic. Saskatoon in the area received heavy browsing. The area received heavy use by both cattle and bighorn sheep. This type was in poor range condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Canada bluegrass (*Poa compressa*)	8.9
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	2.8
Junegrass (*Koeleria macrantha*)	2.6
Columbian needlegrass (*Achnatherum nelsonii*)	1.0
Slender wheatgrass (*Elymus trachycaulus*)	0.7
Kentucky bluegrass (*Poa pratensis*)	0.2
FORBS	
Sulphur cinquefoil (*Potentilla recta*)	21.2
Great mullein (*Verbascum thapsus*)	3.8
Yarrow (*Achillea millefolium*)	2.3
Black medic (*Medicago lupulina*)	2.2
Wild bergamot (*Monarda fistulosa*)	2.0
Yellow salsify (*Tragopogon dubius*)	0.7
Common dandelion (*Taraxacum officinale*)	0.5
Lemonweed (*Lithospermum ruderale*)	0.5
White pussytoes (*Antennaria microphylla*)	0.5
Thyme-leaved sandwort (*Arenaria serpyllifolia*)	0.4
Field pussytoes (*Antennaria neglecta*)	0.4
Spreading dogbane (*Apocynum androsaemifolium*)	0.4
SHRUBS	
Antelope-brush (*Purshia tridentata*)	7.6
Western snowberry (*Symphoricarpos occidentalis*)	6.9
Saskatoon (*Amelanchier alnifolia*)	2.2
Prairie rose (*Rosa woodsii*)	1.5
Birch-leaved spirea (*Spiraea betulifolia*)	0.3
LITTER	74.9
SOIL/ROCK	20.0
MOSS/LICHEN	1.0

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 836 - 877 m

SOIL DRAINAGE: moderate to well

SLOPE (%): 30 - 51

ASPECT: 120º - 123º

FORAGE PRODUCTION (kg/ha)

N=6 (Min/Max/Mean)
Grass: 129 / 981 / 491
Forbs: 93 / 1072 / 547
Shrubs: 38 / 1496 / 516

WINTER FORAGE UTILIZATION (%)

N=4 (Min/Max/Mean)
Grass: 1.6 / 50.2 / 24.5
Forbs: 0.0 / 39.1 / 9.8
Shrubs: 0.0 / 99.1 / 43.4

SUMMER CATTLE FORAGE UTILIZATION (%)

N=4 (Min/Max/Mean)
Grass: 6.1 / 62.6 / 41.9
Forbs: 44.8 / 64.9 / 53.0
Shrubs: 0.0 / 45.0 / 28.6

Bull River Type 5

Bluebunch wheatgrass - Canada bluegrass - cheatgrass / sulphur cinquefoil / antelope-brush – saskatoon
(*Pseudoroegneria spicata - Poa compressa - Bromus tectorum / Potentilla recta / Purshia tridentata - Amelanchier alnifolia*)

(N=2; sites BR-07, BR-09) This community type occurred on steep south-facing slopes above Bull River and was comprised of a shrubland-grassland complex. It appeared to represent the community type for which this ecosystem unit is named, with bluebunch wheatgrass and antelope-brush as common or dominant species. The original native vegetation community on these slopes had been greatly modified by the introduction of non-native agronomic and weed species, including Canada bluegrass, cheatgrass, sulphur cinquefoil, great mullein, thyme-leaved sandwort and black medic, some of which have become dominant or co-dominant species. The area received moderate to heavy use by cattle and occasional use by bighorn sheep. Although litter accumulation was relatively good compared to other types on similarly sloped aspects, the exposed gravel/soil allowed non-native and weedy species to become established and proliferate. This type was in poor range condition based on the site factors. Site BR-07 was burned in the spring of 2000 by the Columbia Basin Fish and Wildlife Compensation Program in an attempt to improve the forage base.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	5.2
Canada bluegrass (*Poa compressa*)	4.0
Cheatgrass (*Bromus tectorum*)	3.7
Junegrass (*Koeleria macrantha*)	0.3
FORBS	
Black medic (*Medicago lupulina*)	3.2
Golden-aster (*Heterotheca villosa*)	2.6
Sulphur cinquefoil (*Potentilla recta*)	2.4
Wild bergamot (*Monarda fistulosa*)	1.6
Great mullein (*Verbascum thapsus*)	1.6
Prairie sagewort (*Artemisia frigida*)	1.2
Yellow salsify (*Tragopogon dubius*)	0.8
Thyme-leaved sandwort (*Arenaria serpyllifolia*)	0.8
Sleepy catchfly (*Silene antirrhina*)	0.7
Yellow sweet-clover (*Melilotus officinalis*)	0.6
Slender penstemon (*Penstemon gracilis*)	0.5
Western blue flax (*Linum lewisii*)	0.4
Slender hawksbeard (*Crepis atribarba*)	0.3
Common dandelion (*Taraxacum officinale*)	0.3
Yarrow (*Achillea millefolium*)	0.3
Tall annual willowherb (*Epilobium brachycarpum*)	0.3
SHRUBS	
Antelope-brush (*Purshia tridentata*)	8.5
Saskatoon (*Amelanchier alnifolia*)	5.0
Western snowberry (*Symphoricarpos occidentalis*)	1.4
Choke cherry (*Prunus virginiana*)	1.1

LITTER	41.5
SOIL/ROCK	53.5
MOSS/LICHEN	0.5

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: xeric
ELEVATION: 862 - 895 m
SOIL DRAINAGE: rapid
SLOPE (%): 53 - 62
ASPECT: 157º - 206º

FORAGE PRODUCTION (kg/ha)

N=6 (Min/Max/Mean)
Grass: 414 / 1230 / 626
Forbs: 255 / 1544 / 539
Shrubs: 0 / 420 / 216

WINTER FORAGE UTILIZATION (%)

N=4 (Min/Max/Mean)
Grass: 14.2 / 83.0 / 46.3
Forbs: 47.1 / 96.0 / 65.0
Shrubs: 79.3 / 100.0 / 94.8

SUMMER CATTLE FORAGE UTILIZATION (%)

N=4 (Min/Max/Mean)
Grass: 0.0 / 12.1 / 4.8
Forbs: 24.7 / 71.2 / 45.9
Shrubs: 0.0 / 38.8 / 12.9

Bull River Type 6

Canada bluegrass - cheatgrass - common timothy / yellow sweet-clover - sulphur cinquefoil / saskatoon - western snowberry
(*Poa compressa - Bromus tectorum - Phleum pratense / Melilotus officinalis - Potentilla recta / Amelanchier alnifolia - Symphoricarpos occidentalis*)

(N=1; site BR-08) This community type occurred on a south-facing slope above Bull River. The original vegetation community was highly modified by non-native species, exemplified by the dominance of Canada bluegrass, cheatgrass, sulphur cinquefoil, black medic and great mullein. The area received moderate to heavy use by cattle and occasional use by bighorn sheep. The abundance of exposed soil, and non-native and weedy species in this type was of concern. It was in a low-poor range condition. The site was burned in the spring of 2000 by the Columbia Basin Fish and Wildlife Compensation Program in an attempt to improve the forage base. It is recommended that cattle be restricted from this area as they are trampling the vegetation, creating numerous trails and causing soil erosion.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Canada bluegrass (*Poa compressa*)	8.4
Cheatgrass (*Bromus tectorum*)	2.5
Common timothy (*Phleum pratense*)	2.2
Kentucky bluegrass (*Poa pratensis*)	1.5
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	0.2
FORBS	
Yellow sweet-clover (*Melilotus officinalis*)	7.3
Sulphur cinquefoil (*Potentilla recta*)	5.8
Wild bergamot (*Monarda fistulosa*)	3.6
Spreading dogbane (*Apocynum androsaemifolium*)	3.4
Yarrow (*Achillea millefolium*)	3.1
Smooth aster (*Aster laevis*)	1.8
Yellow salsify (*Tragopogon dubius*)	1.6
Great mullein (*Verbascum thapsus*)	1.5
American vetch (*Vicia americana*)	1.4
Blue lettuce (*Lactuca tatarica*)	0.9
Common hound's-tongue (*Cynoglossum officinale*)	0.8
Black medic (*Medicago lupulina*)	0.4
Common dandelion (*Taraxacum officinale*)	0.2
Thyme-leaved sandwort (*Arenaria serpyllifolia*)	0.2
SHRUBS	
Saskatoon (*Amelanchier alnifolia*)	15.1
Western snowberry (*Symphoricarpos occidentalis*)	6.9
Prickly rose (*Rosa acicularis*)	2.2
Antelope-brush (*Purshia tridentata*)	0.9
Creeping Oregon-grape (*Mahonia repens*)	0.2
LITTER	72.0
SOIL/ROCK	24.4
MOSS/LICHEN	39.0

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 857 m

SOIL DRAINAGE: rapid

SLOPE (%): 56

ASPECT: 177º

FORAGE PRODUCTION (kg/ha)

N=3 (Min/Max/Mean)
Grass: 533 / 1551 / 1076
Forbs: 192 / 1295 / 726
Shrubs: 107 / 433 / 243

WINTER FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)
Grass: 29.3 / 80.0 / 54.7
Forbs: 3.6 / 89.3 / 46.5
Shrubs: 0.0 / 82.1 / 41.1

SUMMER CATTLE FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)
Grass: 32.8 / 50.6 / 41.7
Forbs: 36.1 / 47.8 / 42.0
Shrubs: 0.0 / 56.1 / 28.1

Bull River Type 7

Needle-and-thread grass - cheatgrass / sweet-clover - prairie sagewort / antelope-brush (*Hesperostipa comata* - *Bromus tectorum* / *Melilotus* spp. - *Artemisia frigida* / *Purshia tridentata*)

(N=2; sites BR-05, BR-13) This community type occurred on a very steep south-facing slope above the lowest river terrace, and was comprised of a grassland-shrubland complex. It differred from the other 5 types on south-facing slopes in having needle-and-thread grass as the dominant grass, along with minor cover of sand dropseed. This community had also become highly invaded by non-native agronomic and weed species, such as cheatgrass, Canada bluegrass, pale alyssum, sweet-clover, great mullein and black medic. The area received moderate use by bighorn sheep. There was an abundance of exposed, loose gravel/soil and a lack of old litter. This community type was in a low-good range condition. The area was very prone to erosion and was highly disturbed by cattle. It is recommended that cattle be restricted from this area.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Needle-and-thread grass (*Hesperostipa comata*)	15.6
Cheatgrass (*Bromus tectorum*)	6.6
Sand dropseed (*Sporobolus cryptandrus*)	1.3
Canada bluegrass (*Poa compressa*)	0.6
FORBS	
Sweet-clover (*Melilotus* spp.)	3.7
Prairie sagewort (*Artemisia frigida*)	2.0
Pale alyssum (*Alyssum alyssoides*)	1.5
Great mullein (*Verbascum thapsus*)	0.7
Black medic (*Medicago lupulina*)	0.6
Yellow salsify (*Tragopogon dubius*)	0.4
Silverleaf phacelia (*Phacelia hastata*)	0.4
Yellow gromwell (*Lithospermum incisum*)	0.4
Lotus milk-vetch (*Astragalus lotiflorus*)	0.4
Black bindweed (*Polygonum convolvulus*)	0.3
SHRUBS	
Antelope-brush (*Purshia tridentata*)	6.5
LITTER	19.0
SOIL/ROCK	79.5
MOSS/LICHEN	0.4

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: xeric

ELEVATION: 807 - 815 m

SOIL DRAINAGE: rapid

SLOPE (%): 56

ASPECT: 160º - 177º

FORAGE PRODUCTION (kg/ha)

N=3 (Min/Max/Mean)
Grass: 400 / 685 / 500
Forbs: 64 / 492 / 254
Shrubs: 0 / 262 / 87

WINTER FORAGE UTILIZATION (%)

N=0 (Min/Max/Mean)
Grass: cage moved, no data
Forbs:
Shrubs:

SUMMER CATTLE FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)
Grass: 44.5 / 62.0 / 53.3
Forbs: 0.0 / 46.7 / 23.4
Shrubs: not in sampling plots

Bull River Type 8

Needle-and-thread grass - cheatgrass - little bluestem / prairie sagewort - sweet-clover / antelope-brush
(*Hesperostipa comata* - *Bromus tectorum* - *Schizachyrium scoparium* / *Artemisia frigida* - *Melilotus* spp. / *Purshia tridentata*)

(N=2; BR range reference area) This community type occurred on a very steep south-facing slope above the lowest river terrace, similar to Type 7. It differed from Type 7 in having little bluestem as a co-dominant grass along with needle-and-thread grass, and was probably unique in the study area. This community had also become highly invaded by non-native agronomic and weed species, such as cheatgrass, sweet-clover, pale alyssum, black medic and alfalfa. The area received moderate use by bighorn sheep. Vegetation and litter cover were sparse, with 75% of the area consisting of exposed loose gravel/soil. Based on the percent prominence value of the desirable plant species, this community type was in high-good range condition (rating of 66.1%) on the private land, compared to low-fair range condition (rating of 27.4%) on the Crown land. The area is very prone to erosion and is highly disturbed by cattle on the south side of the fence (Crown land). It is recommended that cattle be restricted from this area.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Needle-and-thread grass (*Hesperostipa comata*)	4.1
Cheatgrass (*Bromus tectorum*)	4.1
Little bluestem (*Schizachyrium scoparium*)	4.0
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	2.1
Sand dropseed (*Sporobolus cryptandrus*)	0.2
Canada/Kentucky bluegrass (*Poa compressa/ pratensis*)	0.1
FORBS	
Prairie sagewort (*Artemisia frigida*)	1.5
Sweet-clover (*Melilotus* spp.)	1.2
Pale alyssum (*Alyssum alyssoides*)	0.7
Yellow gromwell (*Lithospermum incisum*)	0.4
Black medic (*Medicago lupulina*)	0.2
Alfalfa (*Medicago sativa*)	0.2
Lamb's-quarters (*Chenopodium album*)	0.2
Rushlike skeleton-plant (*Lygodesmia juncea*)	0.2
Little gray aster (*Aster falcatus*)	0.2
Yellow salsify (*Tragopogon dubius*)	0.1
Golden-aster (*Heterotheca villosa*)	0.1
Corrugate-seeded spurge (*Chamaesyce glyptosperma*)	0.1
Ball mustard (*Neslia paniculata*)	0.1
SHRUBS	
Antelope-brush (*Purshia tridentata*)	0.9
LITTER	22.9
SOIL/ROCK	75.3
MOSS/LICHEN	0.0

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: xeric

ELEVATION: 841 m

SOIL DRAINAGE: rapid

SLOPE (%): 60

ASPECT: 184º

FORAGE PRODUCTION (kg/ha)

N=3 (Min/Max/Mean)
Grass: 537 / 975 / 723
Forbs: 49 / 248 / 133
Shrubs: not in sampling plots

WINTER FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)
Grass: 0.0 / 61.4 / 30.7
Forbs: 0.0 / 100.0 / 50.0
Shrubs: not in sampling plots

SUMMER CATTLE FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)
Grass: 40.1 / 82.6 / 61.4
Forbs: 0.0 / 79.0 / 39.5
Shrubs: not in sampling plots

Bull River Type 9

Columbian needlegrass - Junegrass - bluebunch wheatgrass / black medic - sulphur cinquefoil (*Achnatherum nelsonii - Koeleria macrantha - Pseudoroegneria spicata* / *Medicago lupulina - Potentilla recta*)

(N=1; site BR-15) This community type occurred on an upslope terrace above a rocky cliff with exposed bedrock bands interspersed amongst open Douglas-fir forest. It was comprised of a modified grassland with scattered mature Douglas-fir trees. The area received heavy use by cattle and bighorn sheep. There was an abundance of clubmoss and true moss covering shallow soils over bedrock. Site factors limited forage production. The abundance of weedy plant species throughout the area was of great concern. This type was in good range condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Columbian needlegrass (*Achnatherum nelsonii*)	9.1
Junegrass (*Koeleria macrantha*)	3.9
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	2.0
Japanese brome (*Bromus japonicus*)	1.9
Canada bluegrass (*Poa compressa*)	1.4
Cheatgrass (*Bromus tectorum*)	0.5
FORBS	
Black medic (*Medicago lupulina*)	4.7
Sulphur cinquefoil (*Potentilla recta*)	4.0
Common hound's-tongue (*Cynoglossum officinale*)	2.0
Yarrow (*Achillea millefolim*)	1.5
Arrowleaf balsamroot (*Balsamorhiza sagittata*)	0.7
Thread-leaved fleabane (*Erigeron filifolius*)	0.6
Yellow salsify (*Tragopogon dubius*)	0.4
Milk-vetch (*Astragalus* sp.)	0.3
Prairie sagewort (*Artemisia frigida*)	0.2
Shaggy fleabane (*Erigeron pumilus*)	0.2
Golden-aster (*Heterotheca villosa*)	0.2
LITTER	39.9
SOIL/ROCK	37.9
MOSS/LICHEN	19.9

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: sub-mesic

ELEVATION: 926 m

SOIL DRAINAGE: well

SLOPE (%): 21

ASPECT: 208º

FORAGE PRODUCTION (kg/ha)

N=0 (Min/Max/Mean)
Grass: no clip plot
Forbs:
Shrubs:

WINTER FORAGE UTILIZATION (%)

N=0 (Min/Max/Mean)
Grass: no clip plot
Forbs:
Shrubs:

SUMMER CATTLE FORAGE UTILIZATION (%)

N=0 (Min/Max/Mean)
Grass: no clip plot
Forbs:
Shrubs:

Bull River Type 10

Canada bluegrass - Junegrass - Japanese brome - needle-and-thread grass / tufted phlox - black medic
(*Poa compressa - Koeleria macrantha - Bromus japonicus - Hesperostipa comata / Phlox caespitosa - Medicago lupulina*)

(N=1; site BR-14) This community type occurred on an exposed knoll above a rocky cliff and was comprised of a modified grassland with an abundance of exposed soil and non-native weedy plant species, including Canada bluegrass, Japanese brome, cheatgrass, black medic and great mullein. The area received heavy use by cattle and bighorn sheep. Litter accumulation was low as a result of apparently low vegetative growth, high utilization and poor site conditions. The type as in fair range condition.

PLANT COMPOSITION	CANOPY COVER (%)
GRAMINOIDS	
Canada bluegrass (*Poa compressa*)	6.7
Junegrass (*Koeleria macrantha*)	6.3
Japanese brome (*Bromus japonicus*)	4.5
Needle-and-thread grass (*Hesperostipa comata*)	3.9
Columbian needlegrass (*Achnatherum nelsonii*)	1.2
Cheatgrass (*Bromus tectorum*)	1.1
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	0.7
FORBS	
Tufted phlox (*Phlox caespitosa*)	3.7
Black medic (*Medicago lupulina*)	3.4
Prairie sagewort (*Artemisia frigida*)	1.8
Columbia bladderpod (*Lesquerella douglasii*)	1.4
Western blue flax (*Linum lewisii*)	1.2
Great mullein (*Verbascum thapsus*)	1.1
Golden-aster (*Heterotheca villosa*)	0.6
White sweet-clover (*Melilotus alba*)	0.4
Pale alyssum (*Alyssum alyssoides*)	0.4
Thread-leaved fleabane (*Erigeron filifolius*)	0.3
Yellow salsify (*Tragopogon dubius*)	0.3
Woolly plantain (*Plantago patagonica*)	0.3
Bristly stickseed (*Lappula squarrosa*)	0.2
SHRUBS	
Prickly rose (*Rosa acicularis*)	0.1
LITTER	32.3
SOIL/ROCK	60.2
MOSS/LICHEN	3.0

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: xeric

ELEVATION: 896 m

SOIL DRAINAGE: rapid

SLOPE (%): 35

ASPECT: 205º

FORAGE PRODUCTION (kg/ha)

N=0 (Min/Max/Mean)
Grass: no clip plot
Forbs:
Shrubs:

WINTER FORAGE UTILIZATION (%)

N=0 (Min/Max/Mean)
Grass: no clip plot
Forbs:
Shrubs:

SUMMER CATTLE FORAGE UTILIZATION (%)

N=0 (Min/Max/Mean)
Grass: no clip plot
Forbs:
Shrubs:

3.1.4 Mount Broadwood Study Area

Most preferred-habitat transects were placed on west- and south-facing slopes or terraces above the Elk and Wigwam rivers. Several were placed on slopes and flats near the pipeline and trail leading from the lower terrace above the Elk River to the northwest corner of Wigwam Flats. Transects were mainly in the Douglas-fir-Bluebunch Wheatgrass (DB) unit, but also parts of the Abandoned Field (AF), Lodgepole Pine-Saskatoon (LS) and Snowberry-Balsamroot (SB) units. Grasslands dominated the terraces, while grassland/shrubland complexes and patchy forest dominated the west-facing slopes. There was marked invasion by agronomic and weedy species such as sulphur cinquefoil, common St. John's-wort (Figure 2) and spotted knapweed.

Figure 2. Common St. John’s-wort infestation (brown heads) near transect 12 in plant community type 7 (Idaho fescue - Canada bluegrass - Junegrass / large-fruited desert-parsley - common St. John's-wort plant community) at Mount Broadwood study area.

Much of the west-facing slope and terrace above the Elk River was dominated by or had significant cover of non-native species, including common timothy, Canada bluegrass, smooth brome, yellow clover and oxeye daisy. Other non-natives, often at lower covers, included Kentucky bluegrass, Japanese brome, cheatgrass, sulphur cinquefoil, spotted knapweed, black medic, common St. John's-wort, yellow sweet-clover, alfalfa and common dandelion. Prominent native grasses included Idaho fescue, pinegrass and bluebunch wheatgrass, but they seldom dominated except on upper benches. There was often significant shrub cover, comprised mainly of common snowberry, creeping Oregon-grape and prairie rose. Patches of taller shrubs included saskatoon, redstem ceanothus, pin cherry, Douglas maple, soopolallie and willow.

Wigwam Flats, lower terraces and slopes above the flats tended to be dominated by Idaho fescue, with lower cover of Junegrass, bluebunch wheatgrass and Columbian needlegrass.

Patches of open Douglas-fir harboured an understory dominated by poverty oat grass, with lower cover of bluebunch wheatgrass, Idaho fescue, Junegrass and rough fescue. Canada bluegrass was often a co-dominant grass and common St. John's-wort was often a dominant or co-dominant forb. Other non-native species included yellow clover and tall hawkweed.

Throughout this study area, 23 preferred-habitat transects were established which represent 12 community types. These were located in areas identified as key wintering habitat based on radiolocations. Most of the sites had an abundance of non-native and weedy plant species. The community types are described below, using average cover values for the species. Not all species listed, especially those with lower cover values, were present at all sites.

The exclosure was located in fescue grassland under an open canopy of Douglas-fir on the edge of the terrace above the Wigwam River. This community was named the rough fescue - bluebunch wheatgrass/wild bergamot - tufted phlox/birch-leaved spirea type. Rough fescue was the dominant species within the exclosure. There were also several young Douglas-fir trees. Choke cherry, common juniper and prickly rose were common shrubs. Field pussytoes, wild bergamot, large-fruited desert-parsley and tufted phlox were common forbs. Junegrass was also common but at much lower cover than rough fescue. Field chickweed, nodding onion, common harebell and woolly groundsel frequently occurred but at low cover.

Outside the exclosure, there was less vegetative cover and comparatively less grass cover. Rough fescue was still the dominant grass, but bluebunch wheatgrass and Junegrass were more common than inside. Idaho fescue, Canada bluegrass and Sandberg's bluegrass frequently occurred but at low cover. Wild bergamot was dominant. Tufted phlox, woolly groundsel, field chickweed, yarrow and diffuse fleabane also were common. White pussytoes, field pussytoes, yellow rattle, large-fruited desert-parsley, common harebell, spikelike goldenrod and yellow salsify frequently occurred but at low cover. Birch-leaved spirea, prickly rose and choke cherry were the most common shrubs.

Mount Broadwood Type 1

Common snowberry - creeping Oregon-grape / common timothy - Canada bluegrass / arrowleaf balsamroot
(*Symphoricarpos albus - Mahonia repens / Phleum pratense - Poa compressa / Balsamorhiza sagittata*)

(N=3; sites MB-01, MB-20, MB-23) This community type occurred on gentle to moderate lower slopes consisting of a shrubland - non-native grassland complex. The area was once grazed by livestock, which may have contributed to the abundance of agronomic and weedy plant species. The abundance of grass litter suggested the forage of this type was under-utilized. Saskatoon browsing was extensive. The presence of weed species was of concern, particularly sulphur cinquefoil, spotted knapweed and oxeye daisy. The species composition suggested that this type was in low-poor condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Common timothy (*Phleum pratense*)	6.1
Canada bluegrass (*Poa compressa*)	3.8
Kentucky bluegrass (*Poa pratensis*)	1.9
Idaho fescue (*Festuca idahoensis*)	0.8
Pinegrass (*Calamagrostis rubescens*)	0.7
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	0.7
FORBS	
Arrowleaf balsamroot (*Balsamorhiza sagittata*)	4.2
Yellow clover (*Trifolium aureum*)	2.6
Field pussytoes (*Antennaria neglecta*)	2.1
Smooth aster (*Aster laevis*)	2.0
Sulphur cinquefoil (*Potentilla recta*)	1.7
Yarrow (*Achillea millefolium*)	0.9
Spotted knapweed (*Centaurea biebersteinii*)	0.8
Black medic (*Medicago lupulina*)	0.4
Wild stawberry (*Fragaria virginiana*)	0.4
Field chickweed (*Cerastium arvense*)	0.4
Yellow salsify (*Tragopogon dubius*)	0.3
Showy aster (*Aster conspicuus*)	0.3
Oxeye daisy (*Leucanthemum vulgare)*	0.3
Cut-leaved anemone (*Anemone multifida*)	0.2
Diffuse fleabane (*Erigeron divergens*)	0.2
SHRUBS	
Common snowberry (*Symphoricarpos albus*)	15.0
Creeping Oregon-grape (*Mahonia repens*)	9.9
Prairie rose (*Rosa woodsii*)	4.6
Saskatoon (*Amelanchier alnifolia*)	3.1
Redstem ceanothus (*Ceanothus sanguineus*)	2.6
Birch-leaved spirea (*Spiraea betulifolia*)	1.2
LITTER	79.4
SOIL/ROCK	10.6
MOSS/LICHEN	24.5

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 956 - 1033 m

SOIL DRAINAGE: moderate

SLOPE (%): 10 - 33

ASPECT: 197º - 262º

FORAGE PRODUCTION (kg/ha)

N=2 (Min/Max/Mean)
Grass: 658 / 1203 / 931
Forbs: 180 / 221 / 201
Shrubs: 287 / 370 / 328

WINTER FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)
Grass: 25.1 / 52.1 / 38.6
Forbs: 0.0 / 89.5 / 45.0
Shrubs: 30.4 / 88.9 / 59.6

Mount Broadwood Type 2

Common snowberry - redstem ceanothus - creeping Oregon-grape / spreading dogbane - wild bergamot / pinegrass - bluebunch wheatgrass
(*Symphoricarpos albus - Ceanothus sanguineus - Mahonia repens / Apocynum androsaemifolium - Monarda fistulosa / Calamagrostis rubescens - Pseudoroegneria spicata*)

(N=3; sites MB-02, MB-15, MB-17) This community type occurred on moderate lower to mid-slopes and consisted of a shrubland-grassland complex. The area was once grazed by livestock, which may have contributed to the introduction of agronomic and weed plant species. The graminoids were moderately used with an abundant accumulation of litter. Browsing on saskatoon and redstem ceanothus was extensive. The presence of weed species was minor but their presence was of concern, particularly sulphur cinquefoil and common St. John's-wort. The species composition suggested that this type was in poor condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Pinegrass (*Calamagrostis rubescens*)	7.4
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	3.2
Common timothy (*Phleum pratense*)	2.5
Canada bluegrass (*Poa compressa*)	2.0
Kentucky bluegrass (*Poa pratensis*)	1.3
Idaho fescue (*Festuca idahoensis*)	0.6
Junegrass (*Koeleria macrantha*)	0.6
Columbian needlegrass (*Achnatherum nelsonii*)	0.3
FORBS	
Spreading dogbane (*Apocynum androsaemifolium*)	6.7
Wild bergamot (*Monarda fistulosa*)	5.6
Showy aster (*Aster conspicuus*)	2.1
Wild strawberry (*Fragaria virginiana*)	1.9
Yarrow (*Achillea millefolium*)	1.6
Field chickweed (*Cerastium arvense*)	1.4
Yellow clover (*Trifolium aureum*)	1.2
Smooth aster (*Aster laevis*)	1.1
Sulphur cinquefoil (*Potentilla recta*)	1.1
Field pussytoes (*Antennaria neglecta*)	0.9
Yellow salsify (*Tragopogon dubius*)	0.4
Common St. John's-wort (*Hypericum perforatum*)	0.3
Narrow-leaved collomia (*Collomia linearis*)	0.2
SHRUBS	
Common snowberry (*Symphoricarpos albus*)	13.0
Redstem ceanothus (*Ceanothus sanguineus*)	10.6
Creeping Oregon-grape (*Mahonia repens*)	7.9
Saskatoon (*Amelanchier alnifolia*)	7.0
Prairie rose (*Rosa woodsii*)	3.0
Birch-leaved spirea (*Spiraea betulifolia*)	0.2
LITTER	77.7
SOIL/ROCK	10.4
MOSS/LICHEN	16.9

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 1003 - 1066 m

SOIL DRAINAGE: moderate

SLOPE (%): 17 - 37

ASPECT: 224° - 250 °

FORAGE PRODUCTION (kg/ha)

N=4 (Min/Max/Mean)
Grass: 541 / 1253 / 883
Forbs: 107 / 245 / 174
Shrubs: 552 / 1306 / 943

WINTER FORAGE UTILIZATION (%)

N=4 (Min/Max/Mean)
Grass: 0.0 / 7.8 / 2.6
Forbs: 0.0 / 0.0 / 0.0
Shrubs: 0.0 / 67.8 / 51.6

Mount Broadwood Type 3

Bluebunch wheatgrass - pinegrass / common snowberry - creeping Oregon-grape / spotted knapweed
(*Pseudoroegneria spicata - Calamagrostis rubescens* / *Symphoricarpos albus - Mahonia repens* / *Centaurea biebersteinii*)

(N=2; sites MB-03, MB-13) This community type occurred on lower to mid-slopes and consisted of a grassland-shrubland complex. The dominance of spotted knapweed at MB-13 was of concern. The graminoids were unused to moderately used depending on site and year. Little litter accumulation was present around bluebunch wheatgrass plants, which appeared not to be utilized at these sites. Browsing was heavy on saskatoon. The species composition suggested that this type was in fair condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	12.8
Pinegrass (*Calamagrostis rubescens*)	3.2
Canada bluegrass (*Poa compressa*)	2.0
Junegrass (*Koeleria macrantha*)	1.0
Columbian needlegrass (*Achnatherum nelsonii*)	0.5
Common timothy (*Phleum pratense*)	0.3
FORBS	
Spotted knapweed (*Centaurea biebersteinii*)	6.3
Yellow sweet-clover (*Melilotus officinalis*)	2.8
Alfalfa (*Medicago sativa*)	1.7
Wild strawberry (*Fragaria virginiana*)	1.6
Yarrow (*Achillea millefolium*)	1.4
Alberta penstemon (*Penstemon albertinus*)	1.2
Wood strawberry (*Fragaria vesca*)	1.1
Arrowleaf balsamroot (*Balsamorhiza sagittata*)	0.9
Showy aster (*Aster conspicuus*)	0.8
Tall annual willowherb (*Epilobium brachycarpum*)	0.5
Spreading dogbane (*Apocynum androsaemifolium*)	0.4
Common St. John's-wort (*Hypericum perforatum*)	0.3
Smooth aster (*Aster laevis*)	0.3
Field chickweed (*Cerastium arvense*)	0.3
Bastard toadflax (*Comandra umbellata*)	0.3
SHRUBS	
Common snowberry (*Symphoricarpos albus*)	7.4
Creeping Oregon-grape (*Mahonia repens*)	3.2
Saskatoon (*Amelanchier alnifolia*)	1.6
Prairie rose (*Rosa woodsii*)	1.4
Redstem ceanothus (*Ceanothus sanguineus*)	0.3

LITTER	47.5
SOIL/ROCK	38.4
MOSS/LICHEN	16.2

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: sub-xeric

ELEVATION: 975 - 1026 m

SOIL DRAINAGE: moderate

SLOPE (%): 40 - 44

ASPECT: 251º - 335º

FORAGE PRODUCTION (kg/ha)

N=3 (Min/Max/Mean)
Grass: 320 / 881 / 656
Forbs: 38 / 125 / 103
Shrubs: 49 / 135 / 103

WINTER FORAGE UTILIZATION (%)

N=3 (Min/Max/Mean)
Grass: 0.0 / 69.5 / 25.5
Forbs: 0.0 / 97.5 / 51.6
Shrubs: 0.0 / 99.2 / 40.7

Mount Broadwood Type 4

Idaho fescue - pinegrass / wild strawberry - yellow clover - smooth aster / common snowberry (*Festuca idahoensis - Calamagrostis rubescens / Fragaria virginiana - Trifolium aureum - Aster laevis / Symphoricarpos albus*)

(N=1; site MB-19) This community type occurred on the toe of a long slope and consisted of an open grassland-shrubland complex. The cover of Canada bluegrass increased upslope from the site to the access road, where it was likely seeded in the past. Abundance of litter suggested that this area was not used to any extent. The graminoids did not appear to be used. Browsing was moderate on saskatoon and redstem ceanothus. The species composition suggested that this type was in low-fair condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Idaho fescue (*Festuca idahoensis*)	10.8
Pinegrass (*Calamagrostis rubescens*)	3.4
Spreading needlegrass (*Achnatherum richardsonii*)	3.1
Canada bluegrass (*Poa compressa*)	2.5
Junegrass (*Koeleria macrantha*)	0.5
Slender wheatgrass (*Elymus trachycaulus*)	0.3
Common timothy (*Phleum pratense*)	0.2
Rough fescue (*Festuca campestris*)	0.1
FORBS	
Wild strawberry (*Fragaria virginiana*)	21.5
Yellow clover (*Trifolium aureum*)	5.5
Smooth aster (*Aster laevis*)	5.2
Yarrow (*Achillea millefolium*)	1.3
White pussytoes (*Antennaria microphylla*)	1.3
Spikelike goldenrod (*Solidago spathulata*)	0.5
Common harebell (*Campanula rotundifolia*)	0.4
Field chickweed (*Cerastium arvense*)	0.4
Cut-leaved anemone (*Anemone multifida*)	0.3
Spreading dogbane (*Apocynum androsaemifolium*)	0.3
Early blue violet (*Viola adunca*)	0.3
Field pussytoes (*Antennaria neglecta*)	0.2
Yellow penstemon (*Penstemon confertus*)	0.2
SHRUBS	
Common snowberry (*Symphoricarpos albus*)	3.7
Creeping Oregon-grape (*Mahonia repens*)	1.6
Prickly rose (*Rosa acicularis*)	0.4
LITTER	34.7
SOIL/ROCK	3.4
MOSS/LICHEN	83.3

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 1121 m

SOIL DRAINAGE: moderate

SLOPE (%): 0 - 2

ASPECT: variable micro-relief

FORAGE PRODUCTION (kg/ha)

N=1 (Min/Max/Mean)

Grass:	1088 / 1088 / 1088
Forbs:	102 / 102 / 102
Shrubs:	159 / 159 / 159

WINTER FORAGE UTILIZATION (%)

N=1 (Min/Max/Mean)

Grass:	0.0 / 0.0 / 0.0
Forbs:	0.0 / 0.0 / 0.0
Shrubs:	66.7 / 66.7 / 66.7

Mount Broadwood Type 5

Common St. John's-wort - smooth aster / common snowberry - saskatoon / Canada bluegrass - pinegrass - Columbian needlegrass
(*Hypericum perforatum - Aster laevis / Symphoricarpos albus - Amelanchier alnifolia / Poa compressa - Calamagrostis rubescens - Achnatherum nelsonii*)

(N=2; sites MB-06, MB-07) This community type occurred on level undulating terrain to south-facing lower and mid-slopes, consisting of a shrubland-grassland complex. The abundance of the weed, common St. John's-wort, was of great concern in this community. The graminoids were lightly to moderately used depending on the site and year. Browsing was heavy on saskatoon. The species composition suggested that this type was in high-poor condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Canada bluegrass (*Poa compressa*)	4.4
Pinegrass (*Calamagrostis rubescens*)	2.8
Columbian needlegrass (*Achnatherum nelsonii*)	2.7
Idaho fescue (*Festuca idahoensis*)	1.9
Junegrass (*Koeleria macrantha*)	1.8
Rough fescue (*Festuca campestris*)	0.7
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	0.5
Poverty oatgrass (*Danthonia spicata*)	0.5
FORBS	
Common St. John's-wort (*Hypericum perforatum*)	9.6
Smooth aster (*Aster laevis*)	4.3
Spreading dogbane (*Apocynum androsaemifolium*)	2.0
Yarrow (*Achillea millefolium*)	1.8
Golden-aster (*Heterotheca villosa*)	1.8
Spikelike goldenrod (*Solidago spathulata*)	1.6
Field pussytoes (*Antennaria neglecta*)	1.3
White pussytoes (*Antennaria microphylla*)	1.0
Wild strawberry (*Fragaria virginiana*)	1.0
Rough-stemmed fleabane (*Erigeron strigosus*)	0.7
Scouler's hawkweed (*Hieracium scouleri*)	0.6
American vetch (*Vicia americana*)	0.6
Showy daisy (*Erigeron speciosus*)	0.5
Yellow clover (*Trifolium aureum*)	0.5
Woolly groundsel (*Senecio canus*)	0.3
Field chickweed (*Cerastium arvense*)	0.2
SHRUBS	
Common snowberry (*Symphoricarpos albus*)	4.8
Saskatoon (*Amelanchier alnifolia*)	4.0
Creeping Oregon-grape (*Mahonia repens*)	0.9
Redstem ceanothus (*Ceanothus sanguineus*)	0.3
LITTER	47.5
SOIL/ROCK	38.4
MOSS/LICHEN	16.2

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 1122 - 1051 m

SOIL DRAINAGE: moderate

SLOPE (%): 0 - 17

ASPECT: variable micro-relief to 183º at MB-07

FORAGE PRODUCTION (kg/ha)

N=3 (Min/Max/Mean)
Grass: 405 / 743 / 630
Forbs: 282 / 373 / 333
Shrubs: 48 / 441 / 204

WINTER FORAGE UTILIZATION (%)

N=3 (Min/Max/Mean)
Grass: 23.2 / 52.1 / 31.2
Forbs: 0.0 / 39.8 / 10.0
Shrubs: 50.0 / 97.6 / 65.2

Mount Broadwood Type 6

Yellow clover - sulphur cinquefoil / Canada bluegrass - common timothy - smooth brome / prairie rose
(*Trifolium aureum - Potentilla recta / Poa compressa - Phleum pratense - Bromus inermis / Rosa woodsii*)

(N=1; site MB-04) This community type occurred on a level glaciofluvial terrace consisting of a grassland-shrubland complex. The area was once part of a homestead and was seeded with agronomic species. It was not utilized and as a result had an abundance of old litter. The presence of weed species was of concern, particularly sulphur cinquefoil and oxeye daisy. Rose was abundant and likely spreading. The species composition suggested that this type was in low-poor condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Kentucky bluegrass (*Poa pratensis*)	22.8
Common timothy (*Phleum pratense*)	6.3
Smooth brome (*Bromus inermis*)	4.9
Canada bluegrass (*Poa compressa*)	0.9
FORBS	
Yellow clover (*Trifolium aureum*)	36.5
Sulphur cinquefoil (*Potentilla recta*)	2.5
Oxeye daisy (*Leucanthemum vulgare*)	1.5
Black medic (*Medicago lupulina*)	1.4
Field pussytoes (*Antennaria neglecta*)	1.0
Wavy-leaved thistle (*Cirsium undulatum*)	0.9
Yarrow (*Achillea millefolium*)	0.5
Common dandelion (*Taraxacum officinale*)	0.2
SHRUBS	
Prairie rose (*Rosa woodsii*)	8.3
Rocky Mountain juniper (*Juniperus scopulorum*)	5.0
LITTER	97.5
SOIL/ROCK	0.1
MOSS/LICHEN	40.3

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 928 m

SOIL DRAINAGE: moderate

SLOPE (%): 2

ASPECT: variable

FORAGE PRODUCTION (kg/ha)

N=2 (Min/Max/Mean)

	Min	Max	Mean
Grass:	1508	1671	1590
Forbs:	16	500	258
Shrubs:	53	93	73

WINTER FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)

Grass: 0.0 / 0.0 / 0.0
Forbs: 0.0 / 83.1 / 41.6
Shrubs: not present in all sampling plots

Mount Broadwood Type 7

Idaho fescue - Canada bluegrass - Junegrass / large-fruited desert-parsley - common St. John's-wort
(*Festuca idahoensis - Poa compressa / Lomatium macrocarpum - Hypericum perforatum*)

(N=4; sites MB-05, MB-11, MB-12, MB-14) This community type mainly occurred on level terraces, Wigwam Flats and west-facing slopes. It consisted of open grassland with scattered rose and snowberry shrubs, and patches of creeping Oregon-grape. Forage use varied from light to moderate. Common St. John's-wort was a dominant species at 2 of the sites. The species composition suggested that this type was in low-excellent condition.

PLANT COMPOSITION	CANOPY COVER (%)
GRAMINOIDS	
Idaho fescue (*Festuca idahoensis*)	25.5
Canada bluegrass (*Poa compressa*)	3.3
Junegrass (*Koeleria macrantha*)	2.4
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	1.4
Spreading needlegrass (*Achnatherum richardsonii*)	0.3
Columbian needlegrass (*Achnatherum nelsonii*)	0.2
FORBS	
Large-fruited desert-parsley (*Lomatium macrocarpum*)	1.8
Common St. John's-wort (*Hypericum perforatum*)	1.2
Smooth aster (*Aster laevis*)	1.1
Wild bergamot (*Monarda fistulosa*)	1.1
Spreading dogbane (*Apocynum androsaemifolium*)	1.0
White pussytoes (*Antennaria microphylla*)	1.0
Field chickweed (*Cerastium arvense*)	0.8
Yarrow (*Achillea millefolium*)	0.7
Rough-stemmed fleabane (*Erigeron strigosus*)	0.7
Yellow rattle (*Rhinanthus minor*)	0.6
Field pussytoes (*Antennaria neglecta*)	0.6
Wild strawberry (*Fragaria virginiana*)	0.5
Tufted phlox (*Phlox caespitosa*)	0.3
Three-spot mariposa lily (*Calochortus apiculatus*)	0.3
Tall hawkweed (*Hieracium piloselloides*)	0.3
Spikelike goldenrod (*Solidago spathulata*)	0.2
Narrow-leaved collomia (*Collomia linearis*)	0.2
SHRUBS	
Rose (*Rosa* spp.)	1.7
Common snowberry (*Symphoricarpos albus*)	1.6
Creeping Oregon-grape (*Mahonia repens*)	1.4
Saskatoon (*Amelanchier alnifolia*)	0.6
Birch-leaved spirea (*Spiraea betulifolia*)	0.2

LITTER	34.7
SOIL/ROCK	3.4
MOSS/LICHEN	83.3

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: sub-mesic to mesic

ELEVATION: 962 - 1073 m

SOIL DRAINAGE: well to moderate

SLOPE (%): 0 - 28

ASPECT: variable micro-relief to 290º

FORAGE PRODUCTION (kg/ha)

N=7 (Min/Max/Mean)

Grass:	385 / 1156 / 716
Forbs:	0 / 609 / 216
Shrubs:	9 / 145 / 53

WINTER FORAGE UTILIZATION (%)

N=7 (Min/Max/Mean)

Grass:	0.0 / 46.7 / 24.8
Forbs:	0.0 / 66.7 / 22.7
Shrubs:	0.0 / 100.0 / 29.9 (not present in some sampling plots)

Mount Broadwood Type 8

Idaho fescue - Canada bluegrass / field pussytoes - common St. John's-wort - wild bergamot / common snowberry
(*Festuca idahoensis - Poa compressa / Antennaria neglecta - Hypericum perforatum - Monarda fistulosa / Symphoricarpos albus*)

(N=2; sites MB-09, MB-10) This community type mainly occurred on level terraces and Wigwam Flats adjacent to escape terrain. Bighorn sheep use was high. The community consisted of an open grassland with scattered shrubs. The abundance of common St. John's-wort was of concern as it was growing throughout the area. The species composition suggested that this type was in high-fair condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Idaho fescue (*Festuca idahoensis*)	13.6
Canada bluegrass (*Poa compressa*)	4.3
Junegrass (*Koeleria macrantha*)	2.0
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	0.5
Columbian needlegrass (*Achnatherum nelsonii*)	0.4
FORBS	
Field pussytoes (*Antennaria neglecta*)	7.1
Common St. John's-wort (*Hypericum perforatum*)	5.4
Wild bergamot (*Monarda fistulosa*)	4.0
Spreading dogbane (*Apocynum androsaemifolium*)	2.5
Tufted phlox (*Phlox caespitosa*)	1.6
Meadow death camas (*Zigadenus venenosus*)	1.2
White pussytoes (*Antennaria microphylla*)	1.0
Common harebell (*Campanula rotundifolia*)	0.7
Thin-leaved owl-clover (*Orthocarpus tenuifolius*)	0.6
White cinquefoil (*Potentilla arguta*)	0.5
Field chickweed (*Cerastium arvense*)	0.5
Spikelike goldenrod (*Solidago spathulata*)	0.4
Yellow rattle (*Rhinanthus minor*)	0.4
Rough-stemmed fleabane (*Erigeron strigosus*)	0.2
Yarrow (*Achillea millefolium*)	0.2
Orange arnica (*Arnica fulgens*)	0.2
SHRUBS	
Common snowberry (*Symphoricarpos albus*)	1.3
LITTER	34.7
SOIL/ROCK	3.4
MOSS/LICHEN	83.3

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 989 - 992 m

SOIL DRAINAGE: well

SLOPE (%): level

ASPECT: none

FORAGE PRODUCTION (kg/ha)

N=4 (Min/Max/Mean)

Grass:	282 / 1235 / 671
Forbs:	53 / 375 / 182
Shrubs:	0 / 110 / 28

WINTER FORAGE UTILIZATION (%)

N=4 (Min/Max/Mean)

Grass:	0.0 / 44.1 / 25.0
Forbs:	0.0 / 30.6 / 7.7
Shrubs:	not present in all sampling plots

Mount Broadwood Type 9

Rough fescue - bluebunch wheatgrass / wild bergamot - tufted phlox / birch-leaved spirea (*Festuca campestris - Pseudoroegneria spicata / Monarda fistulosa - Phlox caespitosa / Spiraea betulifolia*)

(N=1; MB exclosure) This community type occurred on level terrain in the understory of open Douglas-fir forest on Wigwam Flats. Due to protection from grazing, the rough fescue-dominated community within the exclosure appeared to be unique on Wigwam Flats and would likely represent a climax type in the absence of grazing. The area outside the exclosure represented one of the types on Wigwam Flats having a significant cover of rough fescue, and is described below. Bighorn sheep use was moderate in the open areas along the rim of the canyon, whereas elk use was higher beneath the forest canopy and in the large open areas of the flats. The community consisted of an open grassland with scattered shrubs, including birch-leaved spirea, prickly rose, choke cherry, common juniper and saskatoon. The species composition suggested that this type varied in condition from fair to excellent depending on past long-term use.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Rough fescue (*Festuca campestris*)	5.1
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	3.1
Junegrass (*Koeleria macrantha*)	2.6
Idaho fescue (*Festuca idahoensis*)	0.5
Canada bluegrass (*Poa compressa*)	0.4
Sandberg's bluegrass (*Poa secunda*)	0.2
Poverty oatgrass (*Danthonia spicata*)	0.1
FORBS	
Wild bergamot (*Monarda fistulosa*)	7.0
Tufted phlox (*Phlox caespitosa*)	4.5
Woolly groundsel (*Senecio canus*)	1.8
Field chickweed (*Cerastium arvense*)	1.5
Yarrow (*Achillea millefolium*)	1.3
Diffuse fleabane (*Erigeron divergens*)	1.1
White pussytoes (*Antennaria microphylla*)	1.1
Field pussytoes (*Antennaria neglecta*)	0.9
Yellow rattle (*Rhinanthus minor*)	0.7
Large-fruited desert-parsley (*Lomatium macrocarpum*)	0.7
Common harebell (*Campanula rotundifolia*)	0.6
Spikelike goldenrod (*Solidago spathulata*)	0.5
Yellow salsify (*Tragopogon dubius*)	0.5
Cut-leaved anemone (*Anemone multifida*)	0.3
Tall hawkweed (*Hieracium piloselloides*)	0.3
Common St. John's-wort (*Hypericum perforatum*)	0.2
Thin-leaved owl-clover (*Orthocarpus tenuifolius*)	0.2
White cinquefoil (*Potentilla arguta*)	0.2
SHRUBS	
Birch-leaved spirea (*Spiraea betulifolia*)	1.5
Prickly rose (*Rosa acicularis*)	0.5
Choke cherry (*Prunus virginiana*)	0.4
LITTER	18.5
SOIL/ROCK	3.4
MOSS/LICHEN	79.6

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 1046 m

SOIL DRAINAGE: moderate to well

SLOPE (%): level

ASPECT: none

FORAGE PRODUCTION (kg/ha)

N=2 (Min/Max/Mean)
Grass: 167 / 197 / 182
Forbs: 102 / 223 / 163
Shrubs: 78 / 84 / 81

WINTER FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)
Grass: 0.0 / 32.0 / 16.0
Forbs: 0.0 / 30.0 / 15.0
Shrubs: 0.0 / 40.0 / 20.0

Mount Broadwood Type 10

Poverty grass - Idaho fescue - bluebunch wheatgrass / wild bergamot - smooth aster (*Danthonia spicata - Festuca idahoensis - Pseudoroegneria spicata / Monarda fistulosa - Aster laevis*)

(N=2; sites MB-08, MB-16) This community type occurred on level terrain in the understory of open Douglas-fir forest on Wigwam Flats. Bighorn sheep use was moderate in the open areas, whereas elk use was higher beneath the forest canopy. The community consisted of an open grassland with scattered shrubs, including junipers, soopolallie, saskatoon, pin cherry, common snowberry and prickly rose. The species composition suggested that this type was in high-good condition.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Poverty oatgrass (*Danthonia spicata*)	16.2
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	3.4
Idaho fescue (*Festuca idahoensis*)	3.4
Junegrass (*Koeleria macrantha*)	3.2
Rough fescue (*Festuca campestris*)	2.5
Canada bluegrass (*Poa compressa*)	1.2
FORBS	
Wild bergamot (*Monarda fistulosa*)	5.0
Smooth aster (*Aster laevis*)	3.0
Tufted phlox (*Phlox caespitosa*)	2.2
Compact selaginella (*Selaginella densa*)	1.8
Field pussytoes (*Antennaria neglecta*)	1.3
Rough-stemmed fleabane (*Erigeron strigosus*)	1.0
Spreading dogbane (*Apocynum androsaemifolium*)	1.0
Narrow-leaved collomia (*Collomia linearis*)	0.9
Common harebell (*Campanula rotundifolia*)	0.6
Large-fruited desert-parsley (*Lomatium macrocarpum*)	0.6
Yarrow (*Achillea millefolium*)	0.5
Field chickweed (*Cerastium arvense*)	0.4
Tall annual willowherb (*Epilobium brachycarpum*)	0.4
White cinquefoil (*Potentilla arguta*)	0.4
Yellowish paintbrush (*Castilleja lutescens*)	0.3
Wild strawberry (*Fragaria virginiana*)	0.3
Spikelike goldenrod (*Solidago spathulata*)	0.3
Yellow rattle (*Rhinanthus minor*)	0.2
SHRUBS	
Pin cherry (*Prunus pensylvanica*)	0.2
other species scattered throughout but not on transect	
LITTER	22.3
SOIL/ROCK	5.3
MOSS/LICHEN	75.1

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: mesic

ELEVATION: 1013 - 1025 m

SOIL DRAINAGE: moderate to well

SLOPE (%): level

ASPECT: none

FORAGE PRODUCTION (kg/ha)

N=2 (Min/Max/Mean)
Grass: 414 / 514 / 464
Forbs: 120 / 165 / 143
Shrubs: 0 / 38 / 19

WINTER FORAGE UTILIZATION (%)

N=2 (Min/Max/Mean)
Grass: 5.9 / 38.2 / 22.1
Forbs: 0.0 / 16.0 / 8.0
Shrubs: 17.6 / 17.6 / 17.6
(not present in some sampling plots)

Mount Broadwood Type 11

Idaho fescue - pinegrass / woodrush pussytoes - compact selaginella / common snowberry (*Festuca idahoensis - Calamagrostis rubescens / Antennaria luzuloides - Selaginella densa / Symphoricarpos albus*)

(N=1; site MB-18) This community type occurred on an upland bench consisting of a grassland-shrubland complex. The graminoids were lightly to heavily used depending on proximity to the rock bluff below the site. Bighorn sheep use was high throughout the rock bluff and along the upper edge. The use decreased with distance from escape terrain. The use of bluebunch wheatgrass and pinegrass was low. There was high use of Idaho fescue. Browsing was heavy on saskatoon. The species composition suggested that this type was in high-fair condition.

PLANT COMPOSITION	CANOPY COVER (%)
GRAMINOIDS	
Idaho fescue (*Festuca idahoensis*)	15.5
Pinegrass (*Calamagrostis rubescens*)	2.5
Sandberg's bluegrass (*Poa secunda*)	2.4
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	1.7
Japanese brome (*Bromus japonicus*)	1.7
Junegrass (*Koeleria macrantha*)	1.6
Canada bluegrass (*Poa compressa*)	1.2
Columbian needlegrass (*Achnatherum nelsonii*)	0.5
Rough fescue (*Festuca campestris*)	0.3
FORBS	
Woodrush pussytoes (*Antennaria luzuloides*)	11.9
Compact selaginella (*Selaginella densa*)	6.1
Yellow clover (*Trifolium aureum*)	2.1
Yarrow (*Achillea millefolium*)	2.1
Field pussytoes (*Antennaria neglecta*)	2.3
Old man's whiskers (*Geum triflorum*)	1.6
Death camas (*Zygadenus venenosus*)	1.2
Lance-leaved stonecrop (*Sedum lanceolatum*)	0.8
Yellow glacier lily (*Erythronium grandiflorum*)	0.7
Nodding onion (*Allium cernuum*)	0.6
White pussytoes (*Antennaria microphylla*)	0.4
Narrow-leaved collomia (*Collomia linearis*)	0.4
Orange arnica (*Arnica fulgens*)	0.3
Three-spot mariposa lily (*Calochortus apiculatus*)	0.3
SHRUBS	
Common snowberry (*Symphoricarpos albus*)	4.8
Prickly rose (*Rosa acicularis*)	2.7
Saskatoon (*Amelanchier alnifolia*)	2.4
Creeping Oregon-grape (*Mahonia repens*)	1.7
LITTER	37.3
SOIL/ROCK	5.7
MOSS/LICHEN	46.9

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: sub-mesic

ELEVATION: 1185 m

SOIL DRAINAGE: well

SLOPE (%): 10

ASPECT: 212º

FORAGE PRODUCTION (kg/ha)

N=1 (Min/Max/Mean)
Grass: 607 / 607 / 607
Forbs: 235 / 235 / 235
Shrubs: 164 / 164 / 164

WINTER FORAGE UTILIZATION (%)

N=1 (Min/Max/Mean)
Grass: 62.2
Forbs: not in sampling plot
Shrubs: not in sampling plot

Mount Broadwood Type 12

Compact selaginella / bluebuch wheatgrass - Junegrass
(*Selaginella densa* / *Pseudoroegneria spicata* - *Festuca idahoensis*)

(N=1; site MB-21) This community type occurred on a level upland terrace. It consisted of open exposed bedrock with extensive areas of compact selaginella, moss and lichen. There were patches of various grass and forb species with scattered shrubs, including Douglas maple, mock-orange, saskatoon, choke cherry, snowberry and rose, depending on site factors. There was low cover of sulphur cinquefoil and common St. John's-wort. Bighorn sheep use was moderate to high. The plant species composition suggested that this type was in high-poor condition, but the site factors were harsh.

PLANT COMPOSITION	**CANOPY COVER (%)**
GRAMINOIDS	
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	8.7
Junegrass (*Koeleria macrantha*)	4.9
Idaho fescue (*Festuca idahoensis*)	1.5
Bluegrass (*Poa* sp.)	1.3
Rocky Mountain fescue (*Festuca saximontana*)	0.9
Cheatgrass (*Bromus tectorum*)	0.7
FORBS	
Compact selaginella (*Selaginella densa*)	21.6
Field chickweed (*Cerastium arvense*)	4.1
Large-fruited desert-parsley (*Lomatium macrocarpum*)	3.1
Tall annual willowherb (*Epilobium brachycarpum*)	2.5
Cinquefoil (*Potentilla* sp.)	1.7
Common dandelion (*Taraxacum officinale*)	1.3
Yellow salsify (*Tragopogon dubius*)	0.7
Common St. John's-wort (*Hypericum perforatum*)	0.5
Bastard toadflax (*Comandra umbellata*)	0.5
Draba (*Draba* sp.)	0.3
Cut-leaved daisy (*Erigeron compositus*)	0.2
SHRUBS	
scattered throughout but not on transect	
LITTER	8.7
SOIL/ROCK	19.9
MOSS/LICHEN	52.3

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: xeric

ELEVATION: 1127 m

SOIL DRAINAGE: moderate

SLOPE (%): 3 - 12

ASPECT: 262º

FORAGE PRODUCTION (kg/ha)

N=0 (Min/Max/Mean)
Grass: no clip plot
Forbs:
Shrubs:

WINTER FORAGE UTILIZATION (%)

N=0 (Min/Max/Mean)
Grass: no clip plot
Forbs:
Shrubs:

Mount Broadwood Type 13

Idaho fescue - Bluebunch wheatgrass / sulphur cinquefoil - yellow clover
(*Festuca idahoensis - Pseudoroegneria spicata / Potentilla recta - Trifolium aureum*)

(N=1; site MB-22) This community type occurred on a ridged upland terrace. It was located near MB-21, but due to different site factors, the species composition was different. Although grass species dominated the site, the high cover of sulphur cinquefoil and yellow clover was a threat to this community. A spotted knapweed plant was found along the transect, which could further cause deterioration of this community. Another non-native weedy plant, silvery cinquefoil (*Potentilla argentea*), was also present at low cover. There was browsing on saskatoon, but not on the mock-orange. Bighorn sheep use was moderate. The species composition suggested that this type was in high-good condition.

PLANT COMPOSITION	CANOPY COVER (%)
GRAMINOIDS	
Idaho fescue (*Festuca idahoensis*)	13.1
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	9.2
Canada bluegrass (*Poa compressa*)	2.5
Junegrass (*Koeleria macrantha*)	2.3
Slender wheatgrass (*Elymus trachycaulus*)	0.5
FORBS	
Sulphur cinquefoil (*Potentilla recta*)	3.4
Yellow clover (*Trifolium aureum*)	2.7
Compact selaginella (*Selaginella densa*)	2.4
Yarrow (*Achillea millefolium*)	1.5
Common harebell (*Campanula rotundifolia*)	1.0
Field chickweed (*Cerastium arvense*)	0.8
Cut-leaved daisy (*Erigeron compositus*)	0.5
Cut-leaved anemone (*Anemone multifida*)	0.4
White pussytoes (*Antennaria microphylla*)	0.4
Tall annual willowherb (*Epilobium brachycarpum*)	0.3
Long-leaved fleabane (*Erigeron corymbosus*)	0.3
Wild strawberry (*Fragaria virginiana*)	0.3
Nodding onion (*Allium cernuum*)	0.3
Three-spot mariposa lily (*Calochortus apiculatus*)	0.3
Shrubby penstemon (*Penstemon fruticosus*)	0.2
SHRUBS	
Mallow ninebark (*Physocarpus malvaceus*)	2.0
Common snowberry (*Symphoricarpos albus*)	0.7
Birch-leaved spirea (*Spiraea betulifolia*)	0.5
other species scattered throughout, not on transect	
LITTER	68.5
SOIL/ROCK	12.3
MOSS/LICHEN	23.7

ENVIRONMENTAL VARIABLES

MOISTURE REGIME: sub-mesic

ELEVATION: 1129 m

SOIL DRAINAGE: moderate

SLOPE (%): 1 - 3

ASPECT: 256º

FORAGE PRODUCTION (kg/ha)

N=0 (Min/Max/Mean)
Grass: no clip plot
Forbs:
Shrubs:

WINTER FORAGE UTILIZATION (%)

N=0 (Min/Max/Mean)
Grass: no clip plot
Forbs:
Shrubs:

3.2 Range Reference Area Range Trend

3.2.1 Columbia Lake Exclosure

This exclosure was established in 1966, but the 1966 data could not be located. In 1983, the fence was found to be in disrepair (Davidson 1991). It was rebuilt and read in 1984 and again in 1987, although the 1984 data could not be located. In 1998, the exclosure fence was again found to be in disrepair and repaired again. Although a minor amount of grazing was evident inside the exclosure, the range-reference transects were relocated and an assessment was conducted. Since the “outside of exclosure” transects used in this study (west of the exclosure) were newly established, comparisons between the "outside" 1987 and 1998 data should be made with caution.

The dominant grass species inside and outside were needle-and-thread grass and Junegrass (Table 2). Inside the exclosure, needle-and-thread grass increased in cover from 26.1% in 1987 to 40.1% in 1998. The dominant forb was prairie sagewort which declined in cover from 4.3% to 0.8%. The cover of the dominant shrub, common rabbit-brush, increased from 2.4% to 5.1%. Comparisons of cryptograms, litter and bare ground could not be made since no such data were collected in 1987.

The climax species for this location appeared to be needle-and-thread grass and common rabbit-brush. The range condition inside the exclosure was rated as high-good to low-excellent. The abundance of litter may have affected species composition somewhat. The range condition of the transects outside the exclosure was rated as excellent, with a value of 88.0%. Grass cover was lower and forb cover was higher than inside the exclosure. The cover of needle-and-thread grass and Junegrass was less than inside the exclosure (29.7% versus 40.1%, and 1.0% versus 9.0%, respectively). Prairie sagewort cover was higher than inside the exclosure (3.2% versus 0.8%).

Table 2. Plant species composition and percent cover inside and outside the Columbia Lake exclosure in 1987 (Davidson 1991) and 1998 (this study).

Plant Species	1987		1998	
	In	Out	In	Out
Graminoids				
Thickspike wildrye (*Elymus lanceolatus*)	1.8	0.0	0.0	0.0
Sedge (*Carex* sp.)	1.4	0.1	0.1	0.2
Western bluegrass (*Pascopyrum smithii*)	0.0	0.0	0.9	0.4
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	0.0	0.0	0.6	0.9
Junegrass (*Koeleria macrantha*)	9.0	1.9	9.0	1.0
Canada bluegrass (*Poa compressa*)	0.0	0.0	0.0	+
Sandberg's bluegrass (*Poa secunda*)	0.0	0.0	+	0.0
Sand dropseed (*Sporobolus cryptandrus*)	0.0	0.0	0.1	0.1
Needle-and-thread grass (*Hesperostipa comata*)	26.1	17.4	40.1	29.7
Subtotal foliar cover	38.3	19.4	50.8	32.3
Forbs				
White pussytoes (*Antennaria microphylla*)	0.0	0.0	0.2	0.3
Holboell's rockcress (*Arabis holboellii*)	0.0	0.0	0.1	0.0
Prairie sagewort (*Artemisia frigida*)	4.3	5.2	0.8	3.2
Tarragon (*Artemisia dracunculus*)	0.0	0.0	0.0	1.0
Little gray aster (*Aster falcatus*)	0.0	0.0	0.0	0.1
Blue-eyed Mary (*Collinsia* sp.)	0.6	1.3	0.0	0.0
Bastard toadflax (*Comandra umbellata*)	0.0	0.0	0.7	0.1
Slender hawksbeard (*Crepis atribarba*)	0.0	0.0	+	0.0
Thread-leaved fleabane (*Erigeron filifolius*)	0.0	0.0	0.4	1.5
Shaggy fleabane (*Erigeron pumilus*)	0.0	0.0	0.2	0.1
Fleabane (*Erigeron* sp.)	0.6	2.6	0.0	0.0
Columbia bladderpod (*Lesquerella douglasii*)	0.0	0.0	0.3	1.0
Western blue flax (*Linum lewisii*)	0.0	0.0	0.4	0.1
Yellow gromwell (*Lithospermum incisum*)	0.0	0.0	0.1	0.1
Large-fruited desert-parsley (*Lomatium macrocarpum*)	0.0	0.0	0.0	0.1
Common dandelion (*Taraxacum officinale*)	0.0	0.0	0.1	0.0
Yellow salsify (*Tragopogon dubius*)	0.0	0.0	0.6	+
Subtotal foliar cover	5.5	9.1	3.9	7.6
Shrubs				
Common rabbit-brush (*Ericameria nauseosus*)	2.4	4.7	5.1	4.4
Total foliar cover	46.2	33.2	59.8	44.3
Cryptograms	-	-	36.1	44.8
Litter	-	-	59.3	24.5
Bare ground/rock	-	-	4.6	28.4

3.2.2 Whitetail Pasture/Armstrong's Pasture Range Reference Area

The reference area was situated on glaciofluvial material with a 60% slope and a south aspect, in the Bull River study area. The rounded gravelly nature of the substrate made this site prone to severe erosion. It was unstable, with 75% exposed ground. Animal trails criss-crossed the slope. Vegetation cover was sparse, ranging from 18.5% on Crown land to 22.7% on the deeded land.

This site supported little bluestem, which is on the provincial red list (rank S1)[12]. The fence subjected the population to 2 different management practices. On Crown land, there was an annual livestock grazing regime. On the deeded land, the area was to represent a relatively ungrazed regime but occasional light use had occurred, primarily due to downed fences allowing cattle access. Both areas were available to bighorn sheep.

On the deeded property, little bluestem was the dominant species with a cover of 6.4% (Table 3). Associated grass species were bluebunch wheatgrass (4.0%), needle-and-thread grass (3.7%) and cheatgrass (2.8%). Grasses constituted 74.9% of the total foliar cover. The range condition was rated as good, with a 62.0% prominence value of desirable species.

In Whitetail Pasture, cheatgrass was the dominant species with a cover of 5.4%. Associated grass species were needle-and-thread grass (4.5%) and little bluestem (1.5%). Bluebunch wheatgrass covered only 0.1%. Grasses constituted 64.9% of the total foliar cover. The range condition was rated as fair, with a 38.4% prominence value of desirable species.

Aside from cheatgrass, the slope contained numerous weedy and non-native forb species. These included pale alyssum, black medic, yellow salsify, alfalfa, sweet-clover, lamb's-quarters, common dandelion, bristly stickseed, ball mustard, black bindweed, tall tumble-mustard and thyme-leaved sandwort. Other non-native grasses included Canada bluegrass and Kentucky bluegrass.

This area was highly disturbed from hoof action. To protect, preserve and perpetuate the little bluestem and the other native species, the whole slope should be fenced to restrict livestock access. The objective would be to stabilize the slope with native species.

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[12] The red list includes indigenous species and subspecies that are judged by the provincial Conservation Data Centre to be extirpated, endangered or threatened in British Columbia. The S1 rating denotes a taxon that is critically imperiled in the province because of extreme rarity or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the province (http://www.env.gov.bc.ca/cdc/, accessed 1 March 2007).

Table 3. Plant species composition and percent cover at Whitetail Pasture/Armstrong's pasture range reference area in 1998.

Plant Species	Whitetail Pasture (grazed)	Armstrong's Pasture (ungrazed)
Graminoids		
Cheatgrass (*Bromus tectorum*)	5.4	2.8
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	0.1	4.0
Bluegrass (*Poa compressa*/*pratensis*)	0.1	0.1
Little bluestem (*Schizachyrium scoparium*)	1.5	6.4
Sand dropseed (*Sporobolus cryptandrus*)	0.4	0.0
Needle-and-thread grass (*Hesperostipa comata*)	4.5	3.7
Subtotal foliar cover	12.0	17.0
Forbs		
Holboell's rockcress (*Arabis holboellii*)	0.0	+
Thyme-leaved sandwort (*Arenaria serpyllifolia*)	0.0	+
Pale alyssum (*Alyssum alyssoides*)	1.1	0.2
Prairie sagewort (*Artemisia frigida*)	0.9	2.0
Little gray aster (*Aster falcatus*)	0.0	0.4
Lotus milk-vetch (*Astragalus lotiflorus*)	+	0.1
Goosefoot (*Chenopodium* spp.)	0.0	0.3
Corrugate-seeded spurge (*Chamaesyce glyptosperma*)	+	0.1
Wavy-leaved thistle (*Cirsium undulatum*)	0.0	0.1
Golden-aster (*Heterotheca villosa*)	+	0.2
Bristly stickseed (*Lappula squarrosa*)	0.1	0.0
Western blue flax (*Linum lewisii*)	0.0	0.1
Yellow gromwell (*Lithospermum incisum*)	0.8	0.0
Rushlike skeleton-plant (*Lygodesmia juncea*)	0.0	0.4
Black medic (*Medicago lupulina*)	0.1	0.2
Alfalfa (*Medicago sativa*)	0.1	0.2
Sweet-clover (*Melilotus alba*/*officinalis*)	1.2	1.2
Ball mustard (*Neslia paniculata*)	+	0.1
Slender penstemon (*Penstemon gracilis*)	0.0	0.1
Thread-leaved phacelia (*Phacelia linearis*)	0.1	0.0
Black bindweed (*Polygonum convolvulus*)	0.1	0.0
Tall tumble-mustard (*Sisymbrium altissimum*)	+	0.0
Common dandelion (*Taraxacum officinale*)	0.0	+
Yellow salsify (*Tragopogon dubius*)	0.2	0.0
Subtotal foliar cover	4.7	5.7
Shrubs		
Antelope-brush (*Purshia tridentata*)	1.8	+
Total foliar cover	18.5	22.7
Cryptograms	0.0	0.0
Litter	24.5	21.2
Bare ground / rock	72.9	77.6

3.2.3 Wigwam Flats (Purple Canyon) Exclosure

The Wigwam Flats exclosure at Mount Broadwood was established in 1966 to monitor vegetation response in an ungrazed and grazed regime. It is assumed that the vegetation inside and outside the exclosure site had a homogeneous species composition at the time of establishment since only 1 data set was collected. Junegrass was dominant, along with large-fruited desert-parsley and rose. The range condition was poor to fair (Davidson 1991).

The 1984 assessment indicated a large shift in species composition and foliar cover inside and outside the exclosure (Davidson 1991). Within the exclosure, bluebunch wheatgrass had a cover of 0.6% in 1966, compared to 13.3% cover in 1984. In the 1987 and 1998 assessments, bluebunch wheatgrass had <1% cover (Table 4). We speculate that a mistake may have been made in reporting the cover of this species in 1984. Rough fescue cover increased the most, from 0% in 1966, to 35% in 1984. It then maintained this cover to 1998. Junegrass cover declined from 6.5% in 1966 to 2.2% in 1984 to 1.6% in 1987, and maintained this cover to 1998. This is a result of protection from grazing and reduced interspecific competition due to the litter accumulation of rough fescue, which can prevent germination. Shrub cover has remained relatively constant, between 4% and 5%. However, the dominance has changed from rose to choke cherry and common juniper. Total foliar cover within the exclosure was 23.4% in 1966 compared to a high of 72.6% in 1984. By 1998, the total foliar cover had declined to 53.5%. The ungrazed area represented the "Potential Natural Community" or climax, with an excellent range condition rating. However, the abundance of rough fescue litter may cause future vegetation stagnation and a reduction in plant species biodiversity.

The vegetation in the plot outside the exclosure represented continual grazing pressure and the site was in poor range condition. Between 1966 and 1984, total foliar cover increased from 23.4% to 34.4% and remained at 39.0% to date. Rough fescue increased from 0% in 1966 to 5.1% in 1998. Bluebunch wheatgrass was not recorded in 1966, but was observed to cover 11.3% and 12.5% in 1984 and 1987, respectively. In 1998, its cover was 3.1%. Two forbs, wild bergamot and tufted phlox, continued to increase in cover after 1966. They had the highest cover of all forbs, with values of 7.0% and 4.5%, respectively. Shrub cover declined, from 4.7% in 1966 to 2.7% in 1998, but increased in species diversity. The amount of litter accumulation was low, with only 18.5% outside the exclosure in 1998 compared to 49.5% inside the exclosure.

Since 1966, the exclosure data suggested a marked improvement in range condition inside the exclosure, from poor-fair to excellent, and a slight improvement outside, with an increase in rough fescue, bluebunch wheatgrass and Junegrass, tempered by an increase in forb cover, and the appearance of non-native species such as Canada bluegrass, common timothy, tall hawkweed, common dandelion and common St. John's-wort. The heavy grazing pressure by native herbivores outside the exclosure appeared to be preventing the recovery of the vegetation to the climax state.

Table 4. Plant species composition and percent cover inside and outside Wigwam Flats exclosure in 1966, 1984, 1987 (Davidson 1991) and 1998. Where the common name of a plant species listed in an earlier assessment did not definitively suggest a corresponding scientific name, the latter is omitted below.

Plant Species	1966	1984		1987		1998	
		In	Out	In	Out	In	Out
Grasses							
Hair bentgrass (*Agrostis scabra*)	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Poverty oatgrass (*Danthonia spicata*)	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	0.6	13.3	11.3	0.9	12.5	0.1	3.1
Alpine fescue (*Festuca brachyphylla*)	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Rough fescue (*Festuca campestris*)	0.0	34.8	1.7	33.6	3.0	35.4	5.1
Idaho fescue (*Festuca idahoensis*)	1.0	0.0	0.0	0.0	0.0	0.0	0.5
Junegrass (*Koeleria macrantha*)	6.5	2.2	5.4	1.6	5.4	1.7	2.6
Common timothy (*Phleum pratense*)	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Canada bluegrass (*Poa compressa*)	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Sandberg's bluegrass (*Poa secunda*)	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Subtotal foliar cover	9.8	50.3	18.4	36.1	20.9	37.2	12.3
Forbs							
Yarrow (*Achillea millefolium*)	0.0	0.2	0.6	0.1	1.3	0.2	1.3
Nodding onion (*Allium cernuum*)	0.7	0.0	0.0	0.0	0.0	0.4	+
Pearly everlasting (*Anaphalis margaritacea*)	0.0	0.0	0.0	0.1	0.5	0.0	0.0
Cut-leaved anemone (*Anemone multifida*)	+	0.7	0.3	0.6	0.4	0.1	0.3
White pussytoes (*Antennaria microphylla*)	+	2.2	0.2	0.0	0.0	+	1.1
Field pussytoes (*Antennaria neglecta*)	0.0	0.0	0.0	0.0	0.0	2.4	0.9
Three-spot mariposa lily (*Calochortus apiculatus*)	0.0	0.5	0.1	0.0	0.0	+	+
Common harebell (*Campanula rotundifolia*)	0.0	0.0	0.0	0.0	0.0	0.2	0.6
Yellowish paintbrush (*Castilleja lutescens*)	0.0	0.2	1.5	0.0	0.0	0.2	+
Field chickweed (*Cerastium arvensis*)	0.0	1.4	1.2	0.0	0.0	0.6	1.5
Shootingstar (*Dodecatheon* sp.)	0.0	2.1	0.0	0.0	0.0	0.0	+
Tall annual willowherb (*Epilobium brachycarpum*)	0.0	0.0	0.0	0.0	0.0	+	+
Diffuse fleabane (*Erigeron divergens*)	0.0	0.0	0.0	0.0	0.0	0.1	1.1
Old man's whiskers (*Geum triflorum*)	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Golden-aster (*Heterotheca villosa*)	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Tall hawkweed (*Hieracium piloselloides*)	0.0	0.0	0.0	0.0	0.0	0.1	0.3
Common St. John's-wort (*Hypericum perforatum*)	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Large-fruited desert-parsley (*Lomatium macrocarpum*)	6.7	0.0	0.0	1.1	1.6	1.8	0.7
Wild bergamot (*Monarda fistulosa*)	0.0	4.0	4.7	1.9	6.0	2.3	7.0
Thin-leaved owl-clover (*Orthocarpus tenuifolius*)	0.6	0.0	0.0	0.0	0.8	0.0	0.2
Yellow penstemon (*Penstemon confertus*)	0.0	1.4	0.0	0.0	0.0	0.1	+
Tufted phlox (*Phlox caespitosa*)	0.8	2.4	2.3	2.3	3.4	1.4	4.5
Pink twink (*Phlox gracilis*)	0.0	0.0	0.0	0.0	0.0	+	0.0
Cinquefoil (*Potentilla* sp. - *recta*?)	0.0	0.0	0.0	0.0	0.0	0.0	0.2
White cinquefoil (*Potentilla arguta*)	0.0	0.0	0.0	0.0	0.0	0.1	0.2

Yellow rattle (*Rhinanthus minor*)	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Lance-leaved stonecrop (*Sedum lanceolatum*)	0.0	0.0	0.0	0.0	0.0	+	0.1
Compact selaginella (*Selaginella densa*)	0.0	0.0	0.0	0.0	0.0	0.2	+
Woolly groundsel (*Senecio canus*)	0.0	0.0	0.0	0.0	0	0.2	1.8
Spikelike goldenrod (*Solidago spathulata*)	0.0	0.0	0.0	0.0	0.0	+	0.5
Long-leaved stitchwort	0.0	1.4	1.2	0.8	0.9	0.0	0.0
Common dandelion (*Taraxacum officinale*)	0.0	0.0	0.0	0.0	0.0	+	0.1
Yellow salsify (*Tragopogon dubius*)	0.0	0.0	3.0	0.0	0.0	0.0	0.5
Dogwood violet	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Subtotal foliar cover	8.8	17.5	15.1	6.9	14.9	10.4	24.0
Shrubs							
Saskatoon (*Amelanchier alnifolia*)	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Common juniper (*Juniperus communis*)	0.0	0.0	0.0	0.0	0.0	1.4	0.2
Choke cherry (*Prunus virginiana*)	0.0	1.5	0.0	1.7	0.0	3.5	0.4
Rose (*Rosa* sp.)	4.7	3.3	0.4	2.0	0.7	0.9	0.5
Birch-leaved spirea (*Spiraea betulifolia*)	0.0	T	0.5	0.2	1.0	0.1	1.5
Subtotal foliar cover	4.7	4.8	0.9	3.9	1.7	5.9	2.7
Trees							
Douglas-fir (*Pseudotsuga menziesii*)	-	-	-	-	-	7.2	0.1
Total foliar cover	23.4	72.6	34.4	46.9	37.5	53.5	39.0
Cryptograms	48.8	74.4	53.7	35.0	36.2	55.6	79.6
Litter	11.9	10.6	3.7	22.1	22.3	49.5	18.5
Bare ground / rock	4.4	6.1	6.3	3.7	4.7	2.4	3.4

3.3 Diet

Grasses formed the bulk of scat contents at all 3 study areas (Tables 5 to 7; Appendices 5-7 and 5-8). Data for December and May are not included as data for those months were not available for all study areas. For each herd, needlegrasses (entirely or predominatly needle-and-thread grass) constituted the great majority of plant remains found in scats and appeared to be used well in excess of their availability considering all plant communities collectively (Section 3.1). Wheatgrasses (probably mainly bluebunch wheatgrass) and fescue were of secondary use. Other grass species were either not evident or were much less common. While the type of grass eaten was relatively consistent among study areas, there was some variability over the winter, with the emphasis on needlegrass being especially pronounced during March and April (Figure 3). The amount of forbs, deciduous shrubs, conifers and other food sources consumed varied among herds and months (Tables 5 to 7; Appendices 5-7 and 5-8). Notably common diet items included creeping Oregon-grape at Mount Broadwood, and prairie sagewort at Columbia Lake and Bull River, both of which were particularly abundant early in the winter. Willow was consistently recorded.

Table 5. Forage composition, by weight, for bighorn sheep scats collected at Columbia Lake, January through April of 1997 and 1998. Mean weighted equally by month. December and May data in Appendix 5-7.

Scientific Name	Common Name	Scat Composition (%)									
		Jan	Feb		Mar		Apr		Mean	Min	Max
		1998	1997	1998	1997	1998	1997	1998			
GRAMINOIDS											
Achnatherum hymenoides	Indian ricegrass	0.00	0.00	0.00	1.87	0.00	0.00	0.00	0.23	0.00	1.87
Carex spp.	sedge	0.00	0.00	1.39	0.00	0.00	0.00	0.00	0.17	0.00	1.39
Festuca campestris	rough fescue	26.21	0.00	0.00	0.00	0.00	0.00	0.00	6.55	0.00	26.21
Hesperostipa comata	needle-and-thread grass	52.56	61.14	15.29	87.41	80.76	47.48	94.69	61.49	15.29	94.69
Koeleria macrantha	junegrass	1.22	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	1.22
Muhlenbergia sp.	muhly	0.00	0.00	0.00	1.36	0.00	0.00	0.00	0.17	0.00	1.36
Poa spp.	bluegrass	0.70	1.32	2.89	0.00	0.00	1.65	0.00	0.91	0.00	2.89
Pseudoroegneria, *Elymus* or *Pascopyrum*	wheatgrass	2.29	21.80	12.03	7.24	1.61	3.38	2.53	6.65	1.61	21.80
	unidentified grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Graminoids Total	82.98	84.26	31.60	97.89	82.37	52.51	97.23	76.48	31.60	97.89
FORBS											
Achillea millefolium	yarrow	4.20	0.68	0.00	0.00	0.00	0.00	0.00	1.14	0.00	4.20
Artemisia frigida	prairie sagewort	4.11	1.91	13.59	2.11	9.02	10.20	0.00	5.63	0.00	13.59
Compositae family		0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.07	0.00	0.57
Equisetum spp.	horsetail	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.57
Lesquerella spp.	bladderpod	0.00	0.00	1.39	0.00	2.16	1.10	1.43	0.76	0.00	2.16
Orthocarpus?	owl-clover?	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potentilla pensylvanica	Pennsylvanian cinquefoil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Verbascum thapsus	great mullein	4.37	0.00	5.19	0.00	0.00	13.14	1.35	3.55	0.00	13.14
	Forbs Total	13.25	2.59	20.17	2.11	11.75	24.44	2.77	11.29	2.11	24.44
DECIDUOUS SHRUBS											
Mahonia repens	creeping Oregon-grape	0.00	6.35	0.71	0.00	1.21	0.00	0.00	1.03	0.00	6.35
Purshia spp.	antelope-brush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salix spp.	willow	0.58	4.09	15.39	0.00	0.00	0.00	0.00	2.58	0.00	15.39
Shepherdia spp.	soopolallie	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Deciduous Shrubs Total	0.58	10.44	16.10	0.00	1.21	0.00	0.00	3.61	0.00	16.10
CONIFERS											
Juniperus spp.	juniper	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.06	0.00	0.44
Picea spp.	spruce	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.13	0.00	1.05
Pseudotsuga menziesia	Douglas-fir	3.19	2.71	29.24	0.00	3.63	21.50	0.00	7.93	0.00	29.24
	Conifers Total	3.19	2.71	29.24	0.00	4.07	22.55	0.00	8.12	0.00	29.24
MOSS											
	unidentified moss	0.00	0.00	2.89	0.00	0.00	0.50	0.00	0.42	0.00	2.89
SEEDS											
	unidentified seed	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.08	0.00	0.60

Table 6. Forage composition, by weight, for bighorn sheep scats collected at Bull River, January through April of 1997 and 1998. Mean weighted equally by month. December and May data in Appendix 5-8.

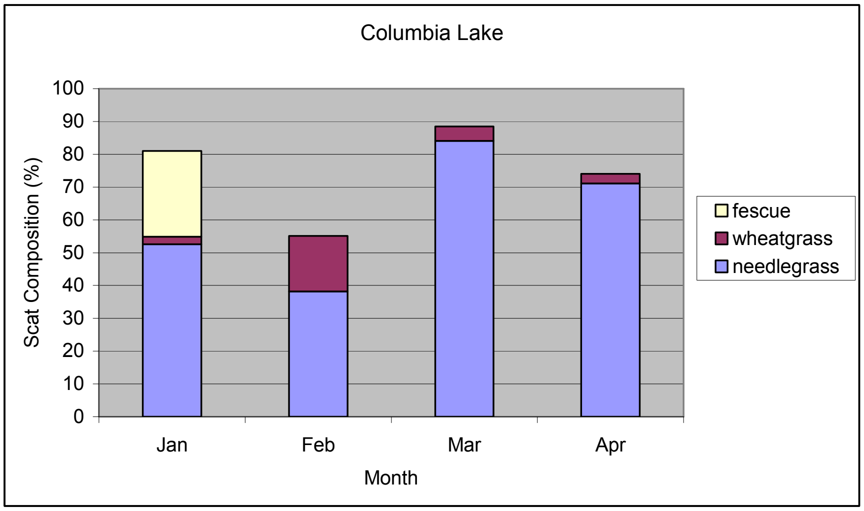
Scientific Name	Common Name	Scat Composition (%)									
		Jan	Feb		Mar		Apr		Mean	Min	Max
		1998	1997	1998	1997	1998	1997	1998			
GRAMINOIDS											
Carex spp.	sedge	0.00	0.00	0.38	0.00	0.67	0.00	0.00	0.13	0.00	0.67
Deschampsia spp.	hairgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Festuca spp.	fescue	14.05	0.00	0.00	0.00	0.00	0.00	0.73	3.60	0.00	14.05
Hesperostipa or *Stipa*	needlegrass[1]	64.89	42.78	80.95	100.00	97.40	90.71	77.75	77.42	42.78	100.00
Koeleria macrantha	junegrass	1.07	0.70	0.00	0.00	0.00	0.00	0.00	0.36	0.00	1.07
Oryzopsis spp.	ricegrass	0.00	0.00	0.00	0.00	0.00	0.00	1.86	0.23	0.00	1.86
Poa spp.	bluegrass	0.00	7.20	0.00	0.00	0.00	0.00	0.00	0.90	0.00	7.20
Pseudoroegneria, *Elymus* or *Pascopyrum*	wheatgrass	0.54	25.16	1.52	0.00	0.00	1.62	8.11	4.69	0.00	25.16
	Graminoids Total	80.55	75.84	82.85	100.00	98.07	92.33	88.45	87.33	75.84	100.00
FORBS									0.00		
Achillea millefolium	yarrow	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.61
Arabis holboellii	Holboell's rockcress	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Artemisia frigida	prairie sagewort	5.83	0.00	3.05	0.00	0.00	0.00	1.12	1.98	0.00	5.83
Astragalus lotiflorus	lotus milk-vetch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alyssum alyssoides	pale alyssum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Compositae family		0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.09	0.00	0.73
Descurainia sp.	tansy mustard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lesquerella spp.	bladderpod	0.00	1.48	0.00	0.00	0.00	1.97	1.17	0.58	0.00	1.97
Neslia paniculata	ball mustard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orthocarpus?	owl-clover?	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.09	0.00	0.75
Phlox spp.	phlox	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potentilla spp.	cinquefoil	0.00	0.00	0.00	0.00	0.00	0.00	1.66	0.21	0.00	1.66
Verbascum sp.	mullein[2]	0.00	0.70	0.58	0.00	0.00	0.92	0.00	0.28	0.00	0.92
	Forbs Total	6.44	2.18	3.63	0.00	0.75	2.89	4.68	3.38	0.00	6.44
DECIDUOUS SHRUBS									0.00		
Amelanchier alnifolia	saskatoon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arctostaphylos uva-ursi	kinnikinnick	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mahonia repens	creeping Oregon-grape	5.20	0.00	3.53	0.00	0.42	0.00	0.00	1.79	0.00	5.20
Prunus virginiana	choke cherry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purshia tridentata	antelope-brush	2.77	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	2.77
Salix spp.	willow	3.33	6.48	4.87	0.00	0.00	3.05	6.34	3.43	0.00	6.48
Shepherdia spp.	soopolallie	0.00	2.43	0.00	0.00	0.00	0.00	0.00	0.30	0.00	2.43
Spiraea betulifolia	birch-leaved spirea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Deciduous Shrubs Total	11.30	8.91	8.40	0.00	0.42	3.05	6.34	6.22	0.00	11.30
CONIFERS									0.00		
Picea spp.	spruce	0.00	0.00	0.00	0.00	0.00	1.73	0.53	0.28	0.00	1.73
Pseudotsuga menziesia	Douglas-fir	1.71	11.44	5.12	0.00	0.42	0.00	0.00	2.55	0.00	11.44
	Conifers Total	1.71	11.44	5.12	0.00	0.42	1.73	0.53	2.83	0.00	11.44
MOSS									0.00		
	unidentified moss	0.00	1.63	0.00	0.00	0.34	0.00	0.00	0.25	0.00	1.63

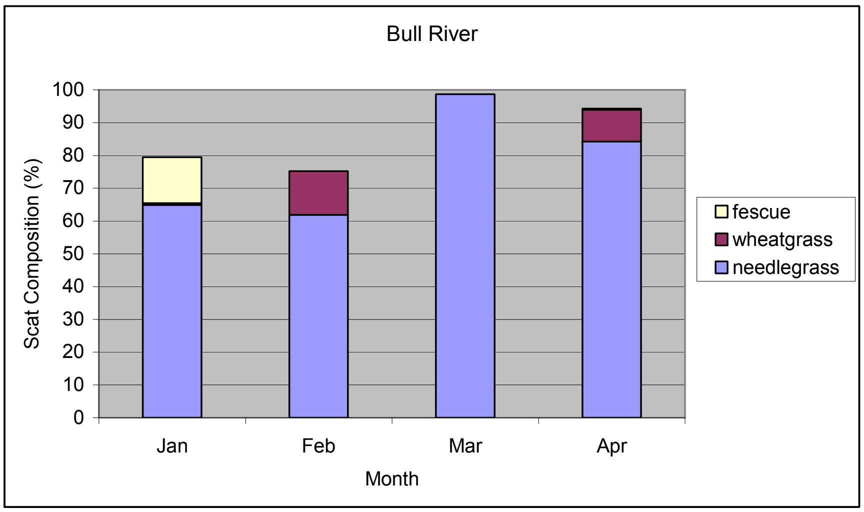
[1] predominantly *H. comata* (needle-and-thread grass)
[2] almost certainly *V. thapsus* (great mullein)

Table 7. Forage composition, by weight, for bighorn sheep scats collected at Mount Broadwood, January through April of 1999.

Scientific Name	Common Name	Scat Composition (%)						
		Jan	Feb	Mar	Apr	Mean	Min	Max
GRAMINOIDS								
Festuca spp.	fescue	11.93	0.00	1.40	9.90	5.81	0.00	11.93
Hesperostipa or *Stipa*	needlegrass	29.21	44.67	84.11	49.78	51.94	29.21	84.11
Pseudoroegneria, *Elymus* or *Pascopyrum*	wheatgrass	0.51	18.63	3.44	10.04	8.16	0.51	18.63
	Graminoids Total	41.65	63.30	88.95	69.72	65.91	41.65	88.95
FORBS								
Artemisia frigida	prairie sagewort	0.00	0.00	0.00	2.30	0.58	0.00	2.30
Compositae family		0.44	0.00	0.00	0.00	0.11	0.00	0.44
Lesquerella spp.	bladderpod	0.00	0.64	0.00	0.00	0.16	0.00	0.64
Verbascum sp.	mullein[1]	0.00	0.00	0.00	1.42	0.36	0.00	1.42
	Forbs Total	0.44	0.64	0.00	3.72	1.20	0.00	3.72
DECIDUOUS SHRUBS								
Mahonia repens	creeping Oregon-grape	48.95	27.38	5.30	7.44	22.27	5.30	48.95
Salix spp.	willow	2.10	1.81	0.00	2.93	1.71	0.00	2.93
Shepherdia spp.	soopolallie	6.86	3.04	1.13	0.64	2.92	0.64	6.86
	Deciduous Shrubs Total	57.91	32.23	6.43	11.01	26.90	6.43	57.91
CONIFERS								
Pseudotsuga menziesia	Douglas-fir	0.00	3.83	4.13	6.18	3.54	0.00	6.18
LICHENS								
	unidentified lichen	0.00	0.00	0.49	0.83	0.33	0.00	0.83
MOSS								
	unidentified moss	0.00	0.00	0.00	8.54	2.14	0.00	8.54

[1] almost certainly *V. thapsus* (great mullein)





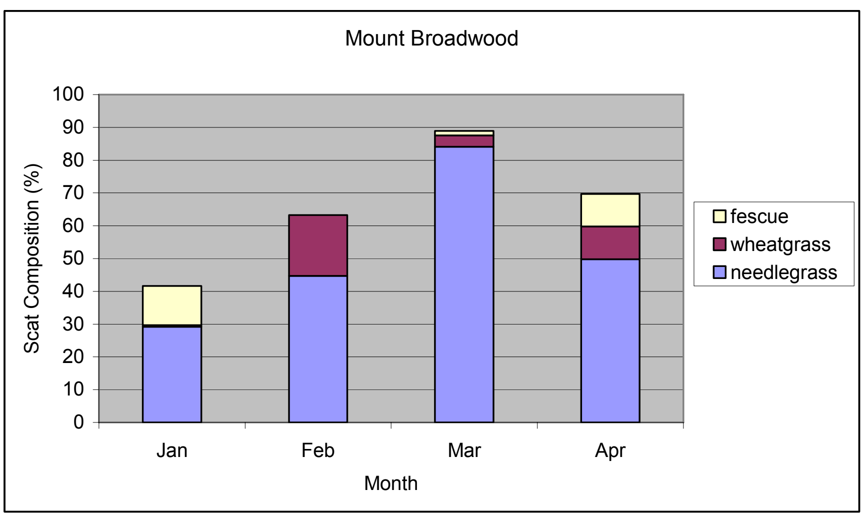


Figure 3. Scat composition at each study area relative to the 3 primary grass types. Values for Columbia Lake and Bull River averaged for the winters of 1997 and 1998; values for Mount Broadwood from 1999. At Columbia Lake, fescue in scat was classified as rough fescue and needlegrass as needle-and-thread grass. At Bull River, needlegrass in scat was classified as primarily needle-and-thread grass.

3.4 Forage Production and Utilization

At all study sites sites, total precipitation and growing season precipitation declined each year as a drought cycle predominated (Table 8). Precipitation values increased from northwest to southeast in the East Kootenay Trench.

Table 8. Growing season (April 1 - October 31) precipitation (mm) at 3 sites in the East Kootenay Trench 1998-2000 (Sources: Environment Canada and British Columbia Ministry of Forests).

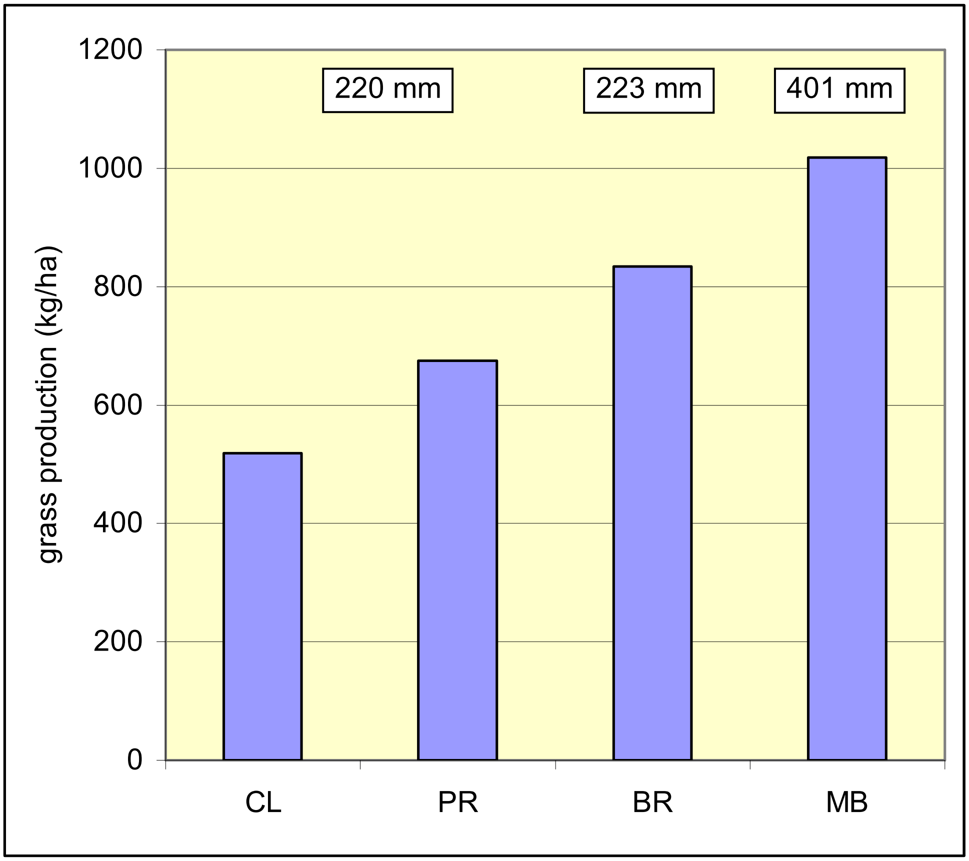
Year	Location: Station (Study Area Represented)		
	Johnson Lake & Wasa Lake (Columbia Lake & Premier Ridge)	Kootenay Fish Hatchery (Bull River)	Elko (Mount Broadwood)
Long-term mean	289.8[1]	247.6[2]	356.8[3]
1998	227.1	280.6	486.3
1999	212.2	165.9	315.8
2000	107.8	132.8	188.7

[1] 1924-1990
[2] 1971-1992
[3] 1923-1990

Associated with the reduced growing-season precipitation from 1998 to 1999, we found a decrease in the mean grass production at Columbia Lake and Premier Ridge, but the reverse at Bull River and Mount Broadwood (Table 9). However, the overall pattern was that there was greater grass production during 1998 and 1999 at sites with more total growing-season precipitation in those years (Figure 4).

Table 9. Mean grass production (kg/ha) for combined community types at each study area.

Year	Columbia Lake	Premier Ridge	Bull River	Mt. Broadwood
1998	578	759	724	953
1999	459	590	945	1084



NW → Location → SE
LOWER → Growing-Season Precipitation → HIGHER

Figure 4. Mean annual grass production for 1998 and 1999 as a function of mean growing-season precipitation in the 4 study areas. Boxes with precipitation values reflect approximate latitudes of weather stations in relation to nearest study areas.

3.4.1 Columbia Lake Study Area

Forage production varied from a low of 256 kg/ha of grass and 26 kg/ha of forbs within open areas and along the margins of the Douglas-fir forest in the bluebunch wheatgrass–Junegrass/compact selaginella community type (Type 6), to a high of 839 kg/ha of grass and 186 kg/ha of forbs in the bluebunch wheatgrass–Junegrass–cheatgrass/prairie sagewort/common rabbit-brush community type (Type 5), on localized shallow-sloped southwest-facing benches along an exposed rock bluff (Table 10). The average grass and forb production throughout the study area was 524 kg/ha and 86 kg/ha, respectively. Shrubs were present at 5 of the 6 types with production varying from 1 kg/ha to 166 kg/ha.

Table 10. Mean forage production and winter utilization for each plant community type in the Columbia Lake study area.

Type	Grasses		Forbs		Shrubs	
	Production (kg/ha)	Utilization (%)	Production (kg/ha)	Utilization (%)	Production (kg/ha)	Utilization (%)
1	628	41.6	68	85.1	85	22.9
2	358	81.1	99	88.6	166	55.0
3	491	45.6	68	46.2	119	35.6
4	573	54.4	69	58.4	1	N/A
5	839	88.2	186	83.4	119	N/A
6	256	20.6	26	69.0	N/A	N/A
Average	524	55.3	86	71.8	98	37.8

Type 1: Needle-and-thread grass/thread-leaved fleabane-prairie sagewort-Columbia bladderpod/ common rabbitbrush
Type 2: Junegrass-needle-and-thread grass-western bluegrass/white pussytoes-bastard toadflax/ common rabbitbrush
Type 3: Bluebunch wheatgrass-needle-and-thread grass-Junegrass/prairie sagewort/common rabbitbrush
Type 4: Bluebunch wheatgrass-Junegrass-cheatgrass/prairie sagewort-shaggy fleabane
Type 5: Bluebunch wheatgrass-Junegrass-cheatgrass/prairie sagewort/common rabbitbrush
Type 6: Bluebunch wheatgrass-Junegrass/compact selaginella

Forage utilization of the grasses averaged 55.3%, ranging from 20.6% in Type 6 to 88.2% in Type 5 (Table 10). Fecal pellets were prolific in Type 5. Forb utilization averaged 71.8%, ranging from 46.2% in the bluebunch wheatgrass–needle-and-thread grass–Junegrass/prairie sagewort/common rabbit-brush community type (Type 3) to 88.6% in the Junegrass–needle-and-thread grass–western bluegrass/white pussytoes–bastard toadflax/common rabbit-brush community type (Type 2). Type 2 also experienced high grass utilization. These open terraces were often dominated by needle-and-thread grass, which provided good forage. The dominant shrub in the area was common rabbit-brush. Average utilization at sites where it was located was 37.8%, ranging from 22.9% in needle-and-thread grass/thread-leaved fleabane–prairie sagewort–Columbia bladderpod/common rabbit-brush community type (Type 1) to 55.0% in Type 2.

3.4.2 Premier Ridge Study Area

In the Premier Ridge study area, grass production averaged 623 kg/ha, with a range from 479 kg/ha in the bluebunch wheatgrass–Junegrass/antelope-brush–common snowberry–saskatoon/golden-aster community type (Type 2) to 796 kg/ha in the bluebunch wheatgrass–Canada bluegrass/antelope-brush–saskatoon community type (Type 4; Table 11). The dominant grass species was bluebunch wheatgrass. Forb production ranged from 27 kg/ha in Type 4, to 163 kg/ha in the spreading dogbane/bluebunch wheatgrass–Junegrass/antelope-brush–saskatoon community type (Type 1), with an average of 83 kg/ha. A variety of shrubs was present with an average production of 106 kg/ha, and ranging from 2 kg/ha in the bluebunch wheatgrass–cheatgrass–Canada bluegrass/antelope-brush community type (Type 3) to 272 kg/ha in the common snowberry–antelope-brush–saskatoon/bluebunch wheatgrass–cheatgrass/golden-aster community type (Type 6).

Table 11. Mean forage production and winter utilization for each plant community type in the Premier Ridge study area.

Type	Grasses		Forbs		Shrubs	
	Production (kg/ha)	Utilization (%)	Production (kg/ha)	Utilization (%)	Production (kg/ha)	Utilization (%)
1	748	70.4	163	60.2	67	N/A
2	479	33.5	41	53.6	110	N/A
3	596	N/A	65	N/A	2	N/A
4	796	1.7	27	22.2	9	N/A
5	593	38.1	152	44.8	174	50.9
6	526	53.8	52	42.8	272	32.7
Average	623	39.5	83	44.7	106	41.8

Type 1: Spreading dogbane/bluebunch wheatgrass-Junegrass/antelope-brush-saskatoon
Type 2: Bluebunch wheatgrass-Junegrass/antelope-brush-common snowberry-saskatoon/golden-aster
Type 3: Bluebunch wheatgrass-cheatgrass-Canada bluegrass/antelope-brush
Type 4: Bluebunch wheatgrass-Canada bluegrass/antelope-brush-saskatoon
Type 5: Bluebunch wheatgrass-Canada bluegrass-Columbian needlegrass/white pussytoes/saskatoon-antelope-brush
Type 6: Common snowberry-antelope-brush-saskatoon/bluebunch wheatgrass-cheatgrass/golden-aster

Although Type 4 had the highest production, it had the lowest utilization. It occurred on the crest of bedrock outcrops and was dominated by bluebunch wheatgrass. Utilization of the grasses ranged from 1.7% in Type 4 to 70.4% in Type 1, with an average of 39.5% (Table 11). Rough fescue, Junegrass and Canada bluegrass appeared to be preferred over bluebunch wheatgrass. Forb utilization varied from 22.2% in Type 4, to a 60.2% in Type 1, with an average of 44.7%. Type 1 had the highest utilization of both grasses and forbs, which has contributed to its poor range condition. It occurs as mixed grassland-shrubland on mid-slopes amongst bedrock outcrops with southwesterly aspects. Shrub use was evident in some localities, with extensive browsing on saskatoon. There was no evidence that antelope-brush, snowberry or birch-leaved spirea had been browsed. However, few of the production cages contained shrubs. At the 2 sites where shrubs were present in the cages, the average utilization was 41.8%.

3.4.3 Bull River Study Area

The Bull River area is used by domestic livestock during the summer and native ungulates all year long. Yearly forage production and summer utilization is presented in Table 12. The remaining forage that is available going into the winter along with the utilization by wild ungulates during winter is presented in Table 13.

Table 12. Mean forage production and summer utilization by livestock and native ungulates for each plant community type in the Bull River study area (production for types 1 and 2 was higher than indicated because production cages were moved in the summer).

Type	Grasses		Forbs		Shrubs	
	Production (kg/ha)	Utilization (%)	Production (kg/ha)	Utilization (%)	Production (kg/ha)	Utilization (%)
1	>1932	>60.2	>141	>61.0	N/A	N/A
2	>981	>55.1	>71	>28.0	126	23.9
3	748	47.3	92	6.5	445	0.0
4	491	41.9	547	53.0	516	28.6
5	626	4.8	539	45.9	216	12.9
6	1076	41.7	726	42.0	243	28.1
7	500	53.3	254	23.4	87	N/A
8	723	61.4	133	39.5	N/A	N/A
9	no data		no data		no data	
10	no data		no data		no data	
Average	>908	>43.5	>338	>37.1	272	18.7

Type 1: Canada bluegrass-smooth brome/black medic-common dandelion
Type 2: Canada bluegrass-spreading needlegrass-bluebunch wheatgrass/black medic/antelope-brush
Type 3: Spreading needlegrass-Canada bluegrass-rough fescue/sulphur cinquefoil-wild bergamot/saskatoon-antelope-brush
Type 4: Canada bluegrass-bluebunch wheatgrass-Junegrass/sulphur cinquefoil/antelope-brush-western snowberry
Type 5: Canada bluegrass-bluebunch wheatgrass-cheatgrass/sulphur cinquefoil/antelope-brush-saskatoon
Type 6: Canada bluegrass-cheatgrass-common timothy/yellow sweet-clover-sulphur cinquefoil/saskatoon-western snowberry
Type 7: Canada bluegrass-cheatgrass/sweet-clover-prairie sagewort/antelope-brush
Type 8: Needle-and-thread grass-cheatgrass-little bluestem/prairie sagewort-sweet-clover/antelope-brush
Type 9: Spreading needlegrass-Canada bluegrass-rough fescue/sulphur cinquefoil-wild bergamot/saskatoon-antelope-brush
Type 10: Canada bluegrass-Junegrass-Japanese brome-needle-and-thread grass/tufted phlox-black medic

Average grass production ranged from a low of 491 kg/ha in the Canada bluegrass–bluebunch wheatgrass–Junegrass/sulphur cinquefoil/antelope-brush–western snowberry community type (Type 4) to over 1,932 kg/ha in the Canada bluegrass–smooth brome/black medic–common dandelion community type (Type 1), with an average of over 908 kg/ha (Table 12). The production cages were moved during the growing season in Types 1 and 2, presumably by the public. We speculate that if the area inside the cages in Type 1 had been fully protected from grazing throughout the growing season, the grass production clipped would have been at least 3 times that reported. Similarly, in the Canada bluegrass–spreading needlegrass–bluebunch wheatgrass/black medic/antelope-brush community type (Type 2), grass production probably would have been at least double that reported. This is based on observations of ungrazed forage production in small localized areas or amongst shrubs where the forage was somewhat protected from grazing.

Table 13. Mean forage availability at end of growing season and winter utilization by native ungulates for each plant community type in the Bull River study area.

Type	Grasses		Forbs		Shrubs	
	Available Forage (kg/ha)	Utilization (%)	Available Forage (kg/ha)	Utilization (%)	Available Forage (kg/ha)	Utilization (%)
1	875	44.5	24	38.7	N/A	N/A
2	425	50.7	28	53.9	48	80.0
3	364	0.9	101	8.8	358	N/A
4	271	24.5	154	9.8	180	43.4
5	659	46.3	187	65.0	201	94.8
6	768	54.7	594	46.5	197	41.1
7	246	N/A	229	N/A	0	N/A
8	349	30.7	89	50.0	N/A	N/A
9	no data		no data		no data	
10	no data		no data		no data	
Avg.	495	31.7	176	37.1	164	64.8

Type 1: Canada bluegrass-smooth brome/black medic-common dandelion
Type 2: Canada bluegrass-spreading needlegrass-bluebunch wheatgrass/black medic/antelope-brush
Type 3: Spreading needlegrass-Canada bluegrass-rough fescue/sulphur cinquefoil-wild bergamot/saskatoon-antelope-brush
Type 4: Canada bluegrass-bluebunch wheatgrass-Junegrass/sulphur cinquefoil/antelope-brush-western snowberry
Type 5: Canada bluegrass-bluebunch wheatgrass-cheatgrass/sulphur cinquefoil/antelope-brush-saskatoon
Type 6: Canada bluegrass-cheatgrass-common timothy/yellow sweet-clover-sulphur cinquefoil/saskatoon-western snowberry
Type 7: Canada bluegrass-cheatgrass/sweet-clover-prairie sagewort/antelope-brush
Type 8: Needle-and-thread grass-cheatgrass-little bluestem/prairie sagewort-sweet-clover/antelope-brush
Type 9: Spreading needlegrass-Canada bluegrass-rough fescue/sulphur cinquefoil-wild bergamot/saskatoon-antelope-brush
Type 10: Canada bluegrass-Junegrass-Japanese brome-needle-and-thread grass/tufted phlox-black medic

Forb production ranged from a low of 71 kg/ha in Type 2 to 92 kg/ha in the spreading needlegrass–Canada bluegrass–rough fescue/sulphur cinquefoil–wild bergamot/saskatoon–antelope-brush community type (Type 3), to a maximum of 726 kg/ha in the Canada bluegrass–cheatgrass–common timothy/ yellow sweet-clover–sulphur cinquefoil/saskatoon–western snowberry community type (Type 6), with an average of over 338 kg/ha for all community types (Table 12). In the types having a shrub component, the range was from 87 kg/ha in Type 7 to 516 kg/ha in Type 4. The average yearly shrub production was 272 kg/ha.

Summer grass utilization, primarily by livestock, ranged from a low of 4.8% in the bluebunch wheatgrass–Canada bluegrass–cheatgrass/sulphur cinquefoil/antelope-brush–saskatoon community type (Type 5), located on steep south-facing slopes above the Bull River, to over 60.2% in Type 1, located on the level glaciofluvial terraces (Table 12). The average for the plant community types studied exceeded 43.5%. Utilization in the bluegrass-dominated areas of Type 1 was almost 100%, with less than a 2 cm stubble height remaining after the cattle were moved off for the year (Figure 5). More grass remained in the smooth brome-dominated area, but utilization was still estimated at over 50%, resulting in an average for the type of over 75%. Similarly, in Type 2 (a level glaciofluvial terrace), grass utilization was likely closer to 75%. Livestock use of grass forage also exceeded 50% on the steep, south-facing slopes of Types 7 and 8, above Types 1 and 2. Summer forb use varied depending upon species and ranged from 6.5% in Type 3 to over 61.0% in Type 1, with an average of 37.1%. Shrub use also varied depending upon species, ranging from non-use to 28.6%, with an average of 18.7%.

Figure 5. Very heavy summer livestock grazing near transect 1 in plant community type 1 (Canada bluegrass – smooth brome / black medic – common dandelion) at Bull River, with nearly 100% utilization of bluegrass-dominated areas.

Winter use of the remaining grass by native herbivores ranged from 0.9% in Type 3 to 54.7% in Type 6, with an overall average use of 31.7% (Table 13). Forb use ranged from 8.8% in Type 3 to 65.0% in Type 5, with an average of 37.1%. Shrub use was evident throughout the study area, but was only detected along transects in 4 of the types, ranging from 41.1% in Type 6 and 94.8% in Type 5, and averaging 64.8%.

Types 1 and 2, the most highly used types by cattle in summer, received continued high use by native ungulates throughout the fall/winter period (44.5% and 50.7%, respectively; Table 13).

3.4.4 Mount Broadwood Study Area

Mean grass production varied from 182 kg/ha in the rough fescue–bluebunch wheatgrass/wild bergamot–tufted phlox/birch-leaved spirea community type (Type 9) to 1,590 kg/ha in the yellow clover–sulphur cinquefoil/Canada bluegrass–common timothy–smooth brome/prairie rose community type (Type 6), with an overall average of 765 kg/ha (Table 14). Forb production ranged from 102 kg/ha in the Idaho fescue–pinegrass/wild strawberry–yellow clover–smooth aster/common snowberry community type (Type 4) to 333 kg/ha in the common St. John's-wort–smooth aster/common snowberry–saskatoon/Canada bluegrass–pinegrass–Columbian needlegrass community type (Type 5), with an average of 192 kg/ha. Shrub production ranged from 19 kg/ha in Type 10 to 943 kg/ha in the common snowberry–redstem ceanothus–creeping

Oregon-grape/spreading dogbane–wild bergamot/pinegrass–bluebunch wheatgrass community type (Type 2), with a mean of 196 kg/ha.

Table 14. Mean forage production and winter utilization for each plant community type in the Mount Broadwood study area.

Type	Grasses		Forbs		Shrubs	
	Production (kg/ha)	Utilization (%)	Production (kg/ha)	Utilization (%)	Production (kg/ha)	Utilization (%)
1	931	38.6	201	45.0	328	59.6
2	883	2.6	174	0.0	943	51.6
3	656	25.5	103	51.6	103	40.7
4	1088	0.0	102	0.0	159	66.7
5	630	31.2	333	10.0	204	65.2
6	1590	0.0	258	41.6	73	N/A
7	716	24.8	216	22.7	53	29.9
8	671	25.0	182	7.7	28	N/A
9	182	16.0	163	15.0	81	20.0
10	464	22.1	143	8.0	19	17.6
11	607	62.2	235	N/A	164	N/A
12	no data		no data		no data	
13	no data		no data		no data	
Average	765	23.2	192	20.7	196	47.3

Type 1: Common snowberry-creeping Oregon-grape/common timothy-Canada bluegrass/arrowleaf balsamroot
Type 2: Common snowberry-redstem ceanothus-creeping Oregon-grape/spreading dogbane-wild bergamot/pinegrass-bluebunch wheatgrass
Type 3: Bluebunch wheatgrass-pinegrass/common snowberry-creeping Oregon-grape/spotted knapweed
Type 4: Idaho fescue-pinegrass/wild strawberry-yellow clover-smooth aster/common snowberry
Type 5: Common St. John's-wort-smooth aster/common snowberry-saskatoon/Canada bluegrass-pinegrass-Columbian needlegrass
Type 6: Yellow clover-sulphur cinquefoil/Canada bluegrass-common timothy-smooth brome/prairie rose
Type 7: Idaho fescue-Canada bluegrass-Junegrass/large-fruited desert-parsley-common St. John's-wort
Type 8: Idaho fescue-Canada bluegrass/field pussytoes-common St. John's-wort-wild bergamot/common snowberry
Type 9: Rough fescue-bluebunch wheatgrass/wild bergamot-tufted phlox/birch-leaved spirea
Type 10: Poverty grass-Idaho fescue-bluebunch wheatgrass/wild bergamot-smooth aster
Type 11: Idaho fescue-pinegrass/woodrush pussytoes-compact selaginella/common snowberry
Type 12: Compact selaginella/bluebunch wheatgrass-Junegrass
Type 13: Bluebunch wheatgrass-Junegrass/sulphur cinquefoil-yellow clover

The utilization of grass, forbs and shrubs varied depending upon species and location. Grass utilization ranged from 0% in Types 4 and 6 to a high of 62.2% in the Idaho fescue–pinegrass/woodrush pussytoes–compact selaginella/common snowberry community type (Type 11), with an average of 23.2% (Table 14). Forb use ranged from 0% in Types 2 and 4, to 51.6% in the bluebunch wheatgrass–pinegrass/common snowberry–creeping Oregon-grape/spotted knapweed community type (Type 3). Shrub use varied from 17.6% in Type 10 to a high of 66.7% in Type 4.

The area of lowest grass production (182 kg/ha) was Type 9, located on level terrain outside the exclosure near Purple Canyon. The utilization during the study was only 16%, and the site had little good forage to offer. The second lowest grass production (464 kg/ha) occurred in the poverty grass–Idaho fescue–bluebunch wheatgrass/wild bergamot–smooth aster community type (Type 10). It is located on level terrain in the openings and beneath the canopy of Douglas-fir dominated stands. Bighorn sheep use appeared to be moderate, while elk use was higher, together resulting in 22.1% utilization. Grass forage production was also low in the Idaho fescue–pinegrass/woodrush pussytoes–compact selaginella/common snowberry community type (Type 11) located on an upland bench near an exposed rock bluff. This site had the highest utilization (62.2%), with a decline in use further from the escape terrain. The use of the bluebunch wheatgrass and pinegrass was low, while use of the Idaho fescue was high. Browsing on the saskatoon was heavy.

Three of the 4 types with the highest grass forage production received very low or no utilization. Most were dominated or highly modified by non-native, agronomic and/or weed species. The highest production was on an abandoned seeded field near an old homestead (west of the orchard area). This yellow clover–sulphur cinquefoil/Canada bluegrass–common timothy–smooth brome/prairie rose community (Type 6) had a grass production of 1590 kg/ha. However, there was no evidence of utilization of the site. The next highest grass production measured was at the toe of a long slope (alluvial fan; MB19) which likely receives subsurface moisture, promoting growth. This Idaho fescue–pinegrass/wild strawberry–yellow clover–smooth aster/common snowberry community (Type 4) produced 1088 kg/ha of grass. There was no evidence of utilization, and there was an abundance of litter which suggested that the area had not been used for many years. The third highest grass production type was the common snowberry–creeping Oregon-grape/common timothy/Canada bluegrass/arrowleaf balsamroot community (Type 1), with a grass production of 931 kg/ha. Utilization of the grasses was 38.6%, that of the shrubs (predominately creeping Oregon-grape) was 59.6%, and that of the forbs (predominately arrowleaf balsamroot) was 45.0%. This type was situated downslope from a mature Douglas-fir stand. Bighorn sheep were often observed at the ecotone of this community type and the forest. There was very low grass utilization (2.6%) of Type 2, the common snowberry–redstem ceanothus–creeping Oregon-grape/spreading dogbane–wild bergamot/pinegrass–bluebunch wheatgrass community. However, it produced the fourth highest grass production (883 kg/ha).

3.5 Forage Analysis

The scat analysis results were not available at the time of the December forage species collections in the Columbia Lake and Bull River study areas, so not all species that appeared to be significant in the diet based on the scat analysis were collected.

Forage nutrient and mineral levels were compared to the nutrient, energy and mineral requirements of domestic sheep (NRC 1985) in Appendices 5-9 to 5-11. The values for TDN, DE, NDIN, ADF and NDF[13] are also provided.

[13] TDN = total digestible nutrients, i.e. sum of digestible crude protein, digestible carbohydrates and 2.25 x digestible crude fat (NRC 1985); equates to in vitro dry matter digestibility; >60% is rated as good, >65% is rated as excellent. DE = digestible energy, i.e. energy consumed minus energy excreted in feces (NRC 1985), or caloric value of the digestible portion of a food; >2.60 Mcal/kg is rated as good, >2.75 Mcal/kg is rated as excellent. NDIN = neutral detergent insoluble nitrogen (protein not available). ADF = acid detergent fibre (indigestible cellulose). NDF = neutral detergent fibre (indigestible cellulose plus hemi-celluose, which is slowly digestible). The higher the NDF, the less is eaten. All interpretations above: K. Mrazek, Norwest Labs, Calgary, pers. comm.

In the Columbia Lake study area (Appendix 5-9), only the April samples of white pussytoes met the requirements for crude protein. TDN and DE were acceptable only in the samples of Douglas-fir and white pussytoes, December samples of great mullein, and spring samples of rabbit-brush from the grassland. Accordingly, these species also had relatively low ADF and NDF values. With values greater than 65% and 2.75%, respectively, the total digestible nutrients and digestible energy were rated as excellent in the white pussytoes and great mullein. Total digestible nutrients in December samples of Douglas-fir were rated as good, with values greater than 60%, and digestible energy was rated as excellent. Grasses and Douglas-fir were lowest in calcium, but all forages met the requirements for calcium. Almost all forages were deficient in phosphorus, particularly the grasses. The only exception was the spring sample of white pussytoes. All of the forages were deficient in sodium. Grasses were low in magnesium compared to the other forages, with most grasses being deficient. Those that met magnesium requirements included all of the forbs, Douglas-fir, rabbit-brush, Idaho fescue, and the December sample of Junegrass on the rocky bluffs. Only rabbit-brush, Douglas-fir and some of the forbs met the requirements for potassium. Only some samples of prairie sagewort met the requirements for sulphur.

In the Bull River study area (Appendix 5-10), most of the forages did not meet the requirements for crude protein. Exceptions included December samples of creeping Oregon-grape, tufted vetch, and Kentucky bluegrass at the drier, north side of the cultivated field. TDN and DE were acceptable only in the Douglas-fir, creeping Oregon-grape, kinnikinnick, and December samples of Kentucky bluegrass at the drier, north side of the cultivated field. Accordingly, these species also had relatively low ADF and NDF values. With values greater than 65% and 2.75%, respectively, the total digestible nutrients and digestible energy were rated as excellent in the creeping Oregon-grape and kinnikinnick. Total digestible nutrients in Douglas-fir were rated as good, with values greater than 60% and digestible energy was rated as excellent. All forages met the requirements for calcium. Forages were deficient in phosphorus, with the exception of creeping Oregon-grape and Douglas-fir, and the December samples of prairie sagewort on a moist slope, Kentucky bluegrass on the drier, north side of the cultivated field, and tufted vetch. All of the forages were deficient in sodium. Most of the grasses were deficient in magnesium with the exception of smooth brome in December. Only creeping Oregon-grape, kinnikinnick, prairie rose, saskatoon, yarrow and prairie sagewort met sheep requirements for magnesium. All of the grasses were deficient in potassium, and only creeping Oregon-grape, Douglas-fir and prairie sagewort consistently met the requirements. Only the December samples of prairie sagewort met the requirements for sulphur.

In the Mount Broadwood study area (Appendix 5-11), only soopolallie met the requirements for crude protein. Total digestible nutrients and digestible energy were acceptable only in Douglas-fir, creeping Oregon-grape, soopolallie and, in some areas, willow and yarrow. With values greater than 65% and 2.75%, respectively, the total digestible nutrients and digestible energy were rated as excellent in the samples of Douglas-fir, creeping Oregon-grape and yarrow from the upper flats (December). Total digestible nutrients and digestible energy in soopolallie and yarrow on the upper flats (April) were rated as good, with values greater than 60% and 2.6%, respectively. Almost all forages met the requirements for calcium. All of the grasses sampled and most of the forbs were deficient in phosphorus. Only Douglas-fir consistently met the requirements for phosphorus, while creeping Oregon-grape, soopolallie, willow, saskatoon, yarrow and golden-aster met the requirements in some cases. All of the forages were deficient in sodium. Only Douglas-fir, great mullein and yarrow consistently met sheep requirements for magnesium, although creeping Oregon-grape almost consistently met the requirements. Willow, saskatoon, golden-aster and bluebunch wheatgrass met the requirements in some cases. All of the grasses were deficient in potassium, and only great mullein, creeping Oregon-grape and

Douglas-fir consistently or almost consistently met the requirements. December samples of yarrow were also acceptable. Only the December samples of creeping Oregon-grape on a west-facing slope met the requirements for sulphur.

3.6 Effects of Prescribed Burns at Bull River

Following the 1998 spring burn, the vegetative cover at transects BR-02 and BR-03 (Appendix 5-2) declined from 1998 through 2000 (Table 15). At BR-02, species that declined in cover included sulphur cinquefoil (35.3% versus 19.4%), great mullein (7.3% versus 2.7%) and Canada bluegrass (2.7% versus 1.9%). Those with notable increases in cover included wild bergamot (2.3% versus 5.7%), bluebunch wheatgrass (3.3% versus 6.3%), antelope-brush (4.9% versus 10.1%) and prairie rose (1.5% versus 2.6%). The charred antelope-brush shrubs were beginning to sprout at the base in the summer of 1998, hence the lower cover, but had regrown somewhat by 2000. At BR-03, several species declined in cover over the 3 years, including sulphur cinquefoil (21.3% versus 13.8%), great mullein (4.3% versus 1.7%), black medic (6.9% versus 1.9%), yellow salsify (2.1% versus 0.3%), common dandelion (1.9% versus 0.4%), field pussytoes (1.7% versus 0.5%), Junegrass (5.3% versus 1.5%), Canada bluegrass (19.5% versus 15.0%), western snowberry (5.7% versus 3.1%) and birch-leaved spirea (1.3% versus 0.5%). As at BR-02, antelope-brush increased in cover from 5.3% to 9.7%. Notable increases in cover were also observed in slender wheatgrass (0.8% versus 2.1%) and Columbian needlegrass (1.0% versus 1.9%). Since no data were available from these sites prior to the burns, it is not possible to know whether the cover values differ from those prior to the burns.

The spring 2000 burn on the slopes containing BR-07 and BR-08 appears to have resulted in a slight increase in vegetative cover (Table 13), along with an increase in bare ground and decrease in litter cover from the pre-burn values in 1998. At both sites, there was a marked increase in cover of yellow sweet-clover (0.2% versus 2.3%, and 2.7% versus 11.9%, respectively). At BR-07, there was also a marked increase in cover of black medic (1.5% versus 11.1%), great mullein (0.3% versus 2.8%) and saskatoon (2.2% versus 6.1%). Sulphur cinquefoil and cheatgrass experienced a less dramatic increase (1.7% versus 3.1%, and 3.5% versus 5.7%, respectively). Notable declines occurred in antelope-brush (10.7% versus 1.7%), bluebunch wheatgrass (5.1% versus 1.1%) and prairie sagewort (1.7% versus 0.9%). At BR-08, there was also an increase in cover of Canada bluegrass (11.5% versus 15.2%), yellow salsify (0.7% versus 2.6%), yarrow (1.6% versus 4.6%) and American vetch (0.9% versus 1.9%). There was a large decline in cheatgrass cover (4.6% versus 0.3%), and slight declines in sulphur cinquefoil (6.6% versus 5.1%), saskatoon (17.6% versus 12.6%) and prairie rose (2.7% versus 1.7%).

Table 15. Plant cover along transects in areas subjected to prescribed burns at Bull River.

Species	Post-burn						Pre-burn	Post-burn	Pre-burn	Post-burn
	BR-02			BR-03			BR-07		BR-08	
	1998	1999	2000	1998	1999	2000	1998	2000	1998	2000
Grasses										
Bluebunch wheatgrass	3.3	2.3	6.3	1.9	1.5	1.3	5.1	1.1	0.1	0.3
Canada bluegrass	2.7	2.3	1.9	19.5	12.1	15.0	8.5	7.3	11.5	15.2
Cheatgrass	0.3	0.1	0	-	-	-	3.5	5.7	4.6	0.3
Columbian needlegrass	0.7	0.8	0.9	1.0	0.8	1.9	-	-	-	-
Junegrass	1.1	3.1	1.1	5.3	3.7	1.5	0.3	0.8	-	-
Kentucky bluegrass	0	0.4	0.3	0	1.0	0	-	-	2.9	0
Slender wheatgrass	-	-	-	0.8	1.3	2.1	-	-	-	-
Slimstem reedgrass	0.4	0.1	0	-	-	-	-	-	-	-
Common timothy	-	-	-	-	-	-	-	-	1.9	2.5
Forbs										
American vetch	-	-	-	-	-	-	-	-	0.9	1.9
Common dandelion	0.5	0.1	0	1.9	0.2	0.4	0.1	0.4	0.1	0.3
Common hound's-tongue							0.1	0	0.4	1.2
Great mullein	7.3	3.8	2.7	4.3	3.0	1.7	0.3	2.8	1.7	1.3
Yarrow	2.5	2.1	3.1	1.5	2.9	1.9	0.2	0.3	1.6	4.6
Black medic	-	-	-	6.9	4.4	1.9	1.5	11.1	0	0.7
Field pussytoes	0.1	0.1	0.1	1.7	0	0.5	-	-	-	-
Lemonweed	-	-	-	1.0	0.7	1.3	-	-	-	-
Prairie sagewort	-	-	-	-	-	-	4.0	0.9	-	-
Pale alyssum	-	-	-	+	0	0.1	0.4	0	-	-
Sleepy catchfly	0.2	0	0	-	-	-	0.7	0	+	0
Slender hawksbeard	-	-	-	-	-	-	0.1	0.5	-	-
Slender penstemon	-	-	-	-	-	-	1.1	0.7	-	-
Smooth aster	-	-	-	-	-	-	-	-	1.7	2.0
Spreading dogbane	0.1	1.8	0.6	-	-	-	-	-	2.9	3.8
Sulphur cinquefoil	35.3	20.7	19.4	21.3	16.6	13.8	1.7	3.1	6.6	5.1
Thyme-leaved sandwort	1.2	0.2	0.3	0.4	0.2	0	1.3	0	0.1	0.2
Yellow salsify	1.2	0	0	2.1	0.3	0.3	0.6	0.7	0.7	2.6
Yellow sweet-clover	-	-	-	-	-	-	0.2	2.3	2.7	11.9
Western blue flax	-	-	-	-	-	-	0.1	0.7	-	-
White pussytoes	-	-	-	0.7	1.7	0.7	-	-	-	-
Wild bergamot	2.3	4.1	5.7	-	-	-	1.7	2.1	3.8	3.5
Shrubs										
Antelope-brush	4.9	9.1	10.1	5.3	6.4	9.7	10.7	1.7	1.7	0.1
Birch-leaved spirea	-	-	-	1.3	0	0.5	-	-	-	-
Prairie rose	1.5	1.9	2.6	1.0	0.8	1.1	-	-	2.7	1.7
Saskatoon	-	-	-	3.9	5.2	4.2	2.2	6.1	17.6	12.6
Western snowberry	6.3	10.0	7.1	5.7	9.2	3.1	2.1	2.1	3.4	4.2
TOTAL COVER	71.9	63.1	62.3	87.6	72.0	62.9	46.6	50.5	69.7	78.0

4.0 Discussion

4.1 Plant Communities

4.1.1. Community Types

Plant communities were diverse, reflecting variability in environmental conditions, structural stage, disturbance, grazing history and weed infestation. Despite the sampling being restricted to TEM polygons dominated by 1 or 2 TEM site series at each study area (smaller portions of several more TEM site series were sampled at Mount Broadwood), from 6 to 13 plant community types were identified within each study area. This variability was also reflected in production and utilization values, so must be considered in any management actions taken.

4.1.2 Non-native Weeds and Agronomic Plants

Agronomic species and other introduced plants were common in all study areas. The aggressive nature of many non-native plants allows them to out-compete the native flora. This causes a change in plant species composition and can affect the quality and quantity of native forage. Franklin et al. (1999) claim that the expansion of invasive non-native plant species is resulting in the greatest long-term degradation of wildlife habitat ever recorded. For example, spotted knapweed in Montana increased from a few plants in 1920 to 2 million ha in 1999.

By potentially changing a grassland to a forb-dominated community, non-native species could affect wildlife habitat (Bedunah 1992). Graminoid production dropped by 90% in some knapweed-infested sites in Alberta and western Montana (Harris and Cranston 1979, Strang et al. 1979, Bedunah 1988 cited in Bedunah 1992). Biomass of key ungulate forage species averaged only 4% on exotic plant-infested sites in North Dakota, versus 77% on non-infested sites (Trammell and Butler 1995). In North Dakota, deer and bison use of leafy spurge-infested habitats averaged 70% and 83%, respectively, less than that for non-infested sites. Similarly, browse use during summer and winter was reduced by an average of 32% in leafy-spurge-infested shrub habitat (Trammell and Butler 1995). Elk use was reduced by 98% on spotted knapweed-infested range compared to bunchgrass-dominated sites (Sheley et al. 1998 cited in DiTomaso 2000). When spotted knapweed was removed from historic elk winter range in western Montana, elk use increased dramatically (Thompson 1996). Agronomic grasses, though not generally considered weeds, can similarly reduce forage quality. If they have not been grazed in spring and early summer, the majority are not palatable in winter due to the abundance of coarse, lignified stems. Annual grasses, such as cheatgrass and Japanese brome, have completely died back by late fall and are no longer available as forage unless conditions are suitable for fall germination. In the latter case, there may be sufficient leafy growth to provide winter forage.

Horizontal and vertical plant diversity, the amount of edge and the degree of interspersion are important characteristics of wildlife habitat. However, as weed infestations become severe, diversity declines and wildlife habitat quality degenerates (Olson 1995). Habitat qualities such as cover, microclimate and food may be altered (Brown et al. 1991). Native vegetation also provides environmental safeguards versus non-native communities. Many native species are fibrous-rooted, causing them to hold soil in place, reduce erosion, promote infiltration and safe release of water, and provide resilience against fire and drought. In contrast, many invasive weeds have tap roots that do not provide these benefits (Asher 2000). Surface water run-off and stream sediment yields were 56% and 192% higher, respectively, in a spotted knapweed-dominated site compared with adjacent native perennial grassland (Lacey et al. 1989 cited in DiTomaso 2000). In addition, water infiltration rates were reduced where spotted knapweed dominated. The deep root systems of noxious weeds allow the plants to actively grow later in the summer compared with native bunchgrasses and forbs, which can influence soil moisture and nutrient availability the following growing season (Gerlach and Rice 1996 cited in DiTomaso 2000).

Weeds are spread by a number of means, including via the wildlife and cattle that inhabit areas of infestation. Spotted knapweed seed heads were found to be eaten by ungulates in Idaho (Wright and Kelsey 1997). Wallander et al. (1995) established that viable spotted knapweed seeds can pass through the digestive systems of mule deer and domestic sheep, though with reduced viability. Weeds are often associated with disturbances, but perennials such as knapweed, oxeye daisy, dalmatian toadflax (*Linaria genistifolia*) and leafy spurge (*Euphorbia esula*) can become established in productive native grasslands (Bedunah 1992, Wallace 1999). Weeds can gain an advantage even when they are not eaten by herbivores if native species are grazed sufficiently to create openings for the weeds (Wallace 1999). Cheatgrass dominated bighorn sheep bedding areas beneath Douglas-fir trees in our study areas, and is likely spread by the sheep when the seeds attach to their coats. Throughout the East Kootenay, past practices of seeding roads, trails and industrial development with non-native species has resulted in their invasion into many native range areas.

Spotted Knapweed

Knapweed can increase exponentially. Without serious control efforts, knapweed that had begun invading the Blackfoot-Clearwater game range in western Montana was expected to result in weed monocultures over the entire game range within 1 or 2 decades (Kummerow 1992). In British Columbia, over 40,000 ha are infested by knapweed, reducing forage potential by up to 90% (Anonymous 1998).

Tyser and Key (1988 cited in Rice et al. 1997) and Tyser (1992 cited in Rice et al. 1997) found that as spotted knapweed increased on a site, other species declined. In Montana, spotted knapweed invasions reduced available winter forage for elk by 50 to 90% (Duncan 1997 cited in Asher 2000). Accordingly, Hakim (1975 cited in Bedunah 1992) found that elk used knapweed sites much less than bunchgrass communities. Rice et al. (1997) surmised that the reduced vigour of native bunchgrass populations on spotted knapweed-infested elk winter ranges might be decreasing the forage value of these sites. After 3 years of herbicide spraying to control the knapweed, herbicide plots averaged 47% greater elk winter forage than the unsprayed plots.

Assumptions regarding the negative effect of spotted knapweed on range quality are based on the understanding that it is rarely grazed by large herbivores, possibly due to the bitter tasting compound cnicin (Watson and Renny 1974, Kelsey and Locken 1987, Willard et al. 1988, Locken and Kelsey 1989). However, Wright and Kelsey (1997) found no evidence of a large reduction in carrying capacity due to spotted knapweed infestation on winter-spring ungulate range in Idaho. Rather, they suggested that spotted knapweed should be considered a potential food when estimating the carrying capacity of a cervid range. Elk, white-tailed deer and mule deer ate knapweed seed heads and rosette leaves. The latter contained energy and protein levels close to those of preferred native forage. Knapweed seed heads were one of the few herbaceous plants readily available in open areas when snow depths exceeded 30 cm. The use of knapweed in this study may be due to high animal densities, limited food choices and relatively high snow cover (Wright and Kelsey 1997). Such conditions do not appear to occur in the East Kootenay.

Spotted knapweed and diffuse knapweed (*Centaurea diffusa*) were major components of California bighorn sheep winter diet in British Columbia (40% in December, 64% in January, and 58% in February). Seed heads were available above the snow, and overwintering basal rosettes became available when the snow receded (Miller 1990 cited in Carey 1995a). Domestic sheep also will graze on spotted knapweed (Olson et al. 1997). However, Olson and Wallander (2001) did not find spotted knapweed to be grazed consistently more than Idaho fescue despite its higher nutritive value. Sheep rumen microbial populations are negatively affected when a sheep's diet contains 70% or more spotted knapweed, especially when parts with higher cnicin concentrations are consumed such as mature leaves and flower heads (Olson and Kelsey 1997). Spotted knapweed was not identified in the bighorn sheep diets in any of our study areas, although a general identification of "composite" was listed at low levels (0.44 to 4.96% relative density), and spotted knapweed is one of several forbs within this group. Thus, it is possible that bighorn sheep in our study areas consumed some knapweed, but there is no evidence that it formed a significant part of the diet. Given this and the effect of knapweed on plant species that are known to be important forage items, the presence of knapweed in the study areas should be considered a negative indication for bighorn sheep range quality.

Common St. John's-Wort

St. John's-wort quickly invades disturbed land and displaces other cover, lowering the grazing capacity of ranges (Gillett and Robson 1981). It is poisonous to cattle if eaten, causing weight loss and possibly death. One of its toxic properties is photosensitization, which affects livestock with light-coloured skin if enough is ingested (Gillett and Robson 1981). Like other problem weeds, common St. John's-wort reduces plant species diversity, but this can be reversed. Following biological control of common St. John's-wort in California rangelands, the number of plant species present increased by 35% (DeLoach 1991 cited in DiTomaso 2000).

Sulphur Cinquefoil

Sulphur cinquefoil is reported to be a very competitive species, infesting disturbed areas, meadows, pasture and rangeland (Werner and Soule 1976), and can dominate a site within 2 to 3 years of first appearance (Jarecki 1990 cited in Carey 1995b). By reducing competition from grass, overgrazing favours sulphur cinquefoil (Callihan et al. 1991 cited in Carey 1995b). In Montana, it has invaded bluebunch wheatgrass rangeland in good condition (Rice et al. 1991 cited in Carey 1995b). It was actually replacing spotted knapweed on some sites in Montana (Rice 1991 cited in Carey 1995b).

Sulphur cinquefoil is unpalatable to most livestock and wildlife due to its high tannin content (Rice et al. 1991 cited in Wright and Kelsey 1997, Werner and Soule 1976). It appears to be less palatable to ruminants than spotted knapweed (Rice et al. 1991 cited in Wright and Kelsey 1997).

Oxeye Daisy

Once established, oxeye daisy can quickly replace 50% of the grass in pastures (Alberta Environmental Centre 1985, Royer and Dickinson 1999).

<u>Cheatgrass</u>

The forage value of cheatgrass, as well as Japanese brome, was rated as poor in elk winter range of western Montana (Rice et al. 1997). Early-spring growth is readily eaten by livestock. However, once the plant has flowered, the sharp awns may injure their eyes and mouth (Royer and Dickinson 1999).

4.2 Forage Choices

The differential durability of the plant epidermis varies by species, so some plants are likely to have been over- or underrepresented in the diet analysis. However, the relatively minor degree of such a bias is unlikely to have affected our overall results, given the magnitude of differences among species or species groups that we observed (B. Davitt, Wildlife Habitat Laboratory, Washington State University, Pullman, WA, pers. comm.), and microhistological analysis of plant fragments from pellets has been considered an effect indicator of bighorn diet in other studies (Todd and Hansen 1973, Wagner and Peek 2006).

Spatial and temporal variability in dietary items likely reflected both true shifts and the effect of small sample sizes. Direct inferences regarding forage species selection (i.e. presence in diet in relation to availability) cannot be made, given that plant community composition was reported only for the areas most intensively used by sheep, rather than all areas available to them. In addition, the results indicated what sheep ate under there current circumstances, not what they would have eaten had there been no competition for forage from cattle, elk and deer, nor under different annual climatic conditions. It is unwise to consider small differences (i.e. <10%) in the data on food habits, but broad patterns in food habits throughout the year can be interpreted (Seip 1983). For example, the importance of 3 grass types (needle-and-thread grass and possibly other needlegrasses, bluebunch wheatgrass and other wheatgrasses, and fescues) was indicated by their strong dominance of scat samples. Conversely, the near absence of Kentucky and Canada bluegrass, Junegrass, cheatgrass and pinegrass in relation to the abundance of those species in at least 1 study area suggests that they were relatively unimportant. In a recent study from central Idaho using the same technique, Rocky Mountain bighorn winter diets were also strongly dominated (~70%) by grasses, though with bluebunch wheatgrass dominant and needle-and-thread grass, *Poa* bluegrasses and Idaho fescue secondary. Bluegrass and fescue fragments appear similar microscopically (B. Davitt, op. cit.), so it is possible that some error occurred in one or other of the studies, but the degree of difference among species suggests that it would have little impact on the results.

At least moderate use of creeping Oregon-grape, prairie sagewort and great mullein occurred at all sites (with very high use of creeping Oregon-grape at Mount Broadwood), reflecting their availability in core-use areas, and also the generally high protein level of those species. Creeping Oregon-grape may be somewhat overrepresented due to its durable plant epidermis in relation to forbs (B. Davitt, op. cit.). Of note, willow was consistently present in scat samples, despite being absent from every described plant community and not being a typical grassland plant. Clearly, sheep were foraging outside of the identified core-use areas, or at least in atypical portions of them. The major dietary forbs and shrubs listed above were either absent or little-used in the winter diets of central Idaho bighorns (Wagner and Peek 2006).

It appears that much of the forage selected and available in the study areas was inadequate to meet maintenance requirements of the sheep. Based on the results of the forage analysis, the most nutritious plants included Douglas-fir, creeping Oregon-grape and white pussytoes. Other nutritious plants included rabbit-brush, soopolallie, willow, kinnikinnick, prairie sagewort, great mullein, tufted vetch, yarrow and Kentucky bluegrass (Bull River, drier portion of the cultivated field). Most of these species were identified in scats, but not generally in great abundance. Rabbit-brush and white pussytoes were not found in scat samples, but the family to which they belong, Asteraceae, was identified in scats from all 3 study areas and sheep were observed feeding on white pussytoes during spring. Tufted vetch was not identified in the scats. In contrast, grasses formed the bulk of the diet in our study and are considered the primary food source for bighorn sheep (Shackleton 1999) yet were the most deficient group nutritionally.

Species composition in California bighorn sheep diets also correlated poorly with apparent forage quality (Wikeem and Pitt 1992). There are at least 3 reasons why this might be the case. It is possible that measures of nutritional quality did not reflect the true forage value for bighorns. Sheep prefer the more digestible portions of plants, such as leaves and blades versus stems (Geist 1971). Food intake depends directly on the rate of passage of food, which is related to food quality. The higher the total digestible content of a food, the more rapidly it passes through the system and the more the sheep can feed on it (Blaxter et al. 1961 cited in Geist 1971). Many of the apparently more nutritious plants have a high stem component so may not be readily digested. Some researchers have developed correction factors for differential digestibilities of plant types but these values may not be accurate when extrapolated to an entirely new situation (Seip 1983). Secondly, secondary plant compounds, such as alkaloids, terpenoids and soluble phenolics, occur in many plants and can have profound effects on herbivore health (Robbins 1993). The presence of these compounds was not measured, so it is probable that some of the apparently more nutritious forage species (such as Douglas-fir) in reality were of less benefit to sheep than grasses. The third potential explanation for the lack of selection for apparently more nutritious plants is that the scat analysis was based on winter diets. Ungulate over-winter survival is related to fat stores put on during the spring, summer and fall, and sheep can expect high-quality forage to be available at those times each year. A distinct seasonal variation in the maintenance energy requirement of sheep has been noted by Blaxter and Boyne (1982) in thermo-neutral environments. There is a peak in July and a decrease by a similar magnitude in winter. Even the best forage is suboptimal during the winter (Wagner and Peek 2006), so if sheep are in “maintenance” mode then, they may simply select readily digestible forage to provide some basic nutrition and keep their digestive flora active, rather than selecting the highest-protein plants. Requirements listed for maintaining domestic sheep in good condition may exceed the needs for (a) bighorn sheep (Wagner and Peek 2006) and (b) basic overwinter survival. Mineral requirements may also decline as diet is restricted. For example, less sulphur is needed when nitrogen intake is low (Seip 1983). Sheep obtain minerals from plants as well as mineral licks, but no soil analyses were done in the study areas. Geist (1971) reported that sheep visit mineral licks primarily in the late spring and early summer, presumably to make up for the scarcity of mineral salts in winter forage. In sum, rather than using predominantly forage with the highest apparent protein, energetic and mineral levels, bighorn sheep in this study appeared to eat mainly grasses and other forages that were available in their grassland habitat and were readily digested, had diets that may have been suboptimal, consumed some coarser material with higher nutritional quality, and made at least some use of non-grassland habitats to obtain willows. A true picture of dietary quality or deficiencies would require knowledge of summer forage and the availability of mineral licks.

4.3 Range Characteristics

The annual forage production and utilization data were collected for only 1, 2 or 3 growing seasons depending on when the site cages were established. They may not represent the long-term average, particularly since growing-season precipitation was lower than average during the study. A close relationship exists between environmental factors and plant growth and development (Leopold and Kriedemann 1975). With weather fluctuations, yearly forage production and species composition can vary, as indicated in numerous studies (Clarke et al. 1947, Coupland 1958, McLean and Smith 1973, Perry 1976, Weaver and Collins 1977, Newbauer et al. 1980, Branson and Miller 1981). However, forage production relates not only to precipitation but to solar radiation and temperature, which in turn can affect the precipitation/evaporation (P/E) ratio. Furthermore, precipitation late in the growing season, (i.e. late July, August and early September) often has little effect on plant growth and therefore forage production, since the vegetation generally matures prior to this time. Generally, effective soil moisture for plant growth is supplied in the spring by melting snow (van Ryswyk et al. 1966). Thus, it is difficult to assess the applicability of the forage production (and by extension, percent utilization) with reference to climatic conditions without data concerning snowpacks, patterns of spring run-off, solar radiation and temperature, i.e. without knowing the net effect on soil moisture. The opposite inter-annual relationship between growing-season rainfall and production for Columbia Lake and Premier Ridge versus Bull River and Mount Broadwood is suggestive of this complexity, although average production values across years were related to growing-season grass production values for those years. In spite of limitations, the production and utilization data provide approximate values showing the range among community types and study areas, for use in estimating carrying capacity (Chapter 6).

According to Fegler (1998), the best way to rate the health of a plant community is by determining the percentage of exotic, or non-native, species present. This would suggest that the health of many of the plant communities in the study areas, particularly Bull River and Mount Broadwood, has been compromised. At Bull River, 25% of species present were non-native, as compared to 16-19% in the other 3 study areas (Appendices 5-3 to 5-6)[14]. Black medic and Canada bluegrass occurred in all ten plant community types at Bull River. Yellow salsify, sulphur cinquefoil (mainly on south-facing slopes), great mullein, cheatgrass, common dandelion, thyme-leave sandwort and sweet-clover were common, but the presence of spotted knapweed (in the CF TEM site series) and common hound’s-tongue is of significant concern. While Mount Broadwood had fewer species of exotics than Bull River (22 versus 29), the dominance of those present was very high, with Canada bluegrass common in at least 12 of the 13 community types and yellow clover, common timothy and smooth brome dominating some areas. These species are very competitive and do not provide good winter forage. Rather, they are best grazed in the spring before they become lignified and less leafy. While St. John’s-wort (open areas of Wigwam Flats, slopes above and below the flats, and west-facing slopes above the Elk River), sulphur cinquefoil, yellow salsify, spotted knapweed and oxeye daisy (west-facing slopes and terraces above the Elk River) generally had somewhat lower canopy coverage, they are all non-palatable and aggressive invaders. The Columbia Lake and Premier Ridge study areas consisted primarily of native vegetation, the most notable exceptions being Canada bluegrass and cheatgrass (in all community types and all but 1 community type, respectively) and, to a lesser extent, yellow salsify. The off-transect abundance of spotted knapweed is of concern at Columbia Lake.

[14] In this report, Kentucky bluegrass is considered native because none of the 3 subspecies introduced to British Columbia (*Poa pratensis pratensis*, *P. p. angustifolia* and *P. p. irrigata* have been recorded in the East Kootenay, whereas 2 of the 3 native subspecies (*P. p. agassizensis* and *P. p. alpigena*) have been (http://www.eflora.bc.ca/, accessed 14 December 2006).

Columbia Lake

Range condition at Columbia Lake varied among community types, with the main indicators of range deterioration being the abundance of cheatgrass and a few other exotic or invasive species on some transects, grass utilization exceeding 50% in 4 of the 6 community types, very high forb utilization, and an abundance of exposed soil. The high utilization in Type 5 corresponded to its high forage production, and is probably because it was desirable from a foraging perspective, and for bedding. The high use of this type is of concern with respect to forage depletion and erosion or instability. Several of the community types were in better condition and the plot outside the range reference exclosure was rated as excellent. The low use of forage in Type 6 may be attributed to the tree cover, creating a less desirable site for bighorn sheep. Overall, range condition at Columbia Lake was mixed. Some slopes are showing signs of erosion due to the recreational use of dirt bikes, quads and four-wheel-drives.

Premier Ridge

At Premier Ridge, utilization of grass and forbs exceeded 50% in only 2 of the 5 community types for which data were available, but range condition was no better than fair condition at any of the 6 types identified. A few introduced species and a high percentage of bare soil were other significant signs of deterioration.

Bull River

Of the 8 plant communities at Bull River for which there were production data, cattle alone used more than 50% of the available grass in 2 of them, and cattle and wild ungulates combined took more than 50% at 6. Correspondingly, only 1 of the 10 plant communities had a rating better than "fair". Primary indicators of the unsatisfactory condition included an abundance of agronomic species, diverse and abundant weeds, and in some cases considerable exposed soil. Livestock grazing appears to be at least partly responsible for the condition, as the area of private land open to wild ungulates but not cattle had a dramatically higher range condition than the Crown land grazed by cattle immediately adjacent. As a result of the particularly high utilization of Types 1 and 2 by both cattle and native ungulates, the preferred forage is ultimately consumed, leaving only the less palatable or undesirable species as carryover for propagation, nutrient recycling and protective ground cover. If this trend continues, further range condition deterioration will undoubtedly occur, reducing the carrying capacity of the land.

Mount Broadwood

At Mount Broadwood, utilization levels were not consistent with range condition. There were utilization data for 11 of the 13 identified plant communities. Of these, only 1 had grass utilization exceeding 50% and only 1 had forb utilization at that level. However, range condition ratings exceeding fair were given to only 1 plant community and parts of 2 others. There was little exposed soil, but agronomic species and weeds were widespread. Conditions outside the range exclosure were poor, compared to excellent within the exclosure. Thus, despite the low utilization in the years studied, range conditions at Mount Broadwood were generally unsatisfactory. In fact, the low utilization may have reflected these poor conditions. The lack of utilization in the high production areas was likely due to the dominance of agronomic or weedy species, which do not provide good winter forage. For plant community Type 9, the current low use may be attributed in part to the abundance of young Douglas-fir trees which reduce the line-of-sight. It is adjacent to the rim of the canyon so has excellent escape terrain, and has previously been heavily used by elk and sheep (Davidson 1991) so would normally be expected to receive concentrated use.

4.4 Habitat Enhancement

The frequent, stand-maintaining fires that once characterized the Trench have been suppressed for many decades, resulting in a shift toward greater crown closure (mainly conifers, particularly Douglas-fir) and less grassland. Gayton (1997) estimated at 3 sites in the Trench that 29% of the open grassland and treed grassland present in 1952 had shifted to open forest or closed forest 38 years later. The significance of this pattern for bighorn sheep, where it occurs within their winter ranges, includes decreasing lines-of-sight and reduced forage. Gayton (1997) found forage production of roughly 750 kg/ha in grassland and 175 kg/ha in forest.

Bighorn sheep habitat was not assessed in relation to forest ingrowth; sheep selected open habitats so sampling occurred only there. The only evidence available was from range reference areas. The Columbia Lake exclosure had no conifer cover 11 years after its establishment, while the Douglas-fir cover inside the Mount Broadwood exclosure increased from 0% in 1987 to 7.2% in 1998. Outside the exclosure, the value increased from 0 to 0.1% over the same period. These data are too limited by area and habitat type to extend widely, but extrapolating the grassland to forest conversion reported by Gayton (1997) in a geometric fashion over 100 years would suggest a 60% loss of grasslands from ingrowth alone. However, to the extent that forest has replaced grassland in the study areas, the loss of forage production would translate to a dramatic loss of ungulate carrying capacity. Using Gayton's figures, assuming a bighorn sheep consumes 20% as much forage as a cow (73 kg per month), considering winter range to be used for 8 months, and targeting a 50% carry-over of forage, every 2 ha of grassland converted to forest results in carrying capacity being reduced by 1 sheep. Thus, even without accounting for the negative effect on production of spreading weed species, carrying capacity is likely to decline dramatically over the coming decades unless significant steps are taken to reverse the trend toward forest ingrowth.

Prescribed burns have been used in some of the study areas to enhance wildlife habitat and increase livestock range. However, invasive weeds are already present in the study areas and some dominate in certain communities, so the potential effect of burning on weed populations must be considered. Plant communities altered by the presence or dominance of non-native species tend not to burn naturally (Asher 2000). Weed populations commonly flourish following a fire, although there is often a window of opportunity to control weeds following a fire but before seed set (Asher 2000).

In Australia, a spring prescription burn was found to promote the development of St. John's-wort populations (Briese 1996). In the open area, where the fire was of relatively low intensity, St. John's-wort recovered rapidly to pre-fire levels, with a slight increase in crown density. In the timbered area, the fire was more intense and there was greater destruction of ground cover and mortality of St. John's-wort crowns. St. John's-wort was the first plant to recover, mainly by vegetative regrowth from surviving roots, which allowed it to become highly dominant (12-36% cover pre-fire to 65% 2 years after the fire). This was mainly due to enhanced growth of individual plants rather than an increase in crown density. A similar but less extreme increase was observed in the open area. Germination of St. John's-wort seeds was also significantly higher than expected but contributed little to plant recovery. The fire appeared to stimulate regrowth in surviving rootstocks. A fall burn 4 years later caused massive germination of forbs and grasses, including St. John's-wort, however it was less competitive than the native species.

Despite recovery of the St. John's-wort, native species still dominated the site a year later (Briese 1996).

Fire has been shown to be beneficial to knapweed species (*Centaurea* spp.). In Utah, when squarrose knapweed (*C. virgata* var. *squarrosa*) is a minor component of a plant community, populations often explode after a fire (Asher 2000). The population of yellow star-thistle (*C. solstitialis*) in northern California was accelerated by a wildfire (Asher 2000). Squarrose and diffuse knapweed sprouted and set seed within 5-8 weeks after fires, producing their second crop of seeds while all other plants were dormant and awaiting the next growing season (Asher 2000). Bailey (1986) suggested that using prescribed fire to reduce big sagebrush (*Artemisia tridentata*) in semi-arid grasslands may expose sites to invasion by spotted knapweed. Spotted knapweed probably resists low-severity fire due to its stout taproot, although such fires probably top-kill the plants. Buried seeds probably remain undamaged by most fires (Carey 1995a). Spotted knapweed appeared to increase its cover and non-natives collectively increased in species richness 2 to 3 years after restoration treatments (burning and thinning) in a ponderosa pine – Douglas-fir stand in northwestern Montana (Metlen et al. 2006).

Cheatgrass becomes completely dry by summer, making it extremely flammable. Frequent fires favour cheatgrass by eliminating competing perennial vegetation. The seeds survive in the unburned organic material on a site. Cheatgrass is able to dominate in the post-burn stand through rapid growth and vigorous reproduction (Klemmedson and Smith 1964, Zouhar 2003). Since cheatgrass produces prolific quantities of seed, which become concentrated in the litter, even a large reduction in the seed pool will not prevent cheatgrass from regaining dominance on a site (Zouhar 2003).

Sulphur cinquefoil appears to have a persistent seed bank which may enable it to colonize after fire. The potential for its vegetative parts to survive fire depends on their depth and the fire severity (Carey 1995b). Fire was tested as a control treatment of sulphur cinquefoil in Montana (Lesica and Martin 1997), but burning appeared to cause an increase in the density of seedlings and had little effect on the density of juvenile and mature plants. Fall burning resulted in an increase in the density of mature plants as well as seedlings. Sulphur cinquefoil generally increased its cover 2 years after restoration burning in a ponderosa pine – Douglas-fir stand in northwestern Montana (Metlen et al. 2006).

It is difficult to say how the prescribed burns in the Bull River study area affected sulphur cinquefoil cover. The burns on the slopes containing transects BR-02 and BR-03 occurred prior to transect establishment. Sulphur cinquefoil dominated the cover several months after the burn, at 35.3% and 21.3% on the 2 transects, but declined to 19.4% and 13.8%, respectively, over the next 2 years. Its dominance in the forb and grass layers was never challenged in the 3 years that the BR-02 transect was read, and it continued to co-dominate with Canada bluegrass at BR-03. Crown density measurements were not taken, but it appeared that the decrease in cover was related to less robust plants and not to a decrease in the number of plants. This may be explained by the fertilizer effect of burning. Grove et al. (1986) found increases in soil nutrients after a fire to be short-term, returning to pre-fire levels within 12 months. There was probably an increase in the production of flowers and seeds the summer following the 1998 burn. Precipitation during the growing season in 1998 was 11.7% higher than the long-term average at the nearby Kootenay Trout Hatchery (280.6 mm versus 247.6 mm), which may have contributed to the vigorous sulphur cinquefoil cover. In addition, the reduction of litter and shrub crown cover resulting from the burn, along with the blackened, warmer ground surface may have supported a sulphur cinquefoil flush. Thus it appears that there was a strong response by sulphur cinquefoil immediately following the burn, then a tapering-off over the next few years.

However, the last cover measurements were taken only 2 years after the burn, so longer-term impacts of fire were not observed. Sulphur cinquefoil was not a dominant species in 1998 at BR-07 and BR-08, where a spring burn took place in 2000. Its cover increased from 1.7% in 1998 to 3.1% in 2000 at BR-07, but decreased from 6.6% to 5.1% at BR-08. After an initial increase in total plant cover there, vegetative cover may decline in future years as at BR-02 and BR-03. There did not appear to be any clear benefit in terms of grass forage in the growing season following the burn. The initial reduction in most shrub species may not be maintained, as tended to be the case at BR-02 and BR-03. The increase in cover of most non-native species is a concern. Overall, the response to fire of the non-native agronomic species in the study area was variable and is likely to be dependent on the timing and severity of the burn and weather conditions following the burn. The effect of fire on a given weed species is highly dependent on that species' adaptations, those of native vegetation, and the specifics of the prescribed fire (Grace et al. 2001). However, based on results at Bull River and reported in the literature, there is a high probability that without careful management, prescribed fire will increase weed abundance.

5.0 Recommendations

Plant community assessments clearly pointed to the poor status of rangelands in the 4 bighorn sheep winter ranges studied. Every plant community had some exotic plant species, most had several, and many were dominated by them. Exotics covered the spectrum from those essentially naturalized to the East Kootenay environment, such as Canada bluegrass and black medic, to aggressive weeds causing serious impacts to forage quality, such as common St. John's-wort and spotted knapweed. Even plant communities with relatively limited coverage of non-natives, such as some of the Columbia Lake and Premier Ridge sites, typically had a high proportion of exposed soil, high forage utilization, nearby sources of weeds, or a combination of those factors. While the permanent range reference area exclosures had greater foliar cover than in past decades, weeds had become established since 1987. The coverage of Douglas-fir was low on preferred-habitat transects because sampling targeted the open habitats most selected by bighorn sheep, but Douglas-fir had become established at the Mount Broadwood exclosure since 1987. Thus, the known pattern of forest encroaching into former grasslands, and the associated dramatic decline in forage production that has been documented, all point to further concerns about range quality.

Regardless of estimates of current carrying capacity (Chapter 6), the above results indicate that steps are needed to prevent continuing loss of range quality, carrying capacity and biodiversity levels on the winter ranges examined. These are listed below.

1. **Weed control** is essential. Chemical, mechanical and biological control actions undertaken since the time of data collection[15] should be continued to ensure that existing infestation sites are reduced to minimal levels. It is also imperative to monitor areas that are susceptible to invasion and eliminate small populations before they are able to become unmanageable. Unlike most other human impacts, non-native species do more damage under the "no action" alternative, allowing a small problem to become a big one (Kummerow

[15] Since about 2002, weed control has been undertaken on some portions of the Columbia Lake and Premier Ridge winter ranges, and through much of the Bull River and Mount Broadwood ranges (I. Teske, Ministry of Environment, Cranbrook, pers. comm.).

1992). If control treatments are implemented, then a monitoring system should be established to determine the effectiveness of the treatments.

2. **Habitat restoration** has been planned to address forest ingrowth throughout the Trench, including in bighorn sheep ranges (Anderson et al. 2006). Planners should ensure that forests encroaching on the Columbia Lake, Premier Ridge, Bull River and Mount Broadwood ranges are targeted, to prevent loss of forage and impairment of the lines-of-sight needed for predator avoidance. Where possible, these sites should be within or adjacent to the composite home ranges of collared ewes (Chapter 4) to maximize the likelihood of them being near escape terrain and in areas known to sheep.

   One important caveat to the value of restoration work is that the use of prescribed fire should be evaluated with respect to its impact on weed populations. Mechanical removal of conifer stems may be a more suitable treatment than prescribed fire where weeds are especially problematic. If burning is deemed the best method to improve habitat and range, weighing all other factors, then a weed management plan must be part of the prescription. It may be appropriate to apply herbicides to certain weeds once they have regrown after a fire, especially if they are more robust and stand above the native vegetation. Control of squarrose knapweed by applying herbicide the first fall after a summer burn was 98 to 100% effective, versus 20% or less in adjacent unburned areas (S. Dewey pers. comm. in Asher 2000). Whether fire or mechanical removal is used, sites with fewer weeds or farther from weed sources should receive priority where possible. If it is not possible to include weed control considerations in the prescription, it may be better to delay habitat restoration rather than risk further range degradation.

   One further consideration in planning restoration activities is that sheep diet was not entirely composed of grasses and grassland-associated forbs. Willow was a significant item at all study areas, and creeping Oregon-grape was heavily used at Mount Broadwood. Prescriptions should consider the effect on such items, so that restoration either regenerates them or (if fire is likely to cause long-term damage) protects them.

3. To **monitor range trends** and determine potential shifts in species composition, the exclosure transects should be re-read on a regular schedule, such as every 3 to 5 years. In addition to responses from grazing, conifer ingrowth and exotic plant infestations, variation in annual weather patterns can alter plant species composition and cover, so ongoing monitoring is necessary to reliably indicate trends. The exclosures themselves should be checked on a regular basis to ensure that the fences are in good repair and the transect pins remain in place.

   Further vegetation monitoring is also possible through the re-reading of the preferred-habitat transects that were established during this study. Although these transects were marked using metal pins and wooden stakes, some had already been vandalized prior to the completion of this project. Those that remain in place could be read every 3 to 5 years. The methodology used in this survey should be adopted to ensure comparable results. Only the percent species composition values should be used for comparative purposes, not the relative cover values. Cover values can vary with the time of observation, short term weather or long term climatic fluctuations. Two or more successive wet or dry years can alter basal frequency cover (Olson et al. 1985).

   If data analysis reveals a change in the species composition, an evaluation of the causes would be warranted. Such changes could result from overuse of the forage due to livestock or wild ungulate grazing in specific range units. If so, management practices should be reviewed to ensure that the natural resources remain sustainable and the range is not deteriorating due to unpalatable forages or weed infestations.

The 4 transects in the areas where controlled burning took place at Bull River in 1998 and 2000 should be re-read periodically to monitor the progression in plant species composition and cover. This will be useful to determine whether there is a trend toward desired species. It is also important to note whether the sulphur cinquefoil colonies remain as numerous and vigorous as they were following the burns. Similarly, if further controlled burns are planned in any of the study areas, then monitoring plots should be established during the growing season prior to the burn and should be re-read the following growing season and periodically thereafter. This is the only way to accurately determine whether the controlled burn is having the desired effect.

4. The degree of **forest ingrowth** has not been investigated recently on bighorn winter ranges. Recent and archived air photos should be compared locally as done at a broader scale by Gayton (1997) to identify the rate of conversion. This should be supplemented by field investigations of conifer seedling establishment to project future trends.

5. Significant **erosion** problems due in large part to livestock grazing were evident on the steep hillside above the Bull River, immediately east of the Wardner – Fort Steele Road bridge. It is recommended that this area be fenced to limit or prevent its use by livestock.

6. The effect of **other ungulates** on sheep winter ranges should be further investigated. In Glacier National Park, Montana, overgrazing by historically high levels of wintering elk has been hypothesized to be a factor in spotted knapweed expansion at the expense of native plant populations in fescue grasslands (Tyser and Key 1988 cited in Rice et al. 1997, Tyser 1992 cited in Rice et al. 1997). Wigwam Flats appeared to have been heavily grazed by elk, so it is possible that the high cover of common St. John's-wort there was attributable to that, and there is potential for further expansion of spotted knapweed. However, elk populations in the greater Mount Broadwood area were actually the lowest of the 4 winter ranges (Table 3 of Chapter 6). Further work is required to determine whether localized high densities of elk or possibly deer have the potential to cause continued weed dispersal.

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Appendix 5-1. Plants identified in the Columbia Lake, Premier Ridge, Bull River and Mount Broadwood study areas. Useage follows http://www.eflora.bc.ca/ (accessed 1 December 2006).

Appendix 5-1A: List sorted by scientific name.

Scientific Name	Common Name	Code
Acer glabrum	Douglas maple	acergla
Achillea millefolium	yarrow	achimil
Achnatherum hymenoides	Indian ricegrass	achnhym
Achnatherum nelsonii	Columbian needlegrass	achnnel
Achnatherum richardsonii	spreading needlegrass	achnric
Agoseris glauca	short-beaked agoseris	agosgla
Allium cernuum	nodding onion	allicer
Alyssum alyssoides	pale alyssum	alysaly
Amelanchier alnifolia	Saskatoon	amelaln
Anemone multifida	cut-leaved anemone	anemmul
Anemone patens ssp. *multifida*	prairie crocus	anempat
Antennaria luzuloides	woodrush pussytoes	anteluz
Antennaria microphylla	white pussytoes	antemic
Antennaria neglecta	field pussytoes	anteneg
Antennaria parvifolia	Nuttall's pussytoes	antepar
Apocynum androsaemifolium	spreading dogbane	apocand
Arabis holboellii	Holboell's rockcress	arabhol
Arctostaphylos uva-ursi	kinnikinnick	arctuva
Arenaria serpyllifolia	thyme-leaved sandwort	arenser
Arnica fulgens var. *sororia*	orange arnica	arniful
Artemesia dracunculus	tarragon	artedra
Artemesia frigida	prairie sagewort	artefri
Aster conspicuus	showy aster	astecon
Aster ericoides	tufted white prairie aster	asteeri
Aster falcatus	little gray aster	astefal
Aster laevis	smooth aster	astelae
Astragalus lotiflorus	lotus milk-vetch	astrlot
Astragalus miser	timber milk-vetch	astrmis
Balsamorhiza sagittata	arrowleaf balsamroot	balssag
Betula occidentalis	water birch	betuocc
Botrychium sp.	grape fern	botrych
Bromus briziformis	rattlesnake grass	brombri
Bromus inermis	smooth brome	bromine
Bromus japonicus	Japanese brome	bromjap
Bromus tectorum	cheatgrass	bromtec
Calamagrostis rubescens	pinegrass	calarub
Calamagrostis stricta	slimstem reedgrass	calastr
Calochortus apiculatus	three-spot mariposa lily	caloapi
Calochortus macrocarpus	sagebrush mariposa lily	calomac
Campanula rotundifolia	common harebell	camprot
Carex filifolia	thread-leaved sedge	carefil
Carex rossii	Ross' sedge	careros
Carex sp.	sedge	carex
Castilleja hispida	harsh paintbrush	casthis
Castilleja lutescens	yellowish paintbrush	castlut
Ceanothus sanguineus	redstem ceanothus	ceansan

Centaurea biebersteinii	spotted knapweed	centbie
Cerastium arvense	field chickweed	ceraarv
Chamaesyce glyptosperma	corrugate-seeded spurge	chamgly
Chenopodium album	lamb's-quarters	chenalb
Chenopodium desiccatum	narrow-leaved goosefoot	chendes
Chenopodium fremontii	Fremont's goosefoot	chenfre
Cirsium undulatum	wavy-leaved thistle	cirsund
Collomia linearis	narrow-leaved collomia	colllin
Comandra umbellata var. *umbellata*	bastard toadflax	comaumb
Crepis atribarba	slender hawksbeard	crepatr
Cynoglossum officinale	common hound's-tongue	cynooff
Danthonia spicata	poverty oatgrass	dantspi
Descurainia incana	Richardson's tansy mustard	descinc
Draba sp.	draba	draba
Elymus repens	quackgrass	elymrep
Elymus trachycaulus	slender wheatgrass	elymtra
Epilobium angustifolium	fireweed	epilang
Epilobium brachycarpum	tall annual willowherb	epilbra
Ericameria nauseosus	common rabbit-brush	ericnau
Erigeron compositus	cut-leaved daisy	erigcom
Erigeron corymbosus	long-leaved fleabane	erigcor
Erigeron divergens	diffuse fleabane	erigdiv
Erigeron filifolius	thread-leaved fleabane	erigfil
Erigeron glabellus	smooth daisy	eriggla
Erigeron pumilus	shaggy fleabane	erigpum
Erigeron speciosus	showy daisy	erigspe
Erigeron strigosus	rough-stemmed fleabane	erigstr
Erythronium grandiflorum	yellow glacier lily	erytgra
Festuca campestris	rough fescue	festcam
Festuca idahoensis	Idaho fescue	festida
Festuca saximontana	Rocky Mountain fescue	festsax
Filago arvensis	field filago	filaarv
Fragaria vesca	wood strawberry	fragves
Fragaria virginiana	wild strawberry	fragvir
Fritillaria pudica	yellow bell	fritpud
Gaillardia aristata	brown-eyed Susan	gailari
Galium aparine	cleavers	galiapa
Galium boreale	northern bedstraw	galibor
Gentianella amarella	northern gentian	gentama
Geranium bicknellii	Bicknell's geranium	gerabic
Geum triflorum	old man's whiskers	geumtri
Helictotrichon hookeri	spike-oat	helihoo
Hesperostipa comata	needle-and-thread grass	hespcom
Heterotheca villosa	golden-aster	hetevil
Heuchera cylindrica	round-leaved alumroot	heuccyl
Hieracium piloselloides	tall hawkweed	hierpio
Hieracium scouleri	Scouler's hawkweed	hiersco
Holodiscus discolor	oceanspray	holodis
Hypericum perforatum	Common St. John’s wort	hypeper
Juniperus communis	common juniper	junicom
Juniperus scopulorum	Rocky Mountain juniper	junisco
Koeleria macrantha	Junegrass	koelmac
Lactuca tatarica	blue lettuce	lacttat

Lappula occidentalis	western stickseed	lappocc
Lappula squarrosa	bristly stickseed	lappsqu
Lepidium densiflorum	prairie pepper-grass	lepiden
Lesquerella douglasii	Columbia bladderpod	lesqdou
Leucanthemum vulgare	oxeye daisy	leucvul
Linum lewisii ssp. lewisii	western blue flax	linulew
Lithospermum incisum	yellow gromwell	lithinc
Lithospermun ruderale	Lemonweed	lithrud
Lomatium macrocarpum	large-fruited desert-parsley	lomamac
Lomatium triternatum	nine-leaved desert-parsley	lomatri
Lygodesmia juncea	rushlike skeleton-plant	lygojun
Mahonia repens	creeping Oregon-grape	mahorep
Medicago lupulina	black medic	medilup
Medicago sativa	alfalfa	medisat
Melilotus alba	white sweet-clover	melialb
Melilotus sp.	sweet-clover	melilot
Melilotus officinalis	yellow sweet-clover	melioff
Microsteris gracilis	pink twink	micrgra
Monarda fistulosa	wild bergamot	monafis
Monolepis nuttalliana	poverty weed	mononut
Neslia paniculata	ball mustard	neslpan
Orobanche ludoviciana	Suksdorf's broomrape	oroblud
Orthocarpus tenuifolius	thin-leaved owl-clover	orthten
Oxytropis sp.	locoweed	oxytrop
Pascopyrum smithii	western bluegrass	pascsmi
Penstemon albertinus	Alberta penstemon	pensalb
Penstemon confertus	yellow penstemon	penscon
Penstemon eriantherus	fuzzy-tongued penstemon	penseri
Penstemon fruticosus	shrubby penstemon	pensfru
Penstemon gracilis	slender penstemon	pensgra
Phacelia hastata	silverleaf phacelia	phachas
Phacelia linearis	thread-leaved phacelia	phaclin
Philadelphus lewisii	mock-orange	phillew
Phleum pratense	common timothy	phlepra
Phlox caespitosa	tufted phlox	phlocae
Physocarpus malvaceus	mallow ninebark	physmal
Pinus ponderosa	ponderosa pine	pinupon
Plantago patagonica	woolly plantain	planpat
Poa compressa	Canada bluegrass	poa com
Poa pratensis	Kentucky bluegrass	poa pra
Poa secunda	Sandberg's bluegrass	poa sec
Polemonium pulcherrimum	showy Jacob's-ladder	polepul
Polygonum convolvulus	black bindweed	polycon
Polygonum douglasii ssp. *douglasii*	Douglas' knotweed	polydou
Populus tremuloides	trembling aspen	poputre
Potentilla argentea	silvery cinquefoil	potearg
Potentilla arguta	white cinquefoil	potearg
Potentilla pensylvanica	Pennsylvanian cinquefoil	potepen
Potentilla recta	sulphur cinquefoil	poterec
Prunus pensylvanica	pin cherry	prunpen
Prunus virginiana	choke cherry	prunpen
Pseudotsuga menziesii	Douglas-fir	pseumen
Pseudoroegneria spicata	bluebunch wheatgrass	pseuspi

Purshia tridentata	antelope-brush	purstri
Ranunculus acris	meadow buttercup	ranuacr
Rhinanthus minor	yellow rattle	rhinmin
Rosa acicularis	prickly rose	rosaaci
Rosa arkansana	Arkansas rose	rosaark
Rosa woodsii	prairie rose	rosawoo
Salix spp.	willow	salix
Sanguisorba annua	western burnet	sangann
Schizachyrium scoparium	little bluestem	schisco
Sedum lanceolatum	lance-leaved stonecrop	sedulan
Selaginella densa	compact selaginella	seladen
Senecio canus	woolly groundsel	senecan
Senecio pauperculus	Canadian butterweed	senepau
Shepherdia canadensis	soopolallie	shepcan
Silene antirrhina	sleepy catchfly	sileant
Silene menziesii	Menzies' campion	silemen
Silene sp.	catchfly	silene
Sisymbrium altissimum	tall tumble-mustard	sisyalt
Sisyrinchium montanum	mountain blue-eyed-grass	sisymon
Solidago spathulata	spikelike goldenrod	solispa
Sonchus arvensis	perennial sow-thistle	soncarv
Spiraea betulifolia	birch-leaved spirea	spirbet
Sporobolus cryptandrus	sand dropseed	sporcry
Symphoricarpos albus	common snowberry	sympalb
Symphoricarpos occidentalis	western snowberry	sympocc
Taraxacum officinale	common dandelion	taraoff
Thlaspi arvense	field pennycress	thlaarv
Tragopogon dubius	yellow salsify	tragdub
Trifolium aureum	yellow clover	trifaur
Trifolium pratense	red clover	trifpra
Trifolium repens	white clover	trifrep
Verbascum thapsus	great mullein	verbtha
Veronica peregrina	purslane speedwell	veroper
Vicia americana	American vetch	viciame
Vicia cracca	tufted vetch	vicicra
Viola sp.	violet	viola
Viola adunca	early blue violet	violadu
Woodsia oregana	western cliff fern	woodore
Zigadenus venenosus	meadow death camas	zygaven

Appendix 5-1B: List sorted by common name.

Scientific Name	Common Name	Code
Penstemon albertinus	Alberta penstemon	pensalb
Medicago sativa	alfalfa	medisat
Vicia americana	American vetch	viciame
Purshia tridentata	antelope-brush	purstri
Rosa arkansana	Arkansas rose	rosaark
Balsamorhiza sagittata	arrowleaf balsamroot	balssag
Neslia paniculata	ball mustard	neslpan
Comandra umbellata var. *umbellata*	bastard toadflax	comaumb
Geranium bicknellii	Bicknell's geranium	gerabic
Spiraea betulifolia	birch-leaved spirea	spirbet
Polygonum convolvulus	black bindweed	polycon
Medicago lupulina	black medic	medilup
Lactuca tatarica	blue lettuce	lacttat
Pseudoroegneria spicata	bluebunch wheatgrass	pseuspi
Lappula squarrosa	bristly stickseed	lappsqu
Gaillardia aristata	brown-eyed Susan	gailari
Poa compressa	Canada bluegrass	poa com
Senecio pauperculus	Canadian butterweed	senepau
Silene sp.	catchfly	silene
Bromus tectorum	cheatgrass	bromtec
Prunus virginiana	choke cherry	prunpen
Galium aparine	cleavers	galiapa
Lesquerella douglasii	Columbia bladderpod	lesqdou
Achnatherum nelsonii	Columbian needlegrass	achnnel
Taraxacum officinale	common dandelion	taraoff
Campanula rotundifolia	common harebell	camprot
Cynoglossum officinale	common hound's-tongue	cynooff
Juniperus communis	common juniper	junicom
Ericameria nauseosus	common rabbit-brush	ericnau
Symphoricarpos albus	common snowberry	sympalb
Hypericum perforatum	Common St. John's wort	hypeper
Phleum pratense	common timothy	phlepra
Selaginella densa	compact selaginella	seladen
Chamaesyce glyptosperma	corrugate-seeded spurge	chamgly
Mahonia repens	creeping Oregon-grape	mahorep
Anemone multifida	cut-leaved anemone	anemmul
Erigeron compositus	cut-leaved daisy	erigcom
Erigeron divergens	diffuse fleabane	erigdiv
Polygonum douglasii ssp. *douglasii*	Douglas' knotweed	polydou
Acer glabrum	Douglas maple	acergla
Pseudotsuga menziesii	Douglas-fir	pseumen
Draba sp.	draba	draba
Viola adunca	early blue violet	violadu
Cerastium arvense	field chickweed	ceraarv
Filago arvensis	field filago	filaarv
Thlaspi arvense	field pennycress	thlaarv
Antennaria neglecta	field pussytoes	anteneg
Epilobium angustifolium	fireweed	epilang
Chenopodium fremontii	Fremont's goosefoot	chenfre

Penstemon eriantherus	fuzzy-tongued penstemon	penseri
Heterotheca villosa	golden-aster	hetevil
Botrychium sp.	grape fern	botrych
Verbascum thapsus	great mullein	verbtha
Castilleja hispida	harsh paintbrush	casthis
Arabis holboellii	Holboell's rockcress	arabhol
Festuca idahoensis	Idaho fescue	festida
Achnatherum hymenoides	Indian ricegrass	achnhym
Bromus japonicus	Japanese brome	bromjap
Koeleria macrantha	Junegrass	koelmac
Poa pratensis	Kentucky bluegrass	poa pra
Arctostaphylos uva-ursi	kinnikinnick	arctuva
Chenopodium album	lamb's-quarters	chenalb
Sedum lanceolatum	lance-leaved stonecrop	sedulan
Lomatium macrocarpum	large-fruited desert-parsley	lomamac
Lithospermun ruderale	Lemonweed	lithrud
Schizachyrium scoparium	little bluestem	schisco
Aster falcatus	little gray aster	astefal
Oxytropis sp.	locoweed	oxytrop
Erigeron corymbosus	long-leaved fleabane	erigcor
Astragalus lotiflorus	lotus milk-vetch	astrlot
Physocarpus malvaceus	mallow ninebark	physmal
Ranunculus acris	meadow buttercup	ranuacr
Zigadenus venenosus	meadow death camas	zygaven
Silene menziesii	Menzies' campion	silemen
Philadelphus lewisii	mock-orange	phillew
Sisyrinchium montanum	mountain blue-eyed-grass	sisymon
Collomia linearis	narrow-leaved collomia	collin
Chenopodium desiccatum	narrow-leaved goosefoot	chendes
Hesperostipa comata	needle-and-thread grass	hespcom
Lomatium triternatum	nine-leaved desert-parsley	lomatri
Allium cernuum	nodding onion	allicer
Galium boreale	northern bedstraw	galibor
Gentianella amarella	northern gentian	gentama
Antennaria parvifolia	Nuttall's pussytoes	antepar
Holodiscus discolor	oceanspray	holodis
Geum triflorum	old man's whiskers	geumtri
Arnica fulgens var. *sororia*	orange arnica	arniful
Leucanthemum vulgare	oxeye daisy	leucvul
Alyssum alyssoides	pale alyssum	alysaly
Potentilla pensylvanica	Pennsylvanian cinquefoil	potepen
Sonchus arvensis	perennial sow-thistle	soncarv
Prunus pensylvanica	pin cherry	prunpen
Calamagrostis rubescens	pinegrass	calarub
Microsteris gracilis	pink twink	micrgra
Pinus ponderosa	ponderosa pine	pinupon
Danthonia spicata	poverty oatgrass	dantspi
Monolepis nuttalliana	poverty weed	mononut
Anemone patens ssp. *multifida*	prairie crocus	anempat
Lepidium densiflorum	prairie pepper-grass	lepiden
Rosa woodsii	prairie rose	rosawoo

Artemesia frigida	prairie sagewort	artefri
Rosa acicularis	prickly rose	rosaaci
Veronica peregrina	purslane speedwell	veroper
Elymus repens	quackgrass	elymrep
Bromus briziformis	rattlesnake grass	brombri
Trifolium pratense	red clover	trifpra
Ceanothus sanguineus	redstem ceanothus	ceansan
Descurainia incana	Richardson's tansy mustard	descinc
Festuca saximontana	Rocky Mountain fescue	festsax
Juniperus scopulorum	Rocky Mountain juniper	junisco
Carex rossii	Ross' sedge	careros
Festuca campestris	rough fescue	festcam
Erigeron strigosus	rough-stemmed fleabane	erigstr
Heuchera cylindrica	round-leaved alumroot	heuccyl
Lygodesmia juncea	rushlike skeleton-plant	lygojun
Calochortus macrocarpus	sagebrush mariposa lily	calomac
Sporobolus cryptandrus	sand dropseed	sporcry
Poa secunda	Sandberg's bluegrass	poa sec
Amelanchier alnifolia	Saskatoon	amelaln
Hieracium scouleri	Scouler's hawkweed	hiersco
Carex sp.	sedge	carex
Erigeron pumilus	shaggy fleabane	erigpum
Agoseris glauca	short-beaked agoseris	agosgla
Aster conspicuus	showy aster	astecon
Erigeron speciosus	showy daisy	erigspe
Polemonium pulcherrimum	showy Jacob's-ladder	polepul
Penstemon fruticosus	shrubby penstemon	pensfru
Phacelia hastata	silverleaf phacelia	phachas
Potentilla argentea	silvery cinquefoil	potearg
Silene antirrhina	sleepy catchfly	sileant
Crepis atribarba	slender hawksbeard	crepatr
Penstemon gracilis	slender penstemon	pensgra
Elymus trachycaulus	slender wheatgrass	elymtra
Calamagrostis stricta	slimstem reedgrass	calastr
Aster laevis	smooth aster	astelae
Bromus inermis	smooth brome	bromine
Erigeron glabellus	smooth daisy	eriggla
Shepherdia canadensis	soopolallie	shepcan
Solidago spathulata	spikelike goldenrod	solispa
Helictotrichon hookeri	spike-oat	helihoo
Centaurea biebersteinii	spotted knapweed	centbie
Apocynum androsaemifolium	spreading dogbane	apocand
Achnatherum richardsonii	spreading needlegrass	achnric
Orobanche ludoviciana	Suksdorf's broomrape	oroblud
Potentilla recta	sulphur cinquefoil	poterec
Melilotus sp.	sweet-clover	melilot
Epilobium brachycarpum	tall annual willowherb	epilbra
Hieracium piloselloides	tall hawkweed	hierpio
Sisymbrium altissimum	tall tumble-mustard	sisyalt
Artemesia dracunculus	tarragon	artedra
Orthocarpus tenuifolius	thin-leaved owl-clover	orthten

Erigeron filifolius	thread-leaved fleabane	erigfil
Phacelia linearis	thread-leaved phacelia	phaclin
Carex filifolia	thread-leaved sedge	carefil
Calochortus apiculatus	three-spot mariposa lily	caloapi
Arenaria serpyllifolia	thyme-leaved sandwort	arenser
Astragalus miser	timber milk-vetch	astrmis
Populus tremuloides	trembling aspen	poputre
Phlox caespitosa	tufted phlox	phlocae
Vicia cracca	tufted vetch	vicicra
Aster ericoides	tufted white prairie aster	asteeri
Viola sp.	violet	viola
Betula occidentalis	water birch	betuocc
Cirsium undulatum	wavy-leaved thistle	cirsund
Linum lewisii ssp. lewisii	western blue flax	linulew
Pascopyrum smithii	western bluegrass	pascsmi
Sanguisorba annua	western burnet	sangann
Woodsia oregana	western cliff fern	woodore
Symphoricarpos occidentalis	western snowberry	sympocc
Lappula occidentalis	western stickseed	lappocc
Potentilla arguta	white cinquefoil	potearg
Trifolium repens	white clover	trifrep
Antennaria microphylla	white pussytoes	antemic
Melilotus alba	white sweet-clover	melialb
Monarda fistulosa	wild bergamot	monafis
Fragaria virginiana	wild strawberry	fragvir
Salix spp.	willow	salix
Fragaria vesca	wood strawberry	fragves
Antennaria luzuloides	woodrush pussytoes	anteluz
Senecio canus	woolly groundsel	senecan
Plantago patagonica	woolly plantain	planpat
Achillea millefolium	yarrow	achimil
Fritillaria pudica	yellow bell	fritpud
Trifolium aureum	yellow clover	trifaur
Erythronium grandiflorum	yellow glacier lily	erytgra
Lithospermum incisum	yellow gromwell	lithinc
Penstemon confertus	yellow penstemon	penscon
Rhinanthus minor	yellow rattle	rhinmin
Tragopogon dubius	yellow salsify	tragdub
Melilotus officinalis	yellow sweet-clover	melioff
Castilleja lutescens	yellowish paintbrush	castlut

Appendix 5-2. Study plot and transect locations.

UTM Coordinates are listed below, with maps on following pages. Coordinates are not precise due to GPS error, especially because American satellites still had intentional selective availability issues at the time of the study. Start and end points of transects were 30 m apart (as indicated by a measuring tape) even where UTM coordinates may indicate otherwise.

Note: The datum used for recording the following locations was not noted in the database, but is believed to be NAD83. The records should be tested against a permanent structure (an exclosure) to confirm this prior to searching for transect locations.

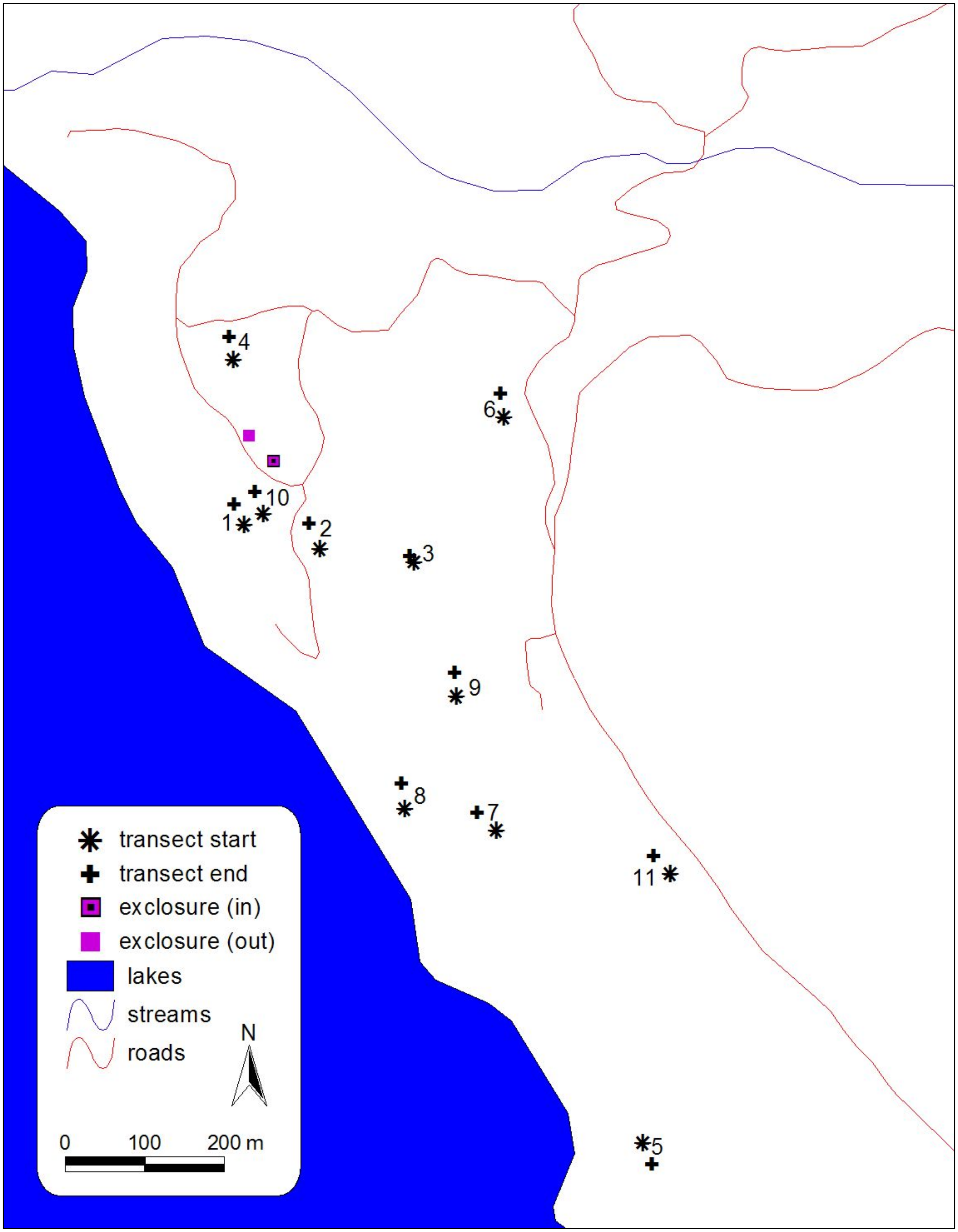
Study Area	Site	Position	Easting	Northing	Accuracy (+/- _ m)[1]	No. of Satellites	Elevation (m)[2]
Columbia Lake	CL-01	0 m	583206	5561718	5	8	853
		30 m	583193	5561745	5	8	854
	CL-02	0 m	583301	5561688	5	8	866
		30 m	583287	5561721	5	8	867
	CL-03	0 m	583419	5561671	6	7	912
		30 m	583414	5561680	6	7	915
	CL-04	0 m	583192	5561925	5	7	879
		30 m	583187	5561955	5	8	881
	CL-05	0 m	583706	5560943	4	7	916
		30 m	583718	5560917	4	7	917
	CL-06	0 m	583532	5561853	4	8	959
		30 m	583528	5561883	4	8	956
	CL-07	0 m	583522	5561335	12	6	954
[3]		30 m	583498	5561358	10	6	959
	CL-08	0 m	583407	5561362	6	7	912
		30 m	583403	5561395	6	7	918
	CL-09	0 m	583472	5561503	12	5	937
		30 m	583470	5561534	12	5	938
	CL-10	0 m	583230	5561732	5	8	862
		30 m	583220	5561760	5	8	863
	CL-11	0 m	583741	5561281	5	6	975
		30 m	583720	5561304	5	6	976
	Exclosure	in	583242	5561798	5	8	863
		out	583211	5561829	5	8	865
Premier Ridge	PR-01	0 m	594832	5526758	10	7	1021
		30 m	594845	5526729	10	7	1013
	PR-02	0 m	595112	5526469	4	8	1038
		30 m	595095	5526494	4	7	1039
	PR-03	0 m	595138	5526666	4	9	1087
		30 m	595127	5526694	4	7	1091
	PR-04	0 m	595174	5526225	5	9	997
		30 m	595162	5526252	5	8	997
	PR-05	0 m	595144	5526357	5	8	1011
		30 m	595114	5526358	5	8	1008
	PR-06	0 m	595271	5526390	4	8	1069
		30 m	595253	5526364	4	9	1068
	PR-07	0 m	595581	5526009	4	10	1083
		30 m	pin missing				
	PR-08	0 m	595541	5525897	5	9	1071
[4]		30 m	595519	5525917	5	9	1072

	PR-09	0 m	595277	5526072	5	8	1011
		30 m	595262	5526097	5	8	1006
	PR-10	0 m	594825	5526662	5	6	996
		30 m	594813	5526688	5	7	996
	PR-11	0 m	594792	5526616	5	6	988
		30 m	594773	5526643	5	6	987
	PR-12	0 m	595127	5526606	4	8	1073
		30 m	595096	5526617	4	7	1067
	PR-13	0 m	595561	5525929	4	10	1088
		30 m	595537	5525947	4	10	1084
Bull River	BR-01	0 m	612289	5481402	4	8	764
		30 m	612316	5481398	5	6	761
	BR-02	0 m	613713	5482360	5	6	877
		30 m	613719	5482388	5	6	875
	BR-03	0 m	613629	5481910	5	7	836
		30 m	613645	5481934	5	6	836
	BR-04	0 m	612679	5481375	4	9	783
		30 m	612649	5481380	4	9	783
	BR-05	0 m	612691	5481562	5	8	807
		30 m	612661	5481559	4	8	809
	BR-06	0 m	614290	5482689	5	6	852
		30 m	614264	5482679	5	6	857
	BR-07	0 m	615187	5483690	5	9	862
		30 m	615213	5483679	5	8	860
	BR-08	0 m	615853	5484004	5	8	858
		30 m	615822	5484004	5	9	857
	BR-09	0 m	614481	5483949	5	8	893
		30 m	614453	5483936	5	8	895
	BR-10	0 m	pin missing	located on	rough location (as marked on air		
		30 m	pin missing	F&W flat	photo) is 612450 E x 5481350 N		
5	BR-11	0 m	612765	5481375	4	9	790
		30 m	612738	5481380	4	9	787
	BR-12	0 m	614311	5482951	4	10	849
		30 m	614292	5482930	4	10	852
	BR-13	0 m	612604	5481546	5	7	815
		30 m	612579	5481537	5	7	813
	BR-14	0 m	609275	5482095	4	9	898
		30 m	609250	5482106	4	10	896
	BR-15	0 m	609464	5482103	4	8	926
		30 m	609442	5482123	4	8	929
	Exclosure	in	612349	5481575	6	8	823
		out	612354	5481552	5	8	819
Mt Broadwood	MB-1	0 m	638432	5460675	4	10	993
		30 m	638402	5460684	4	10	992
	MB-2	0 m	638786	5460117	4	9	997
		30 m	638768	5460143	4	9	996
	MB-3	0 m	638694	5459389	4	9	953
		30 m	638677	5459412	4	9	944
	MB-4	0 m	639134	5457841	5	11	929
		30 m	639113	5457866	5	9	928
	MB-5	0 m	639154	5457504	4	10	926
		30 m	639155	5457534	4	10	926
	MB-6	0 m	639703	5457533	4	11	1023
		30 m	639704	5457549	4	9	1023

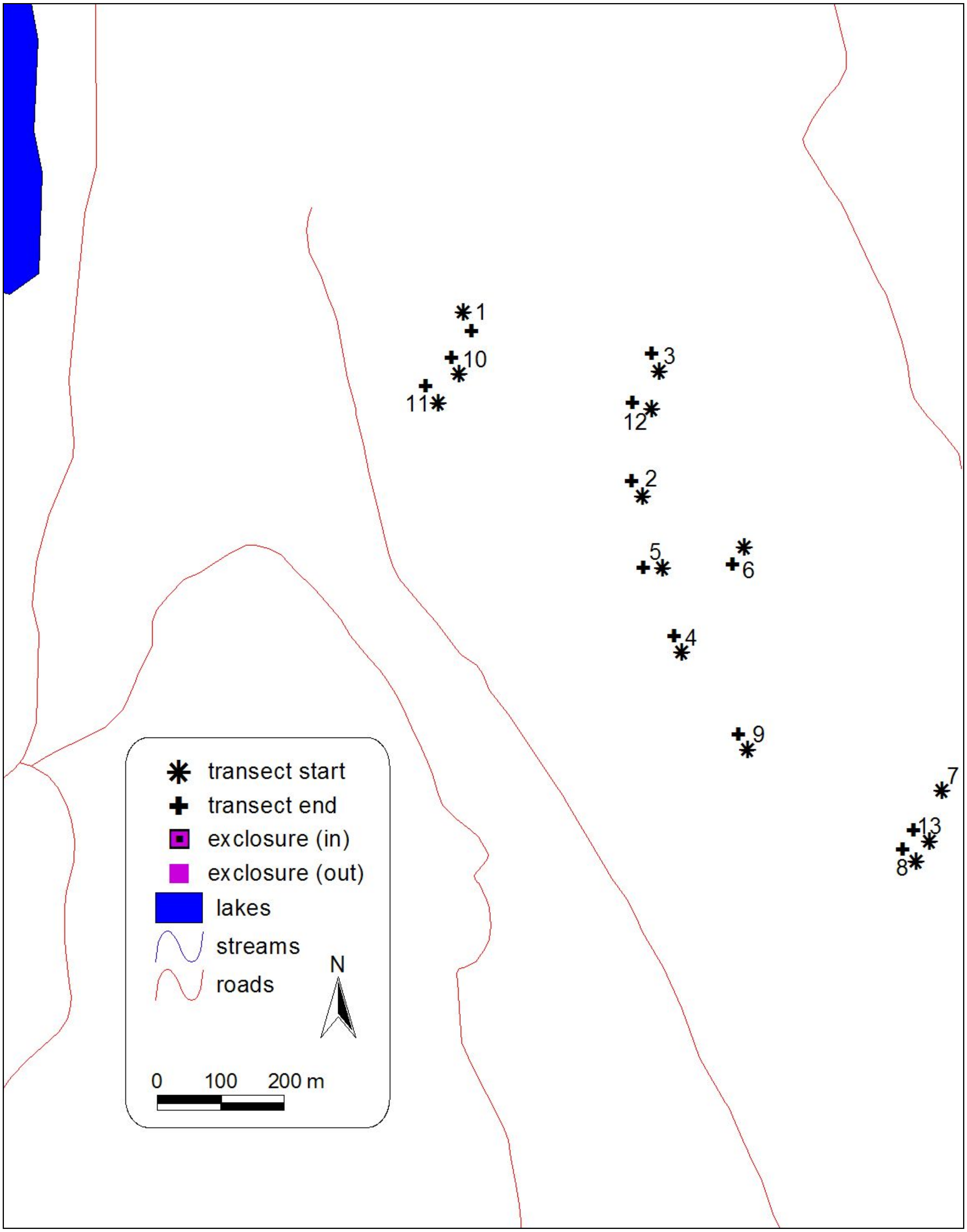
MB-7	0 m	639824	5457856	5	8	1034
	30 m	639792	5457852	5	8	1037
MB-8	0 m	641962	5456600	5	7	1025
	30 m	641940	5456580	4	10	1023
MB-9	0 m	641251	5455827	4	11	989
	30 m	641222	5455828	4	11	992
MB-10	0 m	641406	5455808	4	11	991
	30 m	641377	5455811	4	10	989
MB-11	0 m	641208	5455963	4	10	1008
	30 m	641180	5455977	4	10	1009
MB-12	0 m	640251	5456061	4	10	1003
	30 m	640236	5456084	5	10	1004
MB-13	0 m	639402	5458109	5	9	1039
	30 m	639390	5458138	4	9	1039
MB-14	0 m	639512	5457786	6	9	1034
	30 m	639524	5457817	6	9	1035
MB-15	0 m	639130	5458212	5	10	954
	30 m	639116	5458236	5	9	956
MB-16	0 m	640210	5456543	4	9	1015
	30 m	640178	5456541	4	9	1016
MB-17	0 m	638948	5459096	5	9	1010
	30 m	638935	5459121	4	9	1012
MB-18	0 m	638737	5460843	6	8	1130
	30 m	638710	5460856	7	8	1138
MB-19	0 m	638579	5459770	4	9	956
	30 m	638569	5459796	4	9	956
MB-20	0 m	639257	5457826	5	9	942
	30 m	639248	5457855	5	9	940
MB-21	0 m	638085	5461588	7	9	1107
	30 m	638079	5461618	5	10	1108
MB-22	0 m	638156	5461463	7	8	1101
	30 m	638150	5461492	7	8	1103
MB-23	0 m	638481	5460747	6	8	1010
	30 m	638455	5460758	6	8	1010
Exclosure	in	642710	5456483	15	7	1008
	out	642680	5456500	15	7	1008

[1] Accuracy is nominal, based on probability distribution assumed by GPS unit software.
[2] Elevation based on GPS unit output.
[3] Easting for transect end point listed in original database as 583598 (changed to 583498 to put it at 30 m from start point and to match location marked on air photo).
[4] Northing for transect end point listed in original database as 5525817 (changed to 5525917 to put it at 30 m from start point and to match location marked on air photo).
[5] Based on location marked on air photo, true location may be about 100 m north of these coordinates.

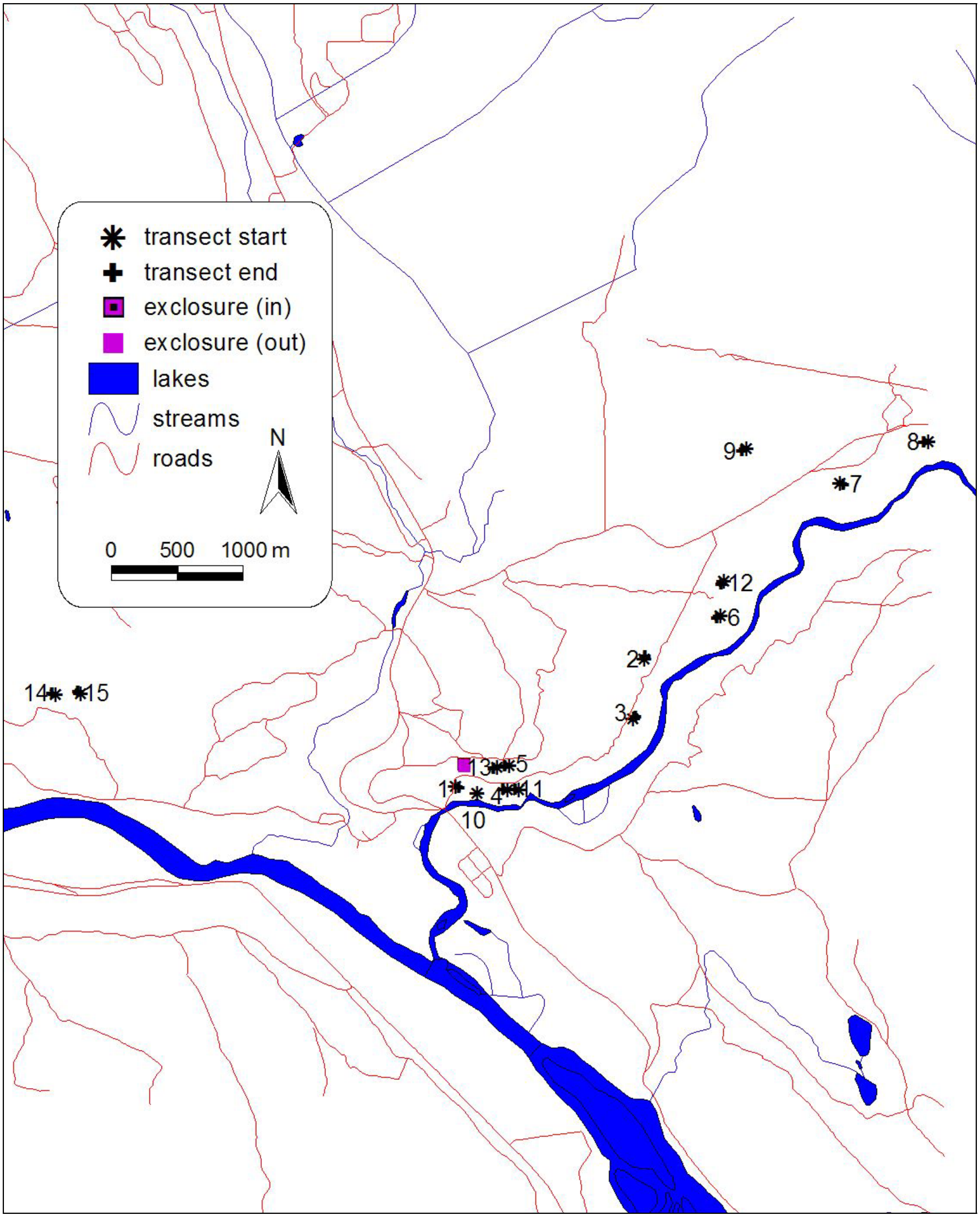
Columbia Lake Sampling Locations



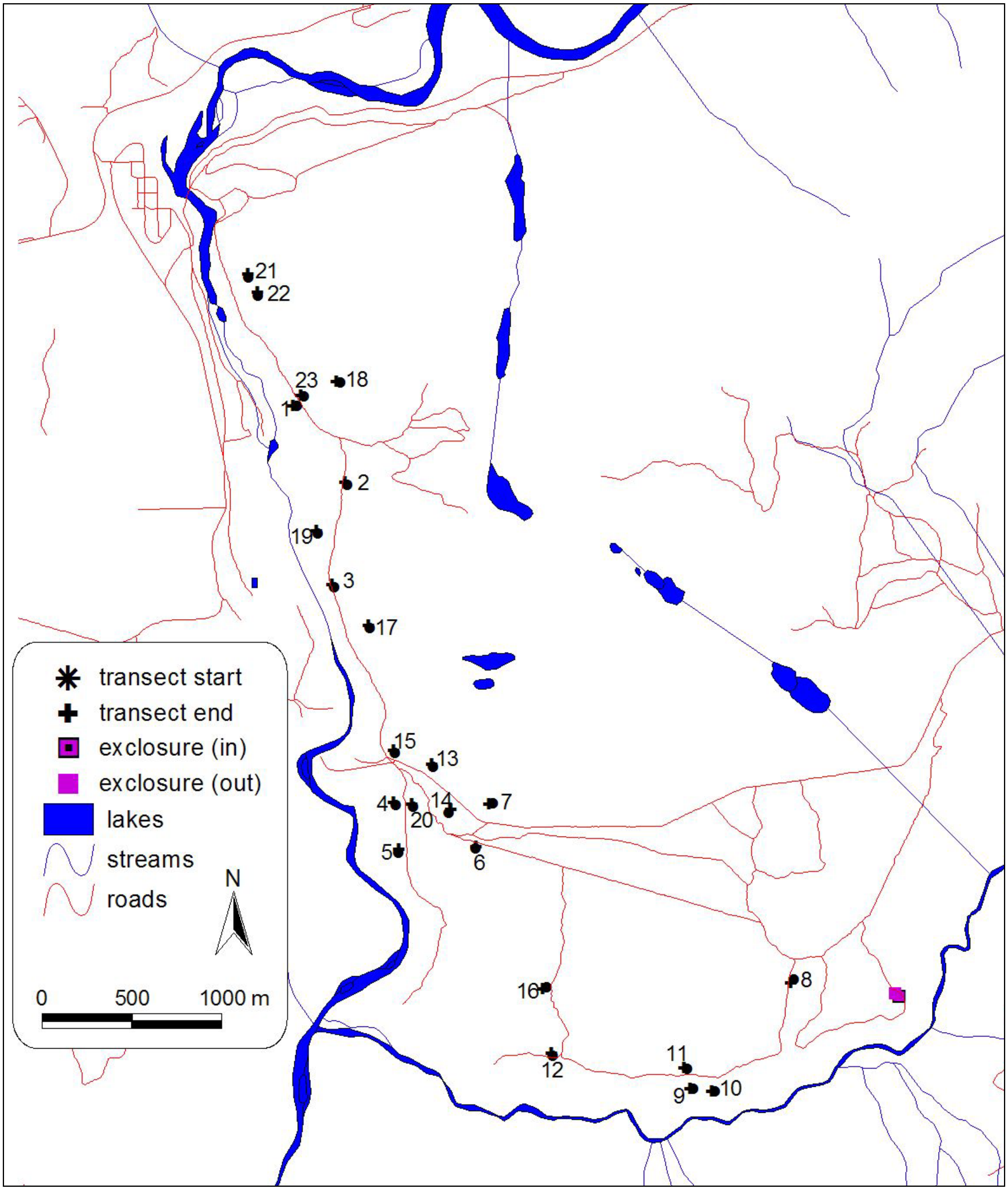
Premier Ridge Sampling Locations



Bull River Sampling Locations



Mount Broadwood Sampling Locations



Appendix 5-3. Plants identified in the Columbia Lake study area.

Scientific Name	Common Name	Relative Abundance	Introduced Status
Achillea millefolium	yarrow	common	
Achnatherum hymenoides	Indian ricegrass	rare	
Allium cernuum	nodding onion	common	
Anemone multifida	cut-leaved anemone	rare	
Anemone patens ssp. *multifida*	prairie crocus	rare	
Antennaria microphylla	white pussytoes	common	
Arabis holboellii	Holboell's rockcress	common	
Artemesia dracunculus	tarragon	rare	
Artemesia frigida	prairie sagewort	abundant	
Aster falcatus	little gray aster	common	
Astragalus miser	timber milk-vetch	common	
Bromus tectorum	cheatgrass	abundant	introduced
Calochortus macrocarpus	sagebrush mariposa lily	rare	
Carex sp.	sedge	common	
Carex filifolia	thread-leaved sedge	rare	
Centauria biebersteinii	spotted knapweed		introduced
Chenopodium album	lamb's-quarters	common	introduced
Chenopodium fremontii	Fremont's goosefoot	rare	
Comandra umbellata var. *umbellata*	bastard toadflax	common	
Crepis atribarba	slender hawksbeard	common	
Descurainia incana	Richardson's tansy mustard	common	
Ericameria nauseosus	common rabbit-brush	abundant	
Erigeron compositus	cut-leaved daisy	common	
Erigeron corymbosus	long-leaved fleabane	rare	
Erigeron filifolius	thread-leaved fleabane	common	
Erigeron pumilus	shaggy fleabane	common	
Festuca campestris	rough fescue	rare	
Gaillardia aristata	brown-eyed Susan	common	
Hesperostipa comata	needle-and-thread grass	abundant	
Heterotheca villosa	golden-aster	common	
Heuchera cylindrica	round-leaved alumroot	rare	
Juniperus scopulorum	Rocky Mountain juniper	abundant	
Koeleria macrantha	junegrass	abundant	
Lappula occidentalis	western stickseed	rare	
Lappula squarrosa	bristly stickseed	common	introduced
Lepidium densiflorum	prairie pepper-grass	rare	
Lesquerella douglasii	Columbia bladderpod	common	
Linum lewisii ssp. *lewisii*	western blue flax	common	
Lithospermum incisum	yellow gromwell	common	
Lithospermun ruderale	lemonweed	common	

Lomatium macrocarpum	large-fruited desert-parsley	common	
Medicago lupulina	black medic	common	introduced
Melilotus sp.	sweet-clover	common	introduced
Monolepis nuttalliana	poverty weed	rare	introduced
Neslia paniculata	ball mustard	rare	introduced
Pascopyrum smithii	western bluegrass	abundant	
Penstemon confertus	yellow penstemon	rare	
Penstemon eriantherus	fuzzy-tongued penstemon	rare	
Phacelia linearis	thread-leaved phacelia	rare	
Poa compressa	Canada bluegrass	common	introduced
Poa secunda	Sandberg's bluegrass	common	
Populus tremuloides	trembling aspen	abundant	
Potentilla pensylvanica	Pennsylvanian cinquefoil	common	
Pseudoroegneria spicata	bluebunch wheatgrass	abundant	
Pseudotsuga menziesii	Douglas-fir	abundant	
Sedum lanceolatum	lance-leaved stonecrop	rare	
Selaginella densa	compact selaginella	common	
Senecio canus	woolly groundsel	common	
Solidago spathulata	spikelike goldenrod	common	
Spiraea betulifolia	birch-leaved spirea	common	
Sporobolus cryptandrus	sand dropseed	rare	
Symphoricarpos albus	common snowberry	common	
Taraxacum officinale	common dandelion	common	introduced
Tragopogon dubius	yellow salsify	common	introduced
Verbascum thapsus	great mullein	common	introduced

Appendix 5-4. Plants identified in the Premier Ridge study area. This list includes only those present on transects, whereas lists for other study areas also include incidental observations.

Scientific Name	Common Name	Introduced Status
Achillea millefolium	yarrow	
Achnatherum nelsonii	Columbian needlegrass	
Achnatherum richardsonii	spreading needlegrass	
Allium cernuum	nodding onion	
Alyssum alyssoides	pale alyssum	introduced
Amelanchier alnifolia	saskatoon	
Antennaria microphylla	white pussytoes	
Apocynum androsaemifolium	spreading dogbane	
Arctostaphylos uva-ursi	kinnikinnick	
Arenaria serpyllifolia	thyme-leaved sandwort	introduced
Aster laevis	smooth aster	
Astragalus miser	timber milk-vetch	
Balsamorhiza sagittata	arrowleaf balsamroot	
Bromus tectorum	cheatgrass	introduced
Calamagrostis stricta	slimstem reedgrass	
Carex sp.	sedge	
Castilleja sp.	paintbrush	
Cirsium undulatum	wavy-leaved thistle	
Comandra umbellata var. *umbellata*	bastard toadflax	
Erigeron pumilus	shaggy fleabane	
Festuca campestris	rough fescue	
Fragaria virginiana	wild strawberry	
Hesperostipa comata	needle-and-thread grass	
Heterotheca villosa	golden-aster	
Hieracium scouleri	Scouler's hawkweed	
Hieracium sp.	hawkweed	
Koeleria macrantha	junegrass	
Lithospermun ruderale	lemonweed	
Oxytropis sp.	locoweed	
Phlox caespitosa	tufted phlox	
Poa compressa	Canada bluegrass	introduced
Poa sp.	bluegrass	
Prunus virginiana	choke cherry	
Pseudoroegneria spicata	bluebunch wheatgrass	
Purshia tridentata	antelope-brush	
Rosa woodsii	prairie rose	
Selaginella densa	compact selaginella	
Senecio sp.	groundsel	

Silene menziesii	Menzies' campion	
Spiraea betulifolia	birch-leaved spirea	
Symphoricarpos albus	common snowberry	
Taraxacum officinale	common dandelion	introduced
Tragopogon dubius	yellow salsify	introduced
Verbascum thapsus	great mullein	introduced

Appendix 5-5. Plants identified in the Bull River study area.

Scientific Name	Common Name	Relative Abundance	Introduced Status
Achillea millefolium	yarrow	common	
Achnatherum nelsonii	Columbian needlegrass	common	
Achnatherum richardsonii	spreading needlegrass	common	
Agoseris glauca	short-beaked agoseris	rare	
Allium cernuum	nodding onion	common	
Alyssum alyssoides	pale alyssum	common	introduced
Amelanchier alnifolia	saskatoon	abundant	
Anemone multifida	cut-leaved anemone	common	
Antennaria microphylla	white pussytoes		
Antennaria neglecta	field pussytoes	common	
Antennaria parvifolia	Nuttall's pussytoes	common	
Apocynum androsaemifolium	spreading dogbane	common	
Arabis holboellii	Holboell's rockcress	common	
Arctostaphylos uva-ursi	kinnikinnick	common	
Arenaria serpyllifolia	thyme-leaved sandwort	common	introduced
Arnica fulgens var. *sororia*	orange arnica	common	
Artemesia frigida	prairie sagewort	common	
Aster ericoides	tufted white prairie aster	common	
Aster falcatus	little gray aster		
Aster laevis	smooth aster	common	
Astragalus lotiflorus	lotus milk-vetch	rare	
Balsamorhiza sagittata	arrowleaf balsamroot		
Bromus inermis	smooth brome	common	introduced
Bromus japonicus	Japanese brome		introduced
Bromus tectorum	cheatgrass	abundant	introduced
Calamagrostis stricta	slimstem reedgrass	rare	
Carex sp.	sedge	common	
Centaurea biebersteinii	spotted knapweed	common	introduced
Chamaesyce glyptosperma	corrugate-seeded spurge	common	
Chenopodium album	lamb's-quarters	common	introduced
Chenopodium desiccatum	narrow-leaved goosefoot	common	
Cirsium undulatum	wavy-leaved thistle	common	
Collomia linearis	narrow-leaved collomia	rare	
Comandra umbellata var. *umbellata*	bastard toadflax	common	
Crepis atribarba	slender hawksbeard	rare	
Cynoglossum officinale	common hound's-tongue	common	introduced
Elymus repens	quackgrass	common	introduced
Elymus trachycaulus	slender wheatgrass	common	
Epilobium brachycarpum	tall annual willowherb	common	
Erigeron divergens	diffuse fleabane	rare	

Erigeron filifolius	thread-leaved fleabane		
Erigeron glabellus	smooth daisy	rare	
Erigeron pumilus	shaggy fleabane	common	
Festuca campestris	rough fescue	common	
Festuca idahoensis	Idaho fescue	common	
Filago arvensis	field filago	common	introduced
Fragaria virginiana	wild strawberry	common	
Gaillardia aristata	brown-eyed Susan	common	
Galium boreale	northern bedstraw	common	
Gentianella amarella	northern gentian	common	
Hesperostipa comata	needle-and-thread grass	common	
Heterotheca villosa	golden-aster	common	
Hieracium piloselloides	tall hawkweed	rare	
Juniperus communis	common juniper	common	
Juniperus scopulorum	Rocky Mountain juniper	common	
Koeleria macrantha	junegrass	common	
Lactuca tatarica	blue lettuce		
Lappula squarrosa	bristly stickseed	rare	introduced
Lepidium densiflorum	prairie pepper-grass	rare	
Lesquerella douglasii	Columbia bladderpod		
Linum lewisii ssp. lewisii	western blue flax	rare	
Lithospermum incisum	yellow gromwell	common	
Lithospermun ruderale	lemonweed	rare	
Lygodesmia juncea	rushlike skeleton-plant	rare	
Mahonia repens	creeping Oregon-grape	common	
Medicago lupulina	black medic	abundant	introduced
Medicago sativa	alfalfa	common	introduced
Melilotus alba	white sweet-clover	common	introduced
Melilotus officinalis	yellow sweet-clover	common	introduced
Monarda fistulosa	wild bergamot	common	
Neslia paniculata	ball mustard	common	introduced
Orobanche ludoviciana	Suksdorf's broomrape	rare	
Pascopyrum smithii	western bluegrass	common	
Penstemon eriantherus	fuzzy-tongued penstemon	common	
Penstemon gracilis	slender penstemon		
Phacelia hastata	silverleaf phacelia	rare	
Phacelia linearis	thread-leaved phacelia	common	
Phleum pratense	common timothy	common	introduced
Phlox caespitosa	tufted phlox	common	
Pinus ponderosa	ponderosa pine	common	
Plantago patagonica	woolly plantain		
Poa compressa	Canada bluegrass	abundant	introduced
Poa pratensis	Kentucky bluegrass	common	[1]

Polygonum convolvulus	black bindweed	rare	introduced
Polygonum douglasii ssp. *douglasii*	Douglas' knotweed	rare	
Populus tremuloides	trembling aspen	common	
Potentilla argentea	silvery cinquefoil	rare	introduced
Potentilla arguta	white cinquefoil	rare	
Potentilla recta	sulphur cinquefoil	abundant	introduced
Prunus virginiana	choke cherry	abundant	
Pseudoroegneria spicata	bluebunch wheatgrass	common	
Pseudotsuga menziesii	Douglas-fir	abundant	
Purshia tridentata	antelope-brush	abundant	
Rosa acicularis	prickly rose	common	
Rosa arkansana	Arkansas rose	common	
Rosa woodsii	prairie rose	common	
Sanguisorba annua	western burnet	rare	
Schizachyrium scoparium	little bluestem	rare	
Silene antirrhina	sleepy catchfly	common	
Silene menziesii	Menzies' campion	common	
Sisymbrium altissimum	tall tumble-mustard	common	introduced
Sisyrinchium montanum	mountain blue-eyed-grass	rare	
Solidago spathulata	spikelike goldenrod	common	
Sonchus arvensis	perennial sow-thistle	rare	introduced
Spiraea betulifolia	birch-leaved spirea	common	
Sporobolus cryptandrus	sand dropseed	common	
Symphoricarpos albus	common snowberry	common	
Symphoricarpos occidentalis	western snowberry	common	
Taraxacum officinale	common dandelion	common	introduced
Thlaspi arvense	field pennycress	common	introduced
Tragopogon dubius	yellow salsify	common	introduced
Trifolium repens	white clover	common	introduced
Verbascum thapsus	great mullein	abundant	introduced
Veronica peregrina	purslane speedwell	rare	
Vicia americana	American vetch	common	
Vicia cracca	tufted vetch	rare	introduced
Viola adunca	early blue violet	common	

[1] some subspecies native, some introduced

Appendix 5-6. Plants identified in the Mt. Broadwood study area.

Scientific Name	Common Name	Relative Abundance	Introduced Status
Acer glabrum	Douglas maple	common	
Achillea millefolium	yarrow	common	
Achnatherum nelsonii	Columbian needlegrass	common	
Achnatherum richardsonii	spreading needlegrass	common	
Allium cernuum	nodding onion	common	
Alyssum alyssoides	pale alyssum	rare	introduced
Amelanchier alnifolia	saskatoon	common	
Anemone multifida	cut-leaved anemone	common	
Anemone patens ssp. *multifida*	prairie crocus	common	
Antennaria luzuloides	woodrush pussytoes	rare	
Antennaria microphylla	white pussytoes	common	
Antennaria neglecta	field pussytoes	common	
Apocynum androsaemifolium	spreading dogbane	common	
Arabis holboellii	Holboell's rockcress	rare	
Arenaria serpyllifolia	thyme-leaved sandwort	common	introduced
Arnica fulgens var. *sororia*	orange arnica	common	
Aster conspicuus	showy aster	common	
Aster laevis	smooth aster	common	
Balsamorhiza sagittata	arrowleaf balsamroot	common	
Betula occidentalis	water birch	rare	
Botrychium sp.	grape fern	rare	
Bromus briziformis	rattlesnake grass	rare	introduced
Bromus inermis	smooth brome	common	introduced
Bromus japonicus	Japanese brome	rare	introduced
Bromus tectorum	cheatgrass	common	introduced
Calochortus apiculatus	three-spot mariposa lily	common	
Calamagrostis rubescens	pinegrass	common	
Campanula rotundifolia	common harebell	common	
Carex sp.	sedge	common	
Carex rossii	Ross' sedge	common	
Castilleja hispida	harsh paintbrush	common	
Castilleja lutescens	yellowish paintbrush	common	
Ceanothus sanguineus	redstem ceanothus	common	
Centaurea biebersteinii	spotted knapweed	common	introduced
Cerastium arvense	field chickweed	common	
Cirsium undulatum	wavy-leaved thistle	common	
Collomia linearis	narrow-leaved collomia	common	
Comandra umbellata var. *umbellata*	bastard toadflax	common	
Crepis atribarba	slender hawksbeard	rare	
Danthonia spicata	poverty oatgrass	common	

Draba sp.	draba	rare	
Elymus trachycaulus	slender wheatgrass	common	
Epilobium angustifolium	fireweed	rare	
Epilobium brachycarpum	tall annual willowherb	common	
Erigeron compositus	cut-leaved daisy		
Erigeron corymbosus	long-leaved fleabane		
Erigeron divergens	diffuse fleabane	common	
Erigeron speciosus	showy daisy	common	
Erigeron strigosus	rough-stemmed fleabane	common	
Erigeron pumilus	shaggy fleabane	common	
Erythronium grandiflorum	yellow glacier lily	rare	
Festuca campestris	rough fescue	common	
Festuca idahoensis	Idaho fescue	common	
Festuca saximontana	Rocky Mountain fescue		
Fragaria vesca	wood strawberry	rare	
Fragaria virginiana	wild strawberry	common	
Fritillaria pudica	yellow bell	rare	
Gaillardia aristata	brown-eyed Susan	common	
Galium aparine	cleavers	rare	
Galium boreale	northern bedstraw	common	
Geranium bicknellii	Bicknell's geranium	rare	
Geum triflorum	old man's whiskers	common	
Helictotrichon hookeri	spike-oat	rare	
Heterotheca villosa	golden-aster	common	
Heuchera cylindrica	round-leaved alumroot	common	
Hieracium piloselloides	tall hawkweed	common	
Hieracium scouleri	Scouler's hawkweed	rare	
Holodiscus discolor	oceanspray	rare	
Hypericum perforatum	common St. John's wort	abundant	introduced
Juniperus communis	common juniper	common	
Juniperus scopulorum	Rocky Mountain juniper	common	
Koeleria macrantha	Junegrass	common	
Leucanthemum vulgare	oxeye daisy	common	introduced
Lithospermun ruderale	lemonweed	common	
Lomatium macrocarpum	large-fruited desert-parsley	rare	
Lomatium triternatum	nine-leaved desert-parsley	rare	
Mahonia repens	creeping Oregon-grape	common	
Medicago lupulina	black medic	abundant	introduced
Medicago sativa	alfalfa	common	introduced
Melilotus officinalis	yellow sweet-clover	common	introduced
Microsteris gracilis	pink twink	rare	
Monarda fistulosa	wild bergamot	common	
Orthocarpus tenuifolius	thin-leaved owl-clover	common	

Penstemon albertinus	Alberta penstemon	rare	
Penstemon confertus	yellow penstemon	common	
Penstemon fruticosus	shrubby penstemon		
Phacelia linearis	thread-leaved phacelia	rare	
Philadelphus lewisii	mock-orange	common	
Phleum pratense	common timothy	common	introduced
Phlox caespitosa	tufted phlox	common	
Physocarpus malvaceus	mallow ninebark	common	
Pinus ponderosa	ponderosa pine	common	
Plantago patagonica	woolly plantain	rare	
Poa compressa	Canada bluegrass	abundant	introduced
Poa pratensis	Kentucky bluegrass	common	[1]
Poa secunda	Sandberg's bluegrass	common	
Polemonium pulcherrimum	showy Jacob's-ladder	rare	
Populus tremuloides	trembling aspen	common	
Potentilla argentea	silvery cinquefoil	rare	introduced
Potentilla arguta	white cinquefoil	common	
Potentilla recta	sulphur cinquefoil	common	introduced
Prunus pensylvanica	pin cherry	common	
Prunus virginiana	choke cherry		
Pseudoroegneria spicata	bluebunch wheatgrass	common	
Pseudotsuga menziesii	Douglas-fir	abundant	
Ranunculus acris	meadow buttercup	rare	introduced
Rhinanthus minor	yellow rattle	common	
Rosa acicularis	prickly rose	common	
Rosa woodsii	prairie rose	common	
Salix spp.	willow	common	
Sedum lanceolatum	lance-leaved stonecrop	common	
Selaginella densa	compact selaginella	common	
Senecio pauperculus	Canadian butterweed	common	
Senecio canus	woolly groundsel	common	
Shepherdia canadensis	soopolallie	common	
Silene sp.	catchfly	rare	
Silene menziesii	Menzies' campion	rare	
Sisyrinchium montanum	mountain blue-eyed-grass	rare	
Solidago spathulata	spikelike goldenrod	common	
Spiraea betulifolia	birch-leaved spirea	common	
Symphoricarpos albus	common snowberry	common	
Taraxacum officinale	common dandelion	common	introduced
Tragopogon dubius	yellow salsify	common	introduced
Trifolium aureum	yellow clover	abundant	introduced
Trifolium pratense	red clover	rare	introduced

Verbascum thapsus	great mullein	common	introduced
Veronica peregrina	purslane speedwell	rare	
Vicia americana	American vetch	common	
Viola sp.	violet	rare	
Viola adunca	early blue violet	rare	
Woodsia oregana	western cliff fern	rare	
Zigadenus venenosus	meadow death camas	common	

[1] some subspecies native, some introduced

Appendix 5-7. Forage plant composition in bighorn sheep scats for Columbia Lake, December through May. Means are weighted equally by month, regardless of number of samples from that month.

Scientific Name	Common Name	Scat Composition (%) Dec 1997	Jan 1998	Feb 1997	Feb 1998	Mar 1997	Mar 1998	Apr 1997	Apr 1998	May 1997	May 1998	Mean	Min	Max
GRAMINOIDS														
Achnatherum hymenoides	Indian ricegrass	0.62	0.00	0.00	0.00	1.87	0.00	0.00	0.00	0.00	0.00	0.26	0.00	1.87
Carex spp.	sedge	0.00	0.00	0.00	1.39	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	1.39
Festuca campestris	rough fescue	43.63	26.21	0.00	0.00	0.00	0.00	0.00	0.00	8.41	16.20	13.69	0.00	43.63
Hesperostipa comata	needle-and-thread grass	13.14	52.56	61.14	15.29	87.41	80.76	47.48	94.69	48.48	55.44	51.84	13.14	94.69
Koeleria macrantha	junegrass	0.00	1.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	1.22
Muhlenbergia sp.	muhly	0.00	0.00	0.00	0.00	1.36	0.00	0.00	0.00	0.00	0.63	0.17	0.00	1.36
Poa spp.	bluegrass	1.30	0.70	1.32	2.89	0.00	0.00	1.65	0.00	4.98	3.30	1.51	0.00	4.98
Pseudoroegneria, *Elymus* or *Pascopyrum*	wheatgrass	0.00	2.29	21.80	12.03	7.24	1.61	3.38	2.53	31.20	8.06	7.70	0.00	31.20
	unidentified grass	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.66
	Graminoids Total	59.35	82.98	84.26	31.60	97.89	82.37	52.51	97.23	93.07	83.63	75.60	31.60	97.89
FORBS														
Achillea millefolium	yarrow	0.00	4.20	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.76	0.00	4.20
Artemisia frigida	prairie sagewort	10.06	4.11	1.91	13.59	2.11	9.02	10.20	0.00	0.75	1.20	5.59	0.00	13.59
Compositae family		4.96	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	1.36	0.99	0.00	4.96
Equisetum spp.	horsetail	2.86	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	2.86
Lesquerella spp.	bladderpod	0.00	0.00	0.00	1.39	0.00	2.16	1.10	1.43	2.17	1.20	0.79	0.00	2.17
Orthocarpus?	owl-clover?	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	1.30
Potentilla pensylvanica	Pennsylvanian cinquefoil	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.75	0.42	0.00	3.75
Verbascum thapsus	great mullein	2.74	4.37	0.00	5.19	0.00	0.00	13.14	1.35	0.00	0.00	2.82	0.00	13.14
	Forbs Total	22.58	13.25	2.59	20.17	2.11	11.75	24.44	2.77	2.92	7.51	12.16	2.11	24.44
DECIDUOUS SHRUBS														
Mahonia repens	creeping Oregon-grape	3.30	0.00	6.35	0.71	0.00	1.21	0.00	0.00	0.00	0.00	1.24	0.00	6.35
Purshia spp.	antelope-brush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.05	0.00	0.63
Salix spp.	willow	3.39	0.58	4.09	15.39	0.00	0.00	0.00	0.00	1.32	0.00	2.40	0.00	15.39
Shepherdia spp.	soopolallie	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.23	0.69	0.00	8.23
	Deciduous Shrubs Total	6.69	0.58	10.44	16.10	0.00	1.21	0.00	0.00	1.32	8.86	4.37	0.00	16.10
CONIFERS														
Juniperus spp.	juniper	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.04	0.00	0.44
Picea spp.	spruce	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.62	0.00	0.14	0.00	1.05
Pseudotsuga menziesia	Douglas-fir	11.38	3.19	2.71	29.24	0.00	3.63	21.50	0.00	2.07	0.00	7.36	0.00	29.24
	Conifers Total	11.38	3.19	2.71	29.24	0.00	4.07	22.55	0.00	2.69	0.00	7.53	0.00	29.24
MOSS														
	unidentified moss	0.00	0.00	0.00	2.89	0.00	0.00	0.50	0.00	0.00	0.00	0.28	0.00	2.89
SEEDS														
	unidentified seed	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.05	0.00	0.60

Appendix 5-8. Forage plant composition in bighorn sheep scats for Bull River, December through May. Means are weighted equally by month, regardless of number of samples from that month.

Scientific Name	Common Name	Scat Composition (%)											
		Dec	Jan	Feb		Mar		Apr		May	Mean	Min	Max
		1997	1998	1997	1998	1997	1998	1997	1998	1997			
GRAMINOIDS													
Carex spp.	sedge	0.00	0.00	0.00	0.38	0.00	0.67	0.00	0.00	0.00	0.09	0.00	0.67
Deschampsia spp.	hairgrass	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.77
Festuca spp.	fescue	17.20	14.05	0.00	0.00	0.00	0.00	0.00	0.73	12.03	7.27	0.00	17.20
Hesperostipa or *Stipa*	needlegrass[1]	36.88	64.89	42.78	80.95	100.00	97.40	90.71	77.75	64.72	68.55	36.88	100.00
Koeleria macrantha	junegrass	0.00	1.07	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	1.07
Oryzopsis spp.	ricegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.86	0.00	0.16	0.00	1.86
Poa spp.	bluegrass	4.70	0.00	7.20	0.00	0.00	0.00	0.00	0.00	3.90	2.03	0.00	7.20
Pseudoroegneria, *Elymus* or *Pascopyrum*	wheatgrass	0.00	0.54	25.16	1.52	0.00	0.00	1.62	8.11	11.02	4.96	0.00	25.16
	Graminoids Total	59.55	80.55	75.84	82.85	100.00	98.07	92.33	88.45	91.67	83.42	59.55	100.00
FORBS													
Achillea millefolium	yarrow	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.61
Arabis holboellii	Holboell’s rockcress	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Artemisia frigida	prairie sagewort	19.19	5.83	0.00	3.05	0.00	0.00	0.00	1.12	0.00	4.52	0.00	19.19
Astragalus lotiflorus	lotus milk-vetch	1.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.44	0.48	0.00	1.44
Alyssum alyssoides	pale alyssum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Compositae family		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	1.20	0.26	0.00	1.20
Descurainia sp.	tansy mustard	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.77
Lesquerella spp.	bladderpod	0.00	0.00	1.48	0.00	0.00	0.00	1.97	1.17	0.62	0.49	0.00	1.97
Neslia paniculata	ball mustard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orthocarpus ?	owl-clover?	2.38	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.46	0.00	2.38
Phlox spp.	phlox	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.11	0.00	0.63
Potentilla spp.	cinquefoil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.66	0.00	0.14	0.00	1.66
Verbascum sp.	mullein[2]	0.00	0.00	0.70	0.58	0.00	0.00	0.92	0.00	0.00	0.18	0.00	0.92
	Forbs Total	23.77	6.44	2.18	3.63	0.00	0.75	2.89	4.68	3.89	6.86	0.00	23.77
DECIDUOUS SHRUBS													
Amelanchier alnifolia	saskatoon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arctostaphylos uva-ursi	kinnikinnick	2.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	2.19
Mahonia repens	creeping Oregon-grape	6.90	5.20	0.00	3.53	0.00	0.42	0.00	0.00	0.00	2.35	0.00	6.90
Prunus virginiana	choke cherry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purshia tridentata	antelope-brush	0.00	2.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	2.77
Salix spp.	willow	6.85	3.33	6.48	4.87	0.00	0.00	3.05	6.34	0.00	3.43	0.00	6.85
Shepherdia spp.	soopolallie	0.00	0.00	2.43	0.00	0.00	0.00	0.00	0.00	2.53	0.62	0.00	2.53
Spiraea betulifolia	birch-leaved spirea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Deciduous Shrubs Total	15.94	11.30	8.91	8.40	0.00	0.42	3.05	6.34	2.53	7.22	0.00	15.94
CONIFERS													
Picea spp.	spruce	0.00	0.00	0.00	0.00	0.00	0.00	1.73	0.53	1.20	0.39	0.00	1.73
Pseudotsuga menziesia	Douglas-fir	0.75	1.71	11.44	5.12	0.00	0.42	0.00	0.00	0.71	1.94	0.00	11.44
	Conifers Total	0.75	1.71	11.44	5.12	0.00	0.42	1.73	0.53	1.91	2.33	0.00	11.44
MOSS													
	unidentified moss	0.00	0.00	1.63	0.00	0.00	0.34	0.00	0.00	0.00	0.16	0.00	1.63

[1] predominately *H. comata* (needle-and-thread grass)

[2] almost certainly *V. thapsus* (great mullein)

Appendix 5-9. Columbia Lake forage chemical analysis, reported on a dry-matter basis.

Species	Location	Mo.	CP (%)	NDIN (%)	ADF (%)	NDF (%)	TDN (%)	DE (Mcal/kg)	Ca (%)	P (%)	Na (%)	Mg (%)	K (%)	S (%)
Grasses														
Elymus spicatum [1]	Rocky bluffs	Dec	3.2	0.20	45.5	60.6	46.5	2.05	0.60	0.05	0.01	0.11	0.10	0.10
		Apr	4.2	0.33	44.1	70.8	48.6	2.14	0.74	0.08	<0.01	0.09	0.13	0.08
	Grassland	Dec	3.0	0.20	49.8	75.5	40.2	1.77	0.62	0.07	0.01	0.10	0.04	0.10
		Apr	3.4	0.21	46.1	69.4	45.6	2.01	0.74	0.06	<0.01	0.09	0.09	0.09
Festuca campestris [1]	Doug.-fir forest	Dec	2.2	0.10	55.9	73.9	31.0	1.36	0.39	0.08	0.01	0.10	0.25	0.10
		Apr	2.0	0.14	55.8	75.4	31.2	1.37	0.42	0.02	<0.01	0.10	0.07	0.05
Festuca idahoensis	Grassland	Dec	4.7	0.30	47.7	77.8	43.2	1.90	0.60	0.07	0.01	0.12	0.22	0.10
Koeleria macrantha [1]	Rocky bluffs	Dec	6.3	0.50	44.8	69.4	47.6	2.10	0.63	0.09	0.01	0.13	0.30	0.10
		Apr	N/S	0.23	53.0	84.6	35.3	1.55	0.38	0.06	0.01	0.08	0.09	N/S
	Grassland	Dec	3.4	0.30	53.7	79.2	34.3	1.51	0.60	0.05	0.01	0.08	0.13	0.10
		Apr	2.9	0.16	51.4	78.8	37.7	1.66	0.47	0.05	<0.01	0.07	0.09	0.06
Stipa comata [1]	Rocky bluffs	Dec	3.9	0.30	45.9	74.9	45.9	2.02	0.49	0.04	<0.01	0.10	0.22	0.10
		Apr	3.9	0.26	44.0	75.8	48.7	2.14	0.53	0.06	<0.01	0.10	0.13	0.08
	Grassland	Dec	4.5	0.40	48.1	77.9	42.7	1.88	0.53	0.07	0.01	0.09	0.17	0.10
		Apr	4.7	0.31	43.0	73.2	50.3	2.21	0.65	0.07	<0.01	0.10	0.14	0.10
Forbs														
Achillea millefolium [2]	Rocky bluffs	Apr	6.0	0.49	43.4	51.4	49.7	2.19	2.07	0.14	0.01	0.32	0.16	0.09
	Grassland	Apr	6.4	0.71	45.3	47.4	46.8	2.06	2.29	0.13	<0.01	0.21	0.14	0.09
Antennaria microphylla [2]	Rocky bluffs	Dec	7.5	0.20	32.0	36.6	66.7	2.93	1.49	0.19	0.01	0.47	1.09	0.10
		Apr	10.0	0.21	24.4	30.9	78.0	3.43	1.19	0.24	0.03	0.21	1.24	0.10
Artemisia frigida [1]	Rocky bluffs	Dec	8.8	0.40	45.3	50.6	46.8	2.06	1.34	0.15	0.02	0.44	0.80	0.20
		Apr	8.8	0.41	47.7	62.1	43.2	1.90	0.88	0.17	0.02	0.23	0.75	0.13
	Grassland	Dec	6.6	0.40	54.4	64.6	33.2	1.46	1.21	0.11	0.02	0.30	0.71	0.10
		Apr	9.2	0.36	43.9	53.2	48.9	2.15	1.25	0.15	0.02	0.27	0.80	0.15
Heterotheca villosa [2]	Rocky bluffs	Dec	8.3	0.70	45.0	46.2	47.2	2.08	3.60	0.12	0.01	0.75	0.24	0.10
		Apr	8.1	0.78	50.2	51.0	39.6	1.74	3.22	0.14	<0.01	0.25	0.13	0.11
Verbascum thapsus [1]	Rocky bluffs	Dec	7.0	0.60	29.0	40.0	71.2	3.13	1.48	0.16	0.02	0.64	0.62	0.10
		Apr	5.8	0.71	58.4	65.6	27.2	1.20	1.94	0.09	0.01	0.57	0.36	0.06
Shrubs														
Chrysothamnus nauseosus [2]	Rocky bluffs	Dec	6.7	0.30	48.7	55.2	41.7	1.84	1.01	0.10	<0.01	0.15	0.56	0.10
		Apr	7.0	0.39	41.7	52.7	52.2	2.30	1.16	0.12	0.01	0.08	0.55	0.11
	Grassland	Dec	7.0	0.30	43.8	52.0	49.1	2.16	0.91	0.12	0.01	0.21	0.64	0.10
		Apr	6.8	0.31	38.9	49.6	56.4	2.48	0.66	0.13	0.01	0.16	0.70	0.12
Trees														
Pseudotsuga menziesii [1]	Rocky bluffs	Dec	7.6	0.50	34.2	41.5	63.4	2.79	0.50	0.19	<0.01	0.25	0.54	0.10
		Apr	6.4	0.63	38.2	48.0	57.4	2.52	0.44	0.14	<0.01	0.17	0.54	0.07
	Grassland	Dec	6.9	0.40	34.1	44.2	63.5	2.79	0.59	0.18	0.02	0.19	0.59	0.10
		Apr	7.8	0.58	34.8	39.0	59.4	2.61	0.58	0.18	<0.01	0.20	0.62	0.11
Sheep Requirements [3]			9.4				55.0	2.40	0.20-0.82	0.16-0.38	0.09-0.18	0.12-0.18	0.50-0.80	0.14-0.26

[1] Plants whose species or genus were identified in the scat analysis
[2] Plants whose family was identified in the scat analysis
[3] Source: NRC (1985); figures are for domestic sheep; non-mineral figures are based on maintenance requirements of a 70 kg ewe
N/S not enough sample to analyze
ADF acid detergent fibre
CP crude protein
DE digestible energy
NDF neutral detergent fibre
NDIN neutral detergent insoluble nitrogen
TDN total digestible nutrients

Appendix 5-10. Bull River forage chemical analysis, reported on a dry-matter basis.

Species	Location	Mo.	CP (%)	NDIN (%)	ADF (%)	NDF (%)	TDN (%)	DE (Mcal/kg)	Ca (%)	P (%)	Na (%)	Mg (%)	K (%)	S (%)
Grasses														
Bromus inermis	CF - low, moist area	Dec	4.7	0.30	48.6	74.8	41.9	1.84	0.72	0.10	0.04	0.14	0.14	0.10
		Apr	3.6	0.27	48.9	71.7	41.5	1.83	0.73	0.07	<0.01	0.11	0.14	0.07
Elymus spicatum [1]	Moist slope	Dec	3.1	0.30	53.4	77.0	34.8	1.53	0.47	0.08	0.01	0.04	0.11	0.10
		Apr	2.4	0.16	54.2	74.5	33.6	1.48	0.36	0.06	<0.01	0.03	0.07	0.04
Festuca campestris [1]	Terrace	Dec	3.1	0.10	54.7	75.0	32.8	1.44	0.38	0.08	0.01	0.06	0.11	0.00
		Apr	2.5	0.16	53.6	84.3	34.4	1.51	0.28	0.08	<0.01	0.04	0.15	0.05
Festuca idahoensis [1]	Terrace	Dec	2.4	0.10	54.6	78.1	33.0	1.45	0.41	0.06	0.01	0.05	0.11	0.00
Koeleria macrantha [1]	Terrace	Apr	6.0	0.16	56.2	84.0	30.5	1.34	0.27	0.07	<0.01	0.04	0.08	0.06
	Moist slope	Dec	5.6	0.30	47.3	69.4	43.9	1.93	0.47	0.14	0.01	0.08	0.27	0.10
		Apr	1.5	0.13	56.1	83.6	30.7	1.35	0.23	0.05	<0.01	0.04	0.08	0.02
Poa spp. [1]	CF - low, moist area	Dec	4.9	0.30	45.6	71.8	46.4	2.04	0.58	0.10	0.01	0.11	0.25	0.10
		Apr	3.5	0.25	46.8	75.8	44.6	1.96	0.60	0.07	<0.01	0.10	0.19	0.07
	CF - higher, drier are	Dec	9.7	0.50	39.7	69.9	55.2	2.43	0.56	0.29	0.02	0.09	0.40	0.10
		Apr	4.1	0.23	47.8	75.4	43.1	1.90	0.46	0.11	<0.01	0.06	0.21	0.07
	Terrace	Dec	8.8	0.50	42.8	71.0	50.5	2.22	0.36	0.15	0.01	0.10	0.36	0.10
		Apr	3.7	0.23	48.0	76.9	42.8	1.88	0.35	0.09	<0.01	0.06	0.20	0.05
	Moist slope	Dec	5.4	0.30	46.4	70.9	45.2	1.99	0.40	0.14	0.01	0.11	0.36	0.10
		Apr	2.7	0.16	52.2	75.6	36.6	1.61	0.34	0.08	<0.01	0.06	0.13	0.04
Stipa comata [1]	Dry slope	Dec	4.5	0.30	48.1	73.8	42.6	1.88	0.78	0.05	0.01	0.11	0.15	0.10
		Apr	4.6	0.38	44.9	71.2	47.4	2.08	0.74	0.09	<0.01	0.09	0.17	0.12
Stipa nelsonii [1]	Moist slope	Dec	2.9	0.20	53.5	79.3	34.7	1.52	0.37	0.08	0.01	0.04	0.12	0.10
Stipa richardsonii [1]	Terrace	Dec	3.8	0.20	47.9	78.1	43.0	1.89	0.39	0.07	0.01	0.05	0.10	0.10
		Apr	2.0	0.15	49.7	80.5	40.3	1.77	0.28	0.06	<0.01	0.04	0.12	0.04
	Moist slope	Apr	2.0	0.14	50.8	79.1	38.6	1.70	0.32	0.05	<0.01	0.04	0.13	0.04
Forbs														
Achillea millefolium [1]	Moist slope	Apr	4.6	0.36	61.6	70.0	22.5	0.99	1.24	0.09	<0.01	0.14	0.14	0.06
Artemisia frigida [1]	Moist slope	Dec	8.3	0.40	49.5	57.3	40.6	1.79	0.79	0.17	0.02	0.20	0.67	0.20
		Apr	5.4	0.37	56.1	68.0	30.7	1.35	0.60	0.12	0.01	0.13	0.58	0.10
	Dry slope	Dec	8.2	0.40	52.8	64.1	35.6	1.57	1.01	0.12	0.02	0.21	0.56	0.20
		Apr	6.2	0.33	54.6	69.4	33.0	1.45	0.73	0.09	0.01	0.15	0.53	0.12
Vicia cracca	CF - low, moist area	Dec	13.9	1.10	56.2	73.7	30.6	1.34	1.43	0.17	0.01	0.10	0.25	0.10
		Apr	5.4	0.36	69.9	86.0	10.1	0.44	0.79	0.05	0.01	0.09	0.10	0.06
Shrubs														
Amelanchier alnifolia	Terrace	Dec	5.5	0.40	55.2	63.9	32.0	1.41	1.00	0.14	0.01	0.16	0.59	0.10
		Apr	4.4	0.29	48.5	63.7	42.1	1.85	0.91	0.13	<0.01	0.10	0.53	0.04
	Moist slope	Dec	6.2	0.30	52.0	56.9	36.9	1.62	0.93	0.14	0.02	0.17	0.49	0.10
		Apr	5.0	0.30	47.2	59.6	44.0	1.94	1.07	0.13	<0.01	0.13	0.41	0.04
Arctostaphylos uva-ursi [1]	Terrace	Dec	6.3	0.60	24.7	38.2	77.6	3.42	0.63	0.12	0.01	0.14	0.37	0.10
		Apr	6.5	0.73	28.6	40.2	71.8	3.16	0.86	0.12	<0.01	0.12	0.44	0.09
Mahonia repens [1]	Terrace	Dec	9.9	0.30	30.2	41.2	69.4	3.05	0.61	0.17	0.01	0.16	0.65	0.10
		Apr	2.9	0.31	36.0	45.4	60.8	2.67	0.66	0.19	0.01	0.18	0.56	0.04
	Moist slope	Dec	9.7	0.30	31.3	43.0	67.8	2.98	0.56	0.25	0.02	0.28	0.58	0.10
		Apr	8.0	0.30	32.2	43.7	66.4	2.92	0.72	0.17	0.01	0.19	0.63	0.10
Purshia tridentata [1]	Terrace	Apr	6.7	0.44	44.4	58.0	48.2	2.12	0.59	0.13	0.01	0.07	0.38	0.04
	Moist slope	Apr	7.2	0.36	46.0	57.5	45.8	2.02	0.44	0.13	0.01	0.10	0.38	0.06
Rosa woodsii	Moist slope	Dec	4.2	0.40	46.8	57.3	44.6	1.96	1.08	0.11	0.02	0.16	0.31	0.10
		Apr	3.9	0.29	45.8	53.6	46.1	2.03	0.94	0.10	0.01	0.16	0.42	0.04
Trees														
Pseudotsuga menziesii [1]	Terrace	Apr	6.9	0.41	34.4	45.8	63.2	2.78	0.57	0.17	<0.01	0.09	0.50	0.09
Sheep Requirements[3]			9.4				55.0	2.40	0.20-0.82	0.16-0.38	0.09-0.18	0.12-0.18	0.50-0.80	0.14-0.26

[1] Plants whose species or genus were identified in the scat analysis
[2] Plants whose family was identified in the scat analysis
[3] Source: NRC (1985); figures are for domestic sheep; non-mineral figures are based on maintenance requirements of a 70 kg ewe
N/S not enough sample to analyze
ADF acid detergent fibre
CP crude protein
DE digestible energy
NDF neutral detergent fibre
NDIN neutral detergent insoluble nitrogen
TDN total digestible nutrients

Appendix 5-11. Mt. Broadwood forage chemical analysis, reported on a dry-matter basis.

Species	Location	Mo.	CP (%)	NDIN (%)	ADF (%)	NDF (%)	TDN (%)	DE (Mcal/kg)	Ca (%)	P (%)	Na (%)	Mg (%)	K (%)	S (%)
Grasses														
Bromus inermis	Lower flats	Dec	3.3	0.18	45.2	72.7	47.0	2.07	0.68	0.07	<0.01	0.10	0.17	0.06
		Apr	2.0	0.12	53.5	75.9	34.6	1.52	0.42	0.03	<0.01	0.05	0.05	0.04
Danthonia spicata	Upper flats	Dec	2.8	0.19	54.5	79.0	33.1	1.46	0.19	0.03	<0.01	0.05	0.16	0.04
		Apr	2.2	0.20	47.6	76.8	43.4	1.91	0.36	0.05	<0.01	0.04	0.18	0.04
Elymus spicatum [1]	Upper flats	Dec	3.3	0.15	52.4	76.5	36.2	1.59	0.37	0.06	<0.01	0.04	0.39	0.06
		Apr	2.7	0.18	55.0	76.8	32.4	1.42	0.29	0.06	<0.01	0.03	0.06	0.04
	S-facing slope - moist	Dec	2.2	0.12	54.6	72.8	33.0	1.45	0.43	0.04	0.01	0.04	0.11	0.03
	W-facing slope	Dec	2.7	0.13	47.0	70.7	44.3	1.95	0.73	0.08	<0.01	0.12	0.48	0.07
	SW-facing slope	Apr	2.3	0.19	52.9	76.3	35.5	1.56	0.42	0.06	<0.01	0.03	0.07	0.04
Festuca campestris [1]	Upper flats	Dec	2.1	0.11	52.1	75.1	36.6	1.61	0.44	0.07	<0.01	0.08	0.20	0.03
		Apr	2.4	0.15	53.2	74.2	35.1	1.54	0.25	0.01	<0.01	0.04	0.03	0.04
Festuca idahoensis [1]	NW-facing slope	Dec	3.7	0.18	48.3	68.5	42.3	1.86	0.47	0.09	<0.01	0.08	0.31	0.05
Koeleria macrantha	Upper flats	Dec	3.0	0.17	53.7	81.6	34.3	1.51	0.22	0.05	<0.01	0.03	0.12	0.03
		Apr	3.1	0.22	54.5	78.8	33.0	1.45	0.33	0.08	<0.01	0.05	0.13	0.05
	S-facing slope - dry	Dec	2.6	0.15	51.4	83.3	37.7	1.66	0.24	0.05	<0.01	0.04	0.12	0.04
	SW-facing slope	Apr	4.3	0.32	51.1	73.2	38.2	1.68	0.64	0.11	<0.01	0.06	0.20	0.06
Poa compressa	Upper flats	Dec	2.9	0.13	46.1	73.8	45.7	2.01	0.18	0.03	<0.01	0.05	0.13	0.02
		Apr	1.5	0.09	49.2	78.0	41.0	1.80	0.43	0.06	<0.01	0.06	0.11	0.03
	Lower flats	Dec	1.8	0.07	42.8	67.1	50.6	2.23	0.23	0.07	<0.01	0.06	0.26	0.04
		Apr	2.2	0.15	51.7	69.6	37.4	1.64	0.44	0.08	<0.01	0.04	0.08	0.03
	W-facing slope	Dec	2.7	0.18	40.8	70.8	53.6	2.36	0.26	0.14	<0.01	0.07	0.21	0.04
Stipa nelsonii [1]	Lower flats	Dec	2.5	0.12	49.7	75.2	40.3	1.77	0.43	0.06	0.01	0.06	0.19	0.04
	S-facing slope - dry	Dec	2.7	0.12	49.4	72.3	40.8	1.79	0.55	0.08	<0.01	0.08	0.23	0.03
Stipa [1]	SW-facing slope	Apr	4.1	0.29	49.8	70.1	40.1	1.76	0.71	0.13	<0.01	0.06	0.18	0.05
Stipa richardsonii [1]	Upper flats	Dec	2.6	0.14	48.5	79.8	42.0	1.85	0.33	0.06	<0.01	0.05	0.31	0.04
		Apr	2.3	0.15	52.5	74.3	36.1	1.59	0.43	0.06	<0.01	0.04	0.08	0.03
	W-facing slope	Dec	1.5	0.10	49.3	85.0	40.9	1.80	0.16	0.05	0.01	0.03	0.40	0.03
Stipa [1]	NW-facing slope	Apr	3.0	0.24	50.8	75.9	38.6	1.70	0.53	0.08	<0.01	0.05	0.10	0.04
Forbs														
Achillea millefolium [2]	Upper flats	Dec	5.6	0.35	31.4	48.7	67.6	2.97	1.69	0.13	0.02	0.26	0.79	0.05
		Apr	5.5	0.51	35.7	51.8	61.2	2.69	1.71	0.08	<0.01	0.18	0.12	0.07
	S-facing slope - moist	Dec	5.9	0.36	40.7	43.2	53.7	2.36	1.75	0.16	<0.01	0.21	0.65	0.06
		Apr	5.6	0.51	47.1	52.1	44.2	1.94	2.12	0.13	<0.01	0.12	0.14	0.09
Heterotheca villosa [2]	Upper flats	Apr	5.2	0.50	56.0	61.2	30.8	1.36	2.16	0.08	<0.01	0.12	0.10	0.09
	S-facing slope - dry	Dec	5.9	0.44	42.9	44.2	50.4	2.22	2.74	0.16	0.01	0.11	0.57	0.08
	S-facing slope - moist	Dec	8.2	N/S	48.0	54.2	42.9	1.89	2.45	0.12	0.01	0.11	0.11	0.09
Verbascum thapsus [1]	WSW-facing slope	Dec	5.0	0.41	45.0	52.6	47.2	2.08	2.76	0.15	0.03	0.37	0.79	0.07
Shrubs														
Amelanchier alnifolia	Upper flats	Dec	4.9	0.22	47.5	59.9	43.5	1.92	0.87	0.10	0.01	0.10	0.42	0.02
	Lower flats	Dec	5.7	0.24	46.5	60.3	45.0	1.98	1.07	0.13	0.01	0.13	0.45	0.04
		Apr	5.5	0.25	49.8	61.5	40.2	1.77	1.10	0.14	<0.01	0.12	0.49	0.05
	W-facing slope	Dec	6.1	0.28	48.4	59.8	42.2	1.86	1.04	0.16	0.02	0.11	0.48	0.05
	SW-facing slope	Apr	4.4	0.22	49.6	65.2	40.4	1.78	0.86	0.11	<0.01	0.10	0.57	0.04
Mahonia repens [1]	Upper flats	Dec	8.1	0.30	30.0	44.2	69.7	3.07	0.90	0.15	0.01	0.20	0.49	0.05
		Apr	7.3	0.30	29.3	40.9	70.7	3.11	0.67	0.14	<0.01	0.18	0.75	0.09
	Lower flats	Dec	9.1	0.28	29.3	41.7	70.8	3.11	0.58	0.19	0.02	0.19	0.75	0.10
		Apr	6.8	0.25	30.3	43.7	69.2	3.04	0.60	0.15	<0.01	0.14	0.81	0.08
	S-facing slope - dry	Dec	8.4	0.26	29.7	41.9	70.2	3.09	0.67	0.22	0.01	0.02	0.75	0.08
	W-facing slope	Dec	9.7	0.31	34.6	45.5	62.8	2.76	0.70	0.26	0.01	0.14	0.74	0.19
	SW-facing slope	Apr	7.3	0.38	32.4	44.3	66.1	2.91	0.63	0.17	<0.01	0.16	0.71	0.10
Salix spp.[1]	Upper flats	Dec	6.1	0.28	38.8	51.1	56.5	2.48	1.06	0.15	0.01	0.09	0.42	0.05
		Apr	6.0	0.32	47.5	52.7	43.6	1.92	1.37	0.14	<0.01	0.14	0.50	0.05
	Lower flats	Dec	6.8	0.24	36.6	53.2	59.8	2.63	0.84	0.18	0.02	0.09	0.47	0.07
		Apr	5.0	0.28	38.1	45.4	57.6	2.53	1.42	0.14	<0.01	0.10	0.43	0.07
	W-facing slope	Dec	5.5	0.28	47.2	53.6	44.0	1.93	1.02	0.15	<0.01	0.11	0.44	0.07
		Apr	5.2	0.37	44.6	55.6	47.9	2.11	1.56	0.14	<0.01	0.12	0.45	0.06
Shepherdia canadensis [1]	Upper flats	Dec	15.3	0.69	35.7	50.4	61.2	2.69	0.22	0.17	0.01	0.08	0.45	0.05
		Apr	14.6	0.76	35.4	52.2	61.7	2.71	0.26	0.12	<0.01	0.07	0.40	0.09
Trees														
Pseudotsuga menziesii [1]	Upper flats	Dec	5.9	0.40	32.1	42.7	66.5	2.93	0.78	0.19	0.01	0.13	0.64	0.06
		Apr	6.4	0.54	31.2	44.1	67.9	2.99	0.46	0.17	<0.01	0.12	0.67	0.09
	W-facing slope - N	Dec	6.3	0.39	30.9	43.9	68.3	3.01	0.59	0.16	0.01	0.12	0.51	0.08
	W-facing slope - S	Dec	5.6	0.41	32.7	47.7	65.7	2.89	0.76	0.16	0.01	0.14	0.78	0.08
Sheep Requirements[3]			9.4				55.0	2.40	0.20-0.82	0.16-0.38	0.09-0.18	0.12-0.18	0.50-0.80	0.14-0.26

[1] Plants whose species or genus were identified in the scat analysis
[2] Plants whose family was identified in the scat analysis
[3] Source: NRC (1985); figures are for domestic sheep; non-mineral figures are based on maintenance requirements of a 70 kg ewe
N/S not enough sample to analyze
ADF acid detergent fibre
CP crude protein
DE digestible energy
NDF neutral detergent fibre
NDIN neutral detergent insoluble nitrogen
TDN total digestible nutrients

Chapter 6: Carrying Capacity

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I. Teske photo

Summary

Carrying capacity for each of the 4 winter ranges was estimated based on each of grass forage production (CC_P) and grass forage utilization (CC_U). Production was estimated at production cages within areas most heavily used by bighorn sheep, then extrapolated to areas meeting all 3 of the following criteria: within the composite home range of radiocollared ewes, in preferred TEM-mapping types, and in either (a) areas identified by regional habitat modeling as the best habitat or (b) all habitat identified by the regional model. The effect of elk and deer grazing and the need to leave 50% forage carry-over to ensure rangeland health were then factored in to create 2 estimates of CC_P: (a) one assuming that sheep foraging occurred almost entirely on the best regional habitats, and (b) one assuming that foraging occurred on all regional habitats. Grass utilization was also measured at production cages within the most preferred habitats. Implicitly assuming that the number of elk and deer present at the time of research would remain constant, and allowing for 50% carryover, utilization levels were used to estimate CC_U. Summer cattle grazing occurred at Bull River[16]. For both CC_P and CC_U at Bull River, estimates were based on data collected before and after cattle grazing so that the effect of cattle could be measured.

The 2 estimates of mean carrying capacity were similar for Columbia Lake, Premier Ridge and Mount Broadwood (CC_P:CC_U of 132:108, 95:63, 337:345, respectively), using the all-habitat estimate of CC_P. In comparison to these estimates, bighorn sheep populations present at the time of research (c. 1999) were at carrying capacity for Columbia Lake, but below it for Premier Lake and Mount Broadwood. However, factoring in known bighorn sheep population growth since that time, the apparent recovery of other ungulates since the late 1990s and the reduced winter range when predation or snowfall become more limiting, it is very likely that Columbia Lake is now over a sustainable carrying capacity, probable that Mount Broadwood is at or over capacity, and possible that Premier Ridge is at capacity.

The situation at Bull River was more difficult to interpret because CC_P estimated under the most realistic assumptions suggested the range was well over carrying capacity (i.e. no capacity for sheep after factoring in the effect of cattle, elk and deer). In fact, even if there were assumed to be no cattle, elk or deer present, CC_P was estimated to be slightly exceeded by the c. 1999 population and considerably exceeded by the 2005 population. This was also true of the CC_U estimate (58 sheep). This strongly suggests the possibilities that (a) the Bull River winter range is over a sustainable carrying capacity, or (b) sheep obtain a significant part of their forage outside of the area considered to contribute to carrying capacity or from forage sources not represented by production cages. Evidence regarding range condition (weediness and erosion) presented in Chapter 5, the relatively high utilization rate and the concentration of telemetry data in the areas where range sampling occurred suggest the first possibility, while observations of sheep movement by Bull River residents suggest the latter. In all likelihood, the current sheep population at Bull River is being supported to a large extent by 1 or a few non-native forage sources and is therefore in a vulnerable position.

Based on the above, it appears that bighorn sheep/native forage-availability issues exist or are imminent at all 4 of the winter ranges studied. In addition to addressing the presence of exotic

[16] Cattle grazing also occurs on much of the Premier Ridge range. There is no grazing on the face of the Rocky Mountains but 100 animal unit months allocated to the 3 pastures along Premier Ridge itself (Elk, Sheep and Quartz pastures; P. Burk, Ministry of Forests and Range, Invermere, pers. comm.). However, there was no cattle activity apparent during sampling periods, perhaps because cattle were in other pastures at that time. As a result, forage utilization by cattle was not estimated for Premier Ridge, so bighorn sheep production-based carrying capacity is therefore likely overestimated.

species, as identified in Chapter 5, the quantity of forage would be increased through restoration of ingrown conifer forests to open forest or grassland. Evidence from elsewhere in the Trench suggests that areas with very low suitability for sheep can become important habitat through the mechanical removal of forest cover, where such activity is within areas having suitable terrain.

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Acknowledgements

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1.0 Introduction

Range characteristics for each study area discussed in Chapter 5 indicated that winter ranges were generally not in good condition. The intent of this chapter is to quantify the current and potential carrying capacities of each winter range in order to indicate the extent to which current numbers of sheep and other ungulates may be influencing range condition, and to provide a crude indication of the potential for these ranges to support increased ungulate numbers under a full ecosystem-restoration scenario.

Carrying capacity was considered using two approaches: forage production and forage utilization (hereafter CC_P and CC_U, respectively). The forage-production approach considered how much grass was available at the end of the growing season in preferred sheep habitat, then determined how many overwintering ungulates (including sheep) could be supported by this forage. The forage-utilization approach was based on the degree to which grasses were consumed by the end of winter, in relation to the number of ungulates (including sheep) present.

Estimates presented here differ from those in an earlier summary of the same material (Jalkotzy 2002). That earlier summary was based on a regional model averaged between versions that did and did not include elevation as a variable. The material presented here used the full regional model (i.e. elevation was a variable in the model), as no rationale was apparent for modifying it. There were also several other minor modifications in assumptions between the former and current estimates. Finally the earlier estimates were production-based, whereas both production- and utilization-based estimates are presented here.

2.0 Methods

2.1 Carrying Capacity Based on Forage Production

Carrying capacity is generally determined through the following formula when basing calculations on the amount of forage available:

$$\text{carrying capacity} = \frac{\text{useable area x production/area x safe-use factor}}{\text{forage consumption.}}$$

For this project, useable area for each herd was considered to be the intersection of 3 map layers: the composite home range of radiocollared ewes, the TEM types selected by bighorn sheep according to the micro-habitat selection analysis (Chapter 3), and the potential bighorn sheep habitat identified by the regional model (Chapter 4). Production estimates were based on the clip data collected in each identified plant community (Chapter 5). However, there were often several plant communities per TEM site series, the plant communities identified did not necessarily represent all types present per TEM site series, the plant communities were not mapped, and not all of the preferred TEM site series were sampled. As a result, the average production per TEM site series or for preferred habitat as a whole could not be calculated. Instead, the production figures for the plots that were sampled were presented as minimum and maximum figures for the preferred habitat. The safe-use factor accounted for the need to leave some of the annual forage production as carry-over, to allow plant regrowth, seed production, winter insulation and erosion control. In the East Kootenay, the safe-use factor is 50% (D. Smith, Ministry of Agriculture and Lands, Cranbrook, pers. comm.). Monthly forage consumption varies by species, so carrying capacity is either species-specific or converted to standardized units representing cattle requirements (see below).

This general concept was applied through the following steps to estimate CC_P.

1. *Home Range Extent*. Composite minimum convex polygon winter home ranges of radiocollared ewes were determined for Columbia Lake, Bull River and Mount Broadwood (Chapter 3; Figure 1). Because sheep were not tagged at Premier Ridge as part of this study, the composite winter home range for that area was based on data from ewes monitored there in 2005 and 2006 as part of another project (L. Ingham, Fish and Wildlife Compensation Program, BC Hydro, Invermere, unpubl. data). Those animals were translocated to Premier Ridge, so there appeared to be greater than normal movement. To minimize the effect of this, the data were screened to exclude locations beyond what is believed to have been the approximate northern and southern bounds of resident sheep there, i.e. the UTM northings of the mouths of Diorite and Lewis creeks, respectively.

2. *"Best" Habitat (Regional Model)*. In a GIS environment, the areal extent of classes 1 and 2 of the regional habitat model (Figure 1) was determined for each composite home range.

3. *Preferred TEM Types Within Best Regional Habitat*. TEM mapping was overlayed on the regional habitat model (Figure 2) to identify the extent of preferred TEM site series and structural stages within the class 1 and 2 regional habitat. Only the leading TEM type occurring in each map polygon was considered. Preferred site series were those in which relative use exceeded relative availability (Chapter 3), whether or not this difference was statistically significant (in effect, this process simply eliminated site series that were avoided). Similarly, preferred structural stages were considered to be those in which use

exceeded availability. Polygons were included only if the leading type in them was both a preferred site series and a preferred structural stage. TEM map polygons coded as exposed soil, rock, talus or non-vegetated were included only if those types were coded as constituting 5/10^{ths} or less of the polygon, because such types would have minimal forage production. Polygons coded as river were not considered.

4. *Correction of Extent of Preferred TEM Types*. Because TEM mapping did not completely cover the composite winter home range at any of the study sites (Figure 2), the area of preferred TEM types identified above was corrected. It was assumed that, within the composite home range, any class 1 and 2 regional habitat that lacked TEM mapping had the same proportion of preferred TEM types as the class 1 and 2 habitat having TEM mapping, so the value obtained in Step 3 was increased proportionally.

5. *Production of Most-Used Grasses Per Hectare*. The only type of forage considered for carrying capacity calculations was graminoids. This was because grasses formed the large majority of total forage evident in scats (Section 3.3 of Chapter 5), and forbs and shrubs were relatively abundant at each study area. There was assumed to be sufficient plasticity in bighorn sheep diets and behavior that if adequate grass forage was available, sheep would be able to obtain at least the minimal amount of forbs or shrubs needed to supplement the grass. To determine grass production in preferred TEM site series, the values for each study area were obtained by first calculating the average production per hectare for all plant community types investigated at each study area (Tables 8, 9, 10, 11 and 12 of Section 3.4 of Chapter 5). At Bull River, the production values were calculated separately for the total production (assuming no cattle utilization) and the production remaining after cattle grazing[17]. At all study areas, much of the grass production was due to unpalatable or otherwise little-used grasses, with needlegrasses, wheatgrasses and fescues being strongly dominant in the diet (Tables 5, 6 and 7 in Section 3.3 of Chapter 5). Total graminoid forage production (per hectare) at each study area was therefore adjusted by: the proportion of foliar cover of the 3 preferred grass types to the total graminoid foliar cover.[18]

6. *Total Production of Most-Used Grasses*. The production of the most-used grasses per hectare (Step 5) was multiplied by the corrected areal extent of preferred TEM types within Class 1 and 2 regional habitat (Step 4) to get the total estimated production of preferred grass types within the best bighorn sheep habitat.

7. *Monthly Preferred Grass Forage Requirement Per Sheep*. A realistic animal-unit (AU) equivalent for mature Rocky Mountain bighorn ewes in British Columbia is about 0.15 and for mature rams is about 0.20 (Table 1). Assuming a population bias toward females and the presence of immature animals in the population, the AU for an "average" sheep should be no more than 0.17, or 61 kg of forage monthly. Because production figures were adjusted downward to reflect only preferred grasses (Step 5), it was necessary to also adjust the forage requirements. For Columbia Lake, Bull River and Mount Broadwood, the

[17] Cattle grazing also occurs on much of the Premier Ridge range. There is no grazing on the face of the Rocky Mountains but 100 animal unit months allocated to the 3 pastures along Premier Ridge itself (Elk, Sheep and Quartz pastures; P. Burk, Ministry of Forests and Range, Invermere, pers. comm.). However, there was no cattle activity apparent during sampling periods, perhaps because cattle were in other pastures at that time.

[18] While foliar cover is not precisely proportional to forage production, the relationship is relatively good when limited to grasses (D. Gayton, FORREX Forest Research Extension Partnership, Summerland, pers. comm.).

local percentage of winter diet consisting of grasses (Tables 5, 6 and 7 in Section 3.3 of Chapter 5) was multiplied by the 61-kg monthly forage requirement to obtain the grass-only monthly requirement (assuming the portion of the diet consisting of forbs and shrubs would not be limiting, as per Step 5). It was assumed that the January-April diet was representative of the entire winter. For Premier Ridge, the mean of values from Columbia Lake and Bull River was used.

8. *Winter-long Preferred Grass Forage Requirement Per Sheep.* The monthly requirement for preferred grasses was multiplied by an assumed 7-month tenure on winter ranges to obtain the winter-long requirement per sheep. This was then doubled to allow for 50% carry-over, i.e. to limit utilization of preferred grasses to 50%.

9. *Expected CC_P.* The total production of preferred grasses (Step 6) was divided by the winter-long requirement for those grasses, allowing for carry-over (Step 8) to estimate the expected carrying capacity for bighorn sheep. This assumed the presence of no other ungulates during the winter.

10. *Minimum and Maximum Current CC_P.* Steps 1 through 9 were repeated twice more, with the only difference being that at Step 5, the gross grass production for all plant communities combined was considered to be (a) that of the least productive plant community (to get a minimum estimate carrying capacity, in the event that the least productive community was more representative of the study area as a whole) and then (b) that of the most productive plant community (to get a maximum estimate of carrying capacity, in the event that the most productive community was more representative of the study area).

11. *Potential CC_P.* Steps 1 through 10 were again repeated, except that the “best” habitat as identified from the regional model (Step 2) was replaced with all areas identified as habitat (classes 1 - 6, rather than just classes 1 and 2). This estimated the upper limit of carrying capacity for bighorn sheep if all areas within the composite home range having the physical capability to support sheep and having preferred TEM types were used by sheep, assuming other assumptions were correct.

12. *Effect of Other Ungulates.* Estimates obtained via steps 1 through 11 above were adjusted downward to account for the presence of elk and deer on the winter ranges.

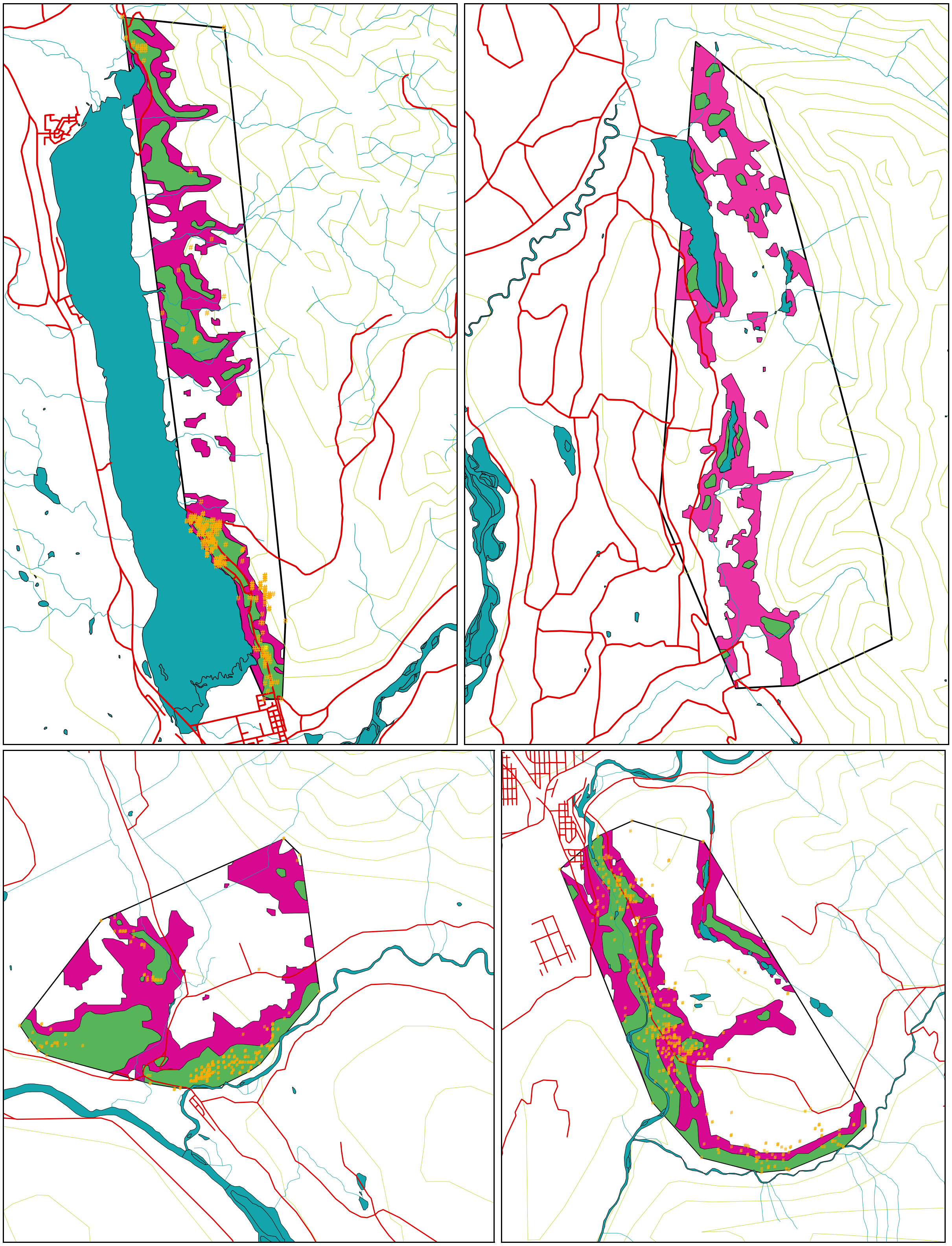

Figure 1. Composite winter home ranges of bighorn ewes at (clockwise from top left) Columbia Lake, Premier Ridge, Mount Broadwood and Bull River in relation to telemetry locations (orange), Class 1 and 2 regional habitat (green), and other regional habitat (pink). No digital telemetry data available for Premier Ridge. Not all to same scale.

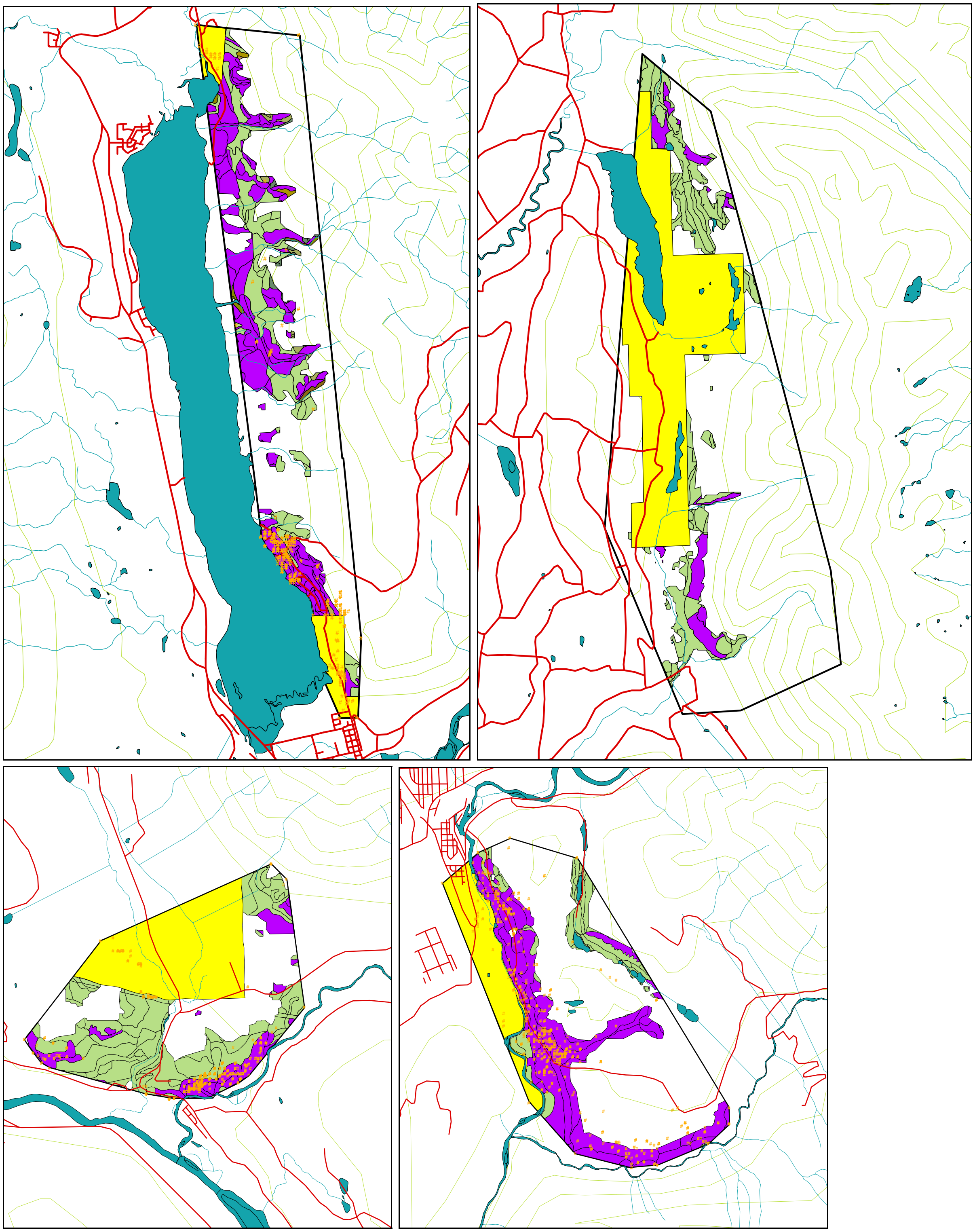

Figure 2. Composite winter home ranges of bighorn ewes at (clockwise from top left) Columbia Lake, Premier Ridge, Mount Broadwood and Bull River in relation to telemetry locations (orange), preferred TEM site series (purple), other TEM site series (green) and areas without TEM mapping (yellow). TEM mapping shown only within areas identified through regional modeling as habitat (Figure 1). Premier Lake map shows preferred structural stages rather than preferred site series. Not all to same scale.

Table 1. Animal-unit equivalent and forage consumption by cattle and mature wild ungulates present in the East Kootenay. Several estimates provided for most species, based on multiple information sources.

Species and Sex	Animal Unit Equivalent[a]	Forage Per Month (kg)	Source
Range Cow and Calf	1.0	358	GLTI 2003, HMC 1990
Bighorn Sheep			
California (female)	0.13	47	HMC 1990
Rocky Mtn (female)	0.15	54	assumes forage consumption difference between ssp. proportional to weight difference; R. Mtn.=72.1 kg (Shackleton 1999), Cal.=61.2 kg (HMC 1990; above)
Rocky Mtn (male)	0.20	72	assumes forage consumption difference between sexes proportional to weight difference; male=93.8 kg, female=72.1 kg (Shackleton 1999, above)
Not Specified	0.2	72	GLTI 2003
Elk			
Female	0.38	136	HMC 1990
Female	0.41	147	HMC (1990) estimate for female elk above based on 226.8 kg; Shackleton (1999) lists weight as 245.5 kg
Male	0.44	154	HMC 1990
Male	0.54	193	HMC (1990) estimate for male elk above based on 285.8-kg; Shackleton (1999) lists weight as 353.5 kg
Not Specified	0.6	215	GLTI 2003
Mule Deer			
Female?	0.13	47	HMC 1990 (sex not specified; assumed to be female based on AU equivalent w.r.t. white-tailed deer female, below)
Male	0.21	75	assumes forage consumption difference between sexes proportional to weight difference; Rocky Mtn ssp. male=103.7 kg, female=64.6 kg (Shackleton 1999)
Not Specified	0.2	72	GLTI 2003
White-tailed deer			
Female	0.125	45	HMC 1990
Male	0.16	59	assumes forage consumption difference between sexes proportional to weight difference; Northwestern ssp. male= 77.0 kg (Shackleton 1999), female=59.0 kg (HMC 1990, above)
Not Specified	0.15	54	GLTI 2003

[a] An animal unit is defined as a 1000-lb (454-kg) cow and her calf up to weaning, or their equivalence (GLTI 2003).

2.2 Carrying Capacity Based on Forage Utilization

Forage utilization levels estimated from cages (Tables 8 - 12 of Section 3.4 of Chapter 5) were used to estimate CC_U for bighorn sheep winter ranges. As with the forage-production approach, only grasses, not forbs or shrubs, were considered. Carrying capacity was estimated as the quotient of the number of sheep present and the proportion of grass production that was utilized, adjusted downward by 50% to allow carry-over, i.e.:

$$CC_U = (\text{number of sheep} / [\%\ \text{utilization}/100]) \times 0.5.$$

Current sheep populations were considered to be the mean of 1997 and 2001 estimates (I. Teske, Ministry of Environment, Cranbrook, unpubl. data). Minimum and maximum CC_U estimates were calculated for each study area, based on plant communities that had the greatest and least forage utilization, respectively. It was not possible to isolate utilization due to sheep from utilization due to other wintering ungulates. Therefore, CC_U estimates implicitly assume that winter grass utilization by species other than sheep is static and that the populations of those species are therefore also fixed.

Because summer cattle grazing occurred at Bull River, utilization there was determined in 2 ways. Under the current situation (with cattle), CC_U was influenced by both summer cattle utilization and winter wild-ungulate utilization. Because winter utilization by wild ungulates recorded through field sampling was within the context of forage that remained after cattle grazing, total utilization was determined as:

total utilization = summer cattle utilization + winter wild-ungulate utilization
= {summer utilization + ([100% - summer utilization] x winter utilization)}.

Theoretical CC_U in the absence of cattle was also determined, with wild ungulate utilization estimated as follows:

wild-ungulate utilization = ([100% - summer utilization] x winter utilization).

3.0 Results

3.1 Production-Based Carrying Capacity

Results of production-based carrying capacity estimates are summarized in Table 2, with details in Appendices 6-1 and 6-2. Carrying capacity estimates presented in Table 2 assumes no competition from other overwintering ungulates. However, all winter ranges have elk, mule deer and white-tailed deer present (Table 3, Table 4, Table 5). Under reasonable assumptions about the distribution and forage requirements of those species, the amount of forage removed by elk and deer would represent roughly 20 to 100% of the bighorn sheep carrying capacity (Table 6).

Table 2. Estimated bighorn sheep carrying capacity (CC_P) on 4 East Kootenay winter ranges, based on production of most-used grasses in preferred habitats c. 1998-2000. No allowance made for winter grazing by other wild ungulates. Min and Max refer to calculations based on plant communities having least and greatest grass production, respectively.

Winter Range	CC_P in Composite Home Range					
	In Best Habitat[a]			In All Habitat[b]		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Columbia Lake	47	95	153	88	180	289
Premier Ridge	18	23	29	104	135	172
Bull River: with cattle	12	23	41	18	35	63
without cattle	23	43	91	35	65	138
Mount Broadwood	37	156	324	104	438	909

[a] based on habitat classes 1 and 2 from regional model and limited to preferred TEM types
[b] based on habitat classes 1 through 6 from regional model and limited to preferred TEM types

Table 3. Effective number of elk on bighorn sheep winter habitat c. 1999 based on average elk densities in local survey blocks and considering differences in habitat use and diet.

Winter Range	Elk Survey Data[a]			Elk Density (no./km^2)	Best Sheep Habitat[b] (km^2)	All Sheep Habitat[b] (km^2)	Cor-rection Factor[c]	Eff. No. Elk[d] (Best)	Eff. No. Elk[d] (All)
	Survey Year	Est. Elk No.	Survey Area (km^2)						
Columbia Lake	1997	165.4	13.9	11.90	1.67	3.16	0.5	10	19
Premier Ridge	1997 2001	203.6	16.0	12.73	0.37	2.18	0.5	2	14
Bull River	2001	76.0	12.2	6.23	1.11	1.69	0.5	3	5
Mt. Broadwood	1997 2001	189.2	35.4	5.34	2.22	6.23	0.5	6	17

[a] sources: Halko and Hebert (1997) and Halko and Hebert (2001); data used from elk survey blocks overlapping with sheep winter ranges
[b] as calculated through Steps 1 to 4 (and Step 11) of forage-based carrying capacity calculations above
[c] elk density assumed to be 25% lower on best sheep habitat than in survey unit generally due to partial habitat-use differences with bighorns (Hudson et al. 1976, Shackleton 1999); partial dietary differences (Shackleton 1999, Ross and Wikeem 2002) assumed to reduce effect of elk on bighorn graminoid forage by a further 33% (0.75 x 0.67 = 0.5)
[d] effective number of elk in best or all habitat = elk density x sheep habitat area x correction factor

Table 4. Effective number of mule deer on bighorn sheep winter habitat in 1994 based on average winter deer densities in local wildlife management unit (WMU) and considering differences in habitat use and diet.

Winter Range	WMU	Best Sheep Habitat[a] (km^2)	All Sheep Habitat[a] (km^2)	Density[b] (no./km^2)	Correction Factor [c]	Eff. No.[d] in Best Hab.	Eff. No.[d] in All Hab.
Columbia Lake	4-25	1.67	3.16	2.33	0.5	2	4
Premier Ridge	4-21	0.37	2.18	6.37	0.5	1	7
Bull River	4-22	1.11	1.69	22.24	0.5	12	19
Mt. Broadwood	4-02	2.22	6.23	20.26	0.5	22	63

[a] as calculated through Steps 1 to 4 (and Step 11) of forage-based carrying capacity calculations above
[b] data reflect 1994 numbers; source: M. Panian, (formerly) Ministry of Environment, Lands and Parks, Nelson, unpubl. data (file date 15 January 1999)
[c] mule deer density assumed to be 20% lower on best sheep habitat than in survey unit generally due to partial habitat-use differences with bighorns (Hudson et al. 1976, Shackleton 1999); partial dietary differences (Shackleton 1999) assumed to reduce effect of mule deer on bighorn graminoid forage by a further 40% (0.8 x 0.6 = 0.48 = ~ 0.5)
[d] effective number of deer = deer density x sheep habitat area x correction factor

Table 5. Effective number of white-tailed deer on bighorn sheep winter habitat in 1994 based on average winter deer densities in local wildlife management unit (WMU) and considering differences in habitat use and diet.

Winter Range	WMU	Best Sheep Habitat[a] (km^2)	All Sheep Habitat[a] (km^2)	Density[b] (no./km^2)	Correction Factor [c]	Eff. No.[d] in Best Hab.	Eff. No.[d] in All Hab.
Columbia Lake	4-25	1.67	3.16	2.76	0.25	1	2
Premier Ridge	4-21	0.37	2.18	4.30	0.25	0	2
Bull River	4-22	1.11	1.69	27.44	0.25	8	12
Mt. Broadwood	4-02	2.22	6.23	7.30	0.25	4	11

[a] as calculated through Steps 1 to 4 of forage-based carrying capacity calculations above
[b] data reflect 1994 numbers; source: M. Panian, (formerly) Ministry of Environment, Lands and Parks, Nelson, unpubl. data (file date 15 January 1999)
[c] white-tailed deer density assumed to be 50% lower on best sheep habitat than in survey unit generally due to partial habitat-use differences with bighorns (Hudson et al. 1976, Shackleton 1999); partial dietary differences (Shackleton 1999) assumed to reduce effect of whitetails on bighorn graminoid forage by a further 50% (0.5 x 0.5 = 0.25)
[d] effective number of deer = deer density x sheep habitat area x correction factor

Table 6. Effect on bighorn sheep carrying capacity of other ungulates sharing their winter ranges c. 1999.

Calculation	Winter Range				
	Columbia Lake	Premier Ridge	Bull River w/ Cattle	Bull River w/o Cattle	Mt. Broadwood
Elk					
Effective Number[a] (Best Habitat)	10	2	3	3	6
Effective Number[a] (All Habitat)	19	14	5	5	17
Occupancy Time[b] (mo)	5.8	5.8	5.2	5.2	5.2
Animal Unit Ratio[c]	2.65	2.65	2.65	2.65	2.65
CC_P Loss[d] (Best Habitat)	22	4	6	6	12
CC_P Loss[d] (All Habitat)	42	31	10	10	33
Mule Deer					
Effective Number[e] (Best Habitat)	2	1	12	12	22
Effective Number[e] (All Habitat)	4	7	19	19	63
Occupancy Time[f] (mo)	7.0	7.0	7.0	7.0	7.0
Animal Unit Ratio[c]	0.94	0.94	0.94	0.94	0.94
CC_P Loss[d] (Best Habitat)	2	1	11	11	21
CC_P Loss[d] (All Habitat)	4	7	18	18	59
White-tailed Deer					
Effective Number[g] (Best Habitat)	1	0	8	8	4
Effective Number[g] (All Habitat)	2	2	12	12	11
Occupancy Time[f] (mo)	7.0	7.0	7.0	7.0	7.0
Animal Unit Ratio[c]	0.82	0.82	0.82	0.82	0.82
CC_P Loss[d] (Best Habitat)	1	0	7	7	3
CC_P Loss[d] (All Habitat)	2	2	10	10	9
Total CC_P Loss[d] (Best Habitat)	*25*	*5*	*24*	*24*	*36*
Total CC_P Loss[d] (All Habitat)	*48*	*40*	*38*	*38*	*101*
Sheep CC_P in BEST Habitat w/o Elk & Deer (min-mean-max)[h]	47-95-153	18-23-29	12-23-41	23-43-91	37-156-324
Sheep CC_P in ALL Habitat w/o Elk & Deer (min-mean-max)[h]	88-180-289	104-135-172	18-35-63	35-65-138	104-438-909
Sheep CC_P in BEST Habitat, w/ Elk & Deer present (min-mean-max)	22-**70**-128	13-**18**-24	0-**0**-17	0-**19**-67	1-**120**-288
Sheep CC_P in ALL Habitat, w/ Elk & Deer present (min-mean-max)	40-**132**-241	64-**95**-132	0-**0**-25	0-**27**-100	3-**337**-808

[a] Table 3
[b] source: Jamieson and Hebert (1993); Premier Ridge and Bull River values are means reported for 2 winters; Columbia Lake assumed to be same as Premier Ridge; Mount Broadwood assumed to be same as Bull River
[c] ratio of elk or deer animal-unit equivalent to bighorn sheep animal-unit equivalent; based on an animal-unit equivalent of 0.17 for bighorn sheep (Step 7 of forage-based carrying capacity calculations above), 0.45 for elk, 0.16 for mule deer, and 0.14 for white-tailed deer assuming a female bias and the presence of some immature animals in population (Table 1)
[d] sheep foraging equivalent = number of that species x animal unit ratio x (species winter range occupancy time / sheep winter range occupancy time [7 mo])
[e] Table 4
[f] assumed to be same as for bighorn sheep (7 mo)
[g] Table 5
[h] Table 2

3.2 Utilization-Based Carrying Capacity

Using grass utilization levels in relation to the number of sheep present, mean estimated CC_U at the 4 study areas ranged between 58 (Bull River) and 345 (Mount Broadwood; Table 7).

Table 7. Estimated bighorn sheep carrying capacity (CC_U) at 4 East Kootenay winter ranges, based on utilization of grass forage c. 1999 in relation to number of sheep present at that time. Utilization due in part to elk and deer, so carrying capacity estimates implicitly assume numbers of those species remain constant. Maximum carrying capacity numbers in brackets unreliable due to extreme outliers in minimum utilization observations.

Winter Range	Grass Utilization (%)			No. of Sheep[a]	CC_U[b]		
	Min	Mean	Max		Min	Mean	Max
Columbia Lake	20.6	55.3	88.2	120	68	108	291
Premier Ridge	1.7	39.5	70.4	50	36	63	(1471)
Bull River w/ cattle[c]	47.8	65.1	77.9	75	48	58	78
Bull River w/o cattle[d]	0.5	20.4	44.1	75	85	184	(7500)
Mt. Broadwood	0.0	23.2	62.2	160	129	345	(∞)

[a] mean of 1997 & 2001 estimates (I. Teske, Ministry of Environment, Cranbrook, unpubl. data)
[b] CC_U = (number of sheep / grass utilization) x carry-over requirement of 0.5
[c] total utilization = {summer utilization + ([100% - summer cattle utilization] x winter utilization)}
[d] wild-ungulate winter utilization = ([100% - summer cattle utilization] x winter utilization)

4.0 Discussion

Bighorn sheep populations were considerably greater than best-habitat CC_P estimates for each of the 4 winter ranges, even without accounting for the effect of sympatric deer and elk (Table 8). However, when all habitat identified by the regional model was considered (within composite home ranges and limited to preferred TEM types), populations were within estimated CC_P for all herds except Bull River. Again, this was true regardless of whether the effect of elk and deer grazing was considered.

The fact that CC_P estimates for all regional habitat appeared more realistic than those restricted to the best regional habitat suggests that bighorn sheep were obtaining much of their forage from areas rated as marginal to moderate habitat under the regional habitat model. However, it would not be expected that lower-quality habitats would contribute as much as the best habitats. Areas with lower ranks in the regional habitat model were rated that way because sheep typically spent less time there, so it is unlikely that use in them would have been sufficient to make use of all the forage available there. This suggests that sheep foraging probably extended into locations not assumed in the calculations to contribute toward carrying capacity, i.e.:

1. The maximal extent of sheep movements, considering both sexes and all individuals, was likely larger than defined by the composite home range of the 10-12 collared ewes per herd.
2. Non-preferred TEM types, while mathematically “avoided”, still experienced some use by bighorn sheep (Chapter 3). Some grassland TEM types fell into this category and even forested sites, to the extent that they were used by sheep, would have contributed to carrying capacity (Appendix 6-3).
3. Likewise, the regional model did not fit sheep habitat use perfectly, so there was some use of areas not identified in the regional habitat model (Chapter 4).

It is likely that the factors listed above were largely responsible for the apparently greater congruency of sheep populations with all-habitat CC_P than best-habitat CC_P but it is possible that other factors contributed in part to either an underestimate of CC_P or an unsustainably high number of sheep. These include:

4. Bighorn sheep populations may have been over carrying capacity at some winter ranges, especially with respect to the need for forage carry-over. If so, the effect was expressed as range degradation rather than population declines.
5. Grasses that were uncommon in the scat samples were used to some extent and may have been used significantly by some animals (such as rams), or during some years, or during some months. The same is true for the use of forbs or shrubs. Any dietary contribution of grasses other than needlegrasses, wheatgrasses and fescues would have increased the true carrying capacity, and any increase in the ratio of forbs and shrubs to grasses in the diet would have had the same effect.
6. CC_P estimates were based on assumptions regarding the representativeness of sampling sites and weather, how long sheep and other ungulates normally remained on winter range, the spatial and foraging overlap between sheep and other ungulates, and other factors. There were no doubt at least small errors in each of these assumptions, which could have cumulatively biased best-habitat CC_P estimates downward.

Table 8. Summary of mean bighorn sheep population estimates at the time of research and in 2005 in relation to estimates of carrying capacity on 4 East Kootenay winter ranges (from Results section above).

Estimate	Winter Range				
	Columbia Lake	Premier Ridge	Bull River w/ cattle	Bull River w/o cattle	Mount Broadwood
Sheep Population[a]					
▪ 1997-2001 mean	120	50	75	75	160
▪ 2005	150	40	100	100	270
▪ CC_P					
Best Habitat[b]					
- not including elk & deer grazing	95	23	23	43	156
- including elk & deer grazing	70	18	0	19	120
All Habitat[c]					
- not including elk & deer grazing	180	135	35	65	438
- including elk & deer grazing	132	95	0	27	337
▪ CC_U	108	63	58	184	345

[a] source: I. Teske, Ministry of Environment, Cranbrook, unpubl. data
[b] intersection of composite ewe home range, class 1 & 2 habitat identified in regional model, and preferred TEM types
[c] intersection of composite ewe home range, all habitat identified in regional model, and preferred TEM types

Thus, it is initially unclear whether the better fit between populations and the all-habitat CC_P was because (a) the all-habitat approach was appropriate and all assumptions were approximately correct, or alternatively (b) there were significant errors in the assumptions but they essentially cancelled each other out when using the all-habitat approach. Regardless of the reason, the all-habitat CC_P estimates (when accounting for elk and deer grazing) appeared realistic for 3 of 4 winter ranges, and were also quite similar to CC_U estimates (Table 8). This lends credence to the utility of either estimator as a approximation of carrying capacity. If so, carrying capacities (allowing 50% carryover, assuming elk and deer numbers continued at 1990s levels, and assuming no expansion in herd home ranges) are roughly:

- 120 sheep at Columbia Lake,
- 80 sheep at Premier Ridge, and
- 340 sheep at Mount Broadwood.

In relation to those estimates, 2005 population numbers suggest that the Columbia Lake range (Table 8) is now over capacity, Mount Broadwood is close to capacity and Premier Ridge was well below capacity, unless significant range enhancement has occurred since the time of research. Considering that elk numbers were likely lower in the years used in calculating carrying capacity than before or since (Bircher et al. 2001), the Mount Broadwood range has probably at least reached capacity and Premier Ridge may be nearing it. In fact, the regional model was based mainly on topographic features (which in turn relate to escape terrain and solar insolation), so lower-rated areas are likely used little if at all by sheep under conditions that make those features more critical, such as periods of high predator numbers or deep snow years. This would push carrying capacity below calculated levels in such years. For example, the limited escape terrain on the portion of the Premier Ridge winter range that is away from the face of the Rockies (i.e. Premier Ridge itself) limits its value when predator numbers are moderate to high (I. Teske, Ministry of Environment, Cranbrook, pers. comm.). The 1990s saw high cougar populations in the Kootenays, with numbers apparently peaking from 1996 to 1998 (Mowat 2006). Thus, during fieldwork, use of the sampling areas (away from escape terrain) was likely unrepresentatively low, and that area will likely contribute comparatively little during any future predator population peaks. In addition, the 100 AUMs of cattle grazing allocated at Premier Ridge was not considered in estimates. Thus, as of 2005, it is highly probable that the Columbia Lake herd is beyond a sustainable carrying capacity, and likely that Mount Broadwood and Premier ridge are at or over that level[19].

Carrying capacity estimates for the Bull River winter range are difficult to interpret given the population numbers there. Under virtually all scenarios and even if no cattle were present, the sheep population exceeded the calculated carrying capacities at the time of field work, then continued to grow through 2005 (Table 8). In fact, the most realistic estimate of CC_P for Bull River showed no capacity to support bighorn sheep after accounting for cattle, elk and deer consumption. In other words, the estimated post-cattle-grazing capacity of 35 sheep would be accounted for by elk and deer. Bull River is the only winter range where CC_U greatly exceeded CC_P (assuming the presence of elk and deer), which suggests that there may have been a problem with CC_P. This could have been partly a result of production cages being moved during the summer, which would underestimate production (Chapter 5). However, production figures for Bull River prior to cattle grazing were actually the highest of those observed at the 4 study sites (Appendix 6-1). Had concentrated sheep activity extended beyond areas where production and utilization were measured, carrying capacity would have been underestimated, but this was not the case among radiocollared ewes (Figure 1 of Chapter 5; Figure 2). Carrying capacity estimates would also have been too low if elk and deer numbers were overestimated, the cattle grazing regime (Appendix 6-4) changed immediately after the research was conducted, or the amount of cattle grazing at cage sites was unrepresentatively high in relation to other areas grazed by bighorn sheep. However, even if one assumed no cattle, deer or elk

[19] Plant-community and forage data at Premier Ridge were actually collected outside the composite home range polygon of translocated sheep. Although the field work was intended to be within the range of residents at that time, the lack of telemetry data for the sampling years and the apparent shift in habitat use between residents and translocted animals makes it unclear how representative the carrying capacity calculations are of the current or even former situation.

present, CC_P would still be lower than the c. 1999 population and certainly less than the 2005 population (Table 8). This indicates that a series of assumptions used in calculating Bull River's CC_P must have been incorrect, possibly including the size of the composite home range, time of occupancy on the winter range or plant species eaten.

Moving beyond inconsistencies with the CC_P estimates for Bull River, the next difficulty is that the CC_U estimate also showed a capacity lower than either the c. 1999 or the 2005 population. As with the CC_P estimate, it would require considerable and unlikely errors in assumptions regarding the numbers or distribution of other wild ungulates and cattle to bring CC_U in line with sheep numbers. In sum, even if the more conservative CC_P approach is rejected (despite its utility at other winter ranges), the CC_U estimate indicates that the Bull River winter range was and remains well above its sustainable carrying capacity. The only reasons that this would not be the case are if sheep at Bull River:

(a) enter winter at such good condition that they can subsist for the winter on very little forage and do not even make maximal use of the available forage;
(b) have diets much different than those observed through the scat samples that showed them to forage in much the same way as sheep at other winter ranges;
(c) exhibit dramatically different behavior between sexes (though Ruckstuhl et al. [2000] found at least gross similarity in foraging by rams and ewes);
(d) utilize the areas where production cages were placed far more than other areas in which they forage; or
(e) have a natural or artificial forage source that far exceeds those investigated.

There is some evidence that this last possibility is at least partially true. Residents of Bull River reported that there is considerable use by sheep of a hay field immediately north of the Bull River and west of Wardner – Fort Steele Road (D. Zehnder, environmental farm consultant, Invermere, pers. comm.). This is outside of the home range of the radiocollared ewes so did not influence CCP estimates, either by its area or its enhanced forage production. The use of it (and other similar areas) would also have reduced utilization in the areas sampled. Considering the various estimates of carrying capacity for Bull River and the possible reasons for the lack of fit between them and the growing population, it seems most likely that there was a strong influence of an underestimate in the areas covered by sheep and especially the forage sources within them. If so, and if agriculture-based food sources become unavailable through fencing or changing land-use patterns, then there are strong indications that carrying capacity for sheep at Bull River will be much reduced.

In summary, there is evidence for each of the 4 winter ranges that carrying capacity is now limiting sheep population growth, soon will limit it, or can be periodically limiting under certain ecological or human-influenced conditions. Competing ungulates will exacerbate this situation if recovery from their late 1990s lows continues. Recent wildlife-proof fencing on many ranches has likely already concentrated elk and deer on bighorn range, further suppressing carrying capacity for sheep. If carrying capacity is to be increased to the point that sheep populations can grow or even remain at current levels without further deterioration of the already-compromised rangeland, forage availability must be increased. Approaches to achieving this, including the control of weeds and reversal of forest ingrowth, are identified in Section 5.0 of Chapter 5 and in Chapter 7.

One specific observation influencing potential habitat restoration work relates to the key factors influencing carrying capacity. There was some variability in production among the plant communities studied (Section 3.4 of Chapter 5), all of which were in open habitats, but their low productivity was related to unchangeable site conditions such as xeric soils, was influenced by occurring at the edge of forests, or was related to an abundance of exotic plant species. More importantly, the variability among the grassland or grass-shrubland communities was generally less than the variability between these communities and forested communities with closed canopies (Appendix 6-3). As such, there is less forage production to be gained by trying to improve existing habitat than from creating new habitat through overstory removal. This is further supported by the observation that prescribed burning of existing grassland for bighorn sheep leads to only a short-term improvement in forage quality (Ruckstuhl et al. 2000). Sheep distribution is of course also linked to terrain characteristics (Chapter 4), but the mechanical conversion of areas relatively near escape terrain from closed-canopy forest to open-canopied forest or non-forest can dramatically increase sheep use of such areas (Dibb and Quinn in press). Increased use coupled with increased forage production provides the opportunity to significantly increase carrying capacity through the creation of new habitat.

In the long term, targets for the numbers of sheep and other ungulates need to be set in relation to the biophysical capability of winter ranges and the degree to which this capability is realized through habitat restoration and weed control. To achieve this, productivity, utilization and range conditions would need to be investigated on larger portions of the winter ranges, rather than just at the sites most heavily used by sheep. Ultimately, one of the major indicators of carrying capacity is sheep physical condition. While forage-based calculations are instructive, measures of body condition are the ultimate indicator of whether sheep occur at densities beyond the capacity of their winter ranges.

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Appendix 6-1. Detailed calculations for estimates provided in Table 2 of production-based bighorn sheep carrying capacity (CC_P) on "best" regional habitat and preferred TEM types (assuming no other wild ungulates). Steps outlined in Section 2.1

Step	Calculation	Columbia Lake	Premier Ridge	Bull River (w/ cattle)	Bull River (w/o cattle)	Mount Broadwood
1	composite home-range polygon (ha)	3370.7	4154.8	1592.8	1592.8	1977.2
2	class 1 & 2 in c.h.r. polygon (ha)	564.8	101.7	345.4	345.4	379.6
3	area of preferred site series having preferred structural stages (ha)[a]	132.0	16.4	102.8	102.8	161.3
4	TEM mapping extent within class 1 & 2 in c.h.r. polygon (ha)	446.7	44.8	319.4	319.4	275.9
4	TEM mapping within class 1 & 2 in c.h.r. poly (% of class 1 & 2)	79.1	44.1	92.5	92.5	72.7
4	preferred s.series & st.stage, corr. for missing TEM mapping (ha)	166.8	37.3	111.2	111.2	221.9
5	minimum grass production (kg/ha) from tables 8 - 12 of Chapter 5	256.0	479.0	246.0	491.0	182.0
5	mean grass production (kg/ha) from tables 8 - 12 of Chapter 5	524.2	623.0	494.6	908.0	765.3
5	maximum grass production (kg/ha) from tables 8 - 12 of Chapter 5	839.0	796.0	875.0	1932.0	1590.0
5	needlegrasses, wheatgrasses & fescues (% of graminoid canopy)	71.2	69.5	31.6	31.6	51.7
5	minimum effective grass production (kg/ha)	182.3	332.7	77.6	155.0	94.1
5	mean effective grass production (kg/ha)	373.2	432.7	156.1	286.6	395.8
5	maximum effective grass production (kg/ha)	597.4	552.8	276.2	609.7	822.3
6	minimum total production of 3 main grasses (kg)	30412	12395	8630	17225	20890
6	mean total production of 3 main grasses (kg)	62269	16122	17352	31853	87838
6	maximum total production of 3 main grasses (kg)	99670	20599	30696	67776	182501
7	forage requirement per sheep per month, assuming 0.17 AU (kg)	61	61	61	61	61
7	% of winter diet composed of grasses (%) [if 7-mo avg = 4-mo avg][b]	76.5	81.9	87.3	87.3	65.9
7	grass required / sheep / mo assuming adequate forbs & shrubs (kg)	46.7	50.0	53.3	53.3	40.2
8	assumed length of stay on winter range (mo)	7	7	7	7	7
8	dietary grass requirement per sheep per winter (kg)	326.6	349.8	372.9	372.9	281.4
8	total grass requirement / sheep / winter allowing 50% carryover (kg)	653	700	746	746	563
9	minimum estimated bighorn sheep carrying capacity	47	18	12	23	37
9	**mean estimated bighorn sheep carrying capacity**	**95**	**23**	**23**	**43**	**156**
9	maximum estimated bighorn sheep carrying capacity	153	29	41	91	324

[a] Preferred site series (in descending order):
Columbia Lake – SW, AW, ES, DJ
Premier Ridge – all; would normally be assumed to be AW & CF (as at Columbia Lake and Bull River), but none of those exist in the preferred regional habitat at Premier Ridge
Bull River – AW, CF, NV
Mount Broadwood – AF, WS, DB, NV, SB, LS
Polygons having non-vegetated type (ES, NV) as leading site series included only if that type forms <5/10ths of the polygon (otherwise too little forage production to consider)
Preferred structural stages (in descending order):
Columbia Lake – 2, 3, 1
Premier Ridge – 2, 3, 1 (as at Columbia Lake; coding system different at Bull River)
Bull River – 3a, 2
Mount Broadwood – 1, 2, 4

[b] grass proportion in winter diet for Premier Ridge assumed to be mean of Columbia Lake and Bull River values, as no diet analysis done at Premier Ridge

Appendix 6-2. Detailed calculations for estimates provided in Table 2 of production-based bighorn sheep carrying capacity (CC_P) on all habitat identified in regional model having preferred TEM types (assuming no other wild ungulates). Steps outlined in Section 2.1.

Step	Calculation	Columbia Lake	Premier Ridge	Bull River (w/ cattle)	Bull River (w/o cattle)	Mount Broadwood
1	composite home-range polygon (ha)	3370.7	4154.8	1592.8	1592.8	1977.2
2	regional habitat in c.h.r. polygon (ha)	1453.2	980.6	851.1	851.1	866.5
3	area of preferred site series having preferred structural stages (ha)[a]	271.5	117.5	136.0	136.0	475.6
4	TEM mapping extent within regional habitat in c.h.r. polygon (ha)	1250.7	528.2	684.9	684.9	662.0
4	TEM mapping within regional habitat in c.h.r. poly (% of reg. hab.)	86.1	53.9	80.5	80.5	76.4
4	preferred s.series & st.stage, corr. for missing TEM mapping (ha)	315.5	218.2	169.0	169.0	622.5
5	minimum grass production (kg/ha) from tables 8 - 12 of Chapter 5	256.0	479.0	246.0	491.0	182.0
5	mean grass production (kg/ha) from tables 8 - 12 of Chapter 5	524.2	623.0	494.6	908.0	765.3
5	maximum grass production (kg/ha) from tables 8 - 12 of Chapter 5	839.0	796.0	875.0	1932.0	1590.0
5	needlegrasses, wheatgrasses & fescues (% of graminoid canopy)	71.2	69.5	31.6	31.6	51.7
5	minimum effective grass production (kg/ha)	182.3	332.7	77.6	155.0	94.1
5	mean effective grass production (kg/ha)	373.2	432.7	156.1	286.6	395.8
5	maximum effective grass production (kg/ha)	597.4	552.8	276.2	609.7	822.3
6	minimum total production of 3 main grasses (kg)	57512	72583	13124	26195	58592
6	mean total production of 3 main grasses (kg)	117758	94404	26389	48443	246366
6	maximum total production of 3 main grasses (kg)	188487	120619	46682	103074	511871
7	forage requirement per sheep per month, assuming 0.17 AU (kg)	61	61	61	61	61
7	% of winter diet composed of grasses (%) [if 7-mo avg = 4-mo avg][b]	76.5	81.9	87.3	87.3	65.9
7	grass required / sheep / mo assuming adequate forbs & shrubs (kg)	46.7	50.0	53.3	53.3	40.2
8	assumed length of stay on winter range (mo)	7	7	7	7	7
8	dietary grass requirement per sheep per winter (kg)	326.6	349.8	372.9	372.9	281.4
8	total grass requirement / sheep / winter allowing 50% carryover (kg)	653	700	746	746	563
9	minimum estimated potential bighorn sheep carrying capacity	88	104	18	35	104
9	**mean estimated potential bighorn sheep carrying capacity**	**180**	**135**	**35**	**65**	**438**
9	maximum estimated potential bighorn sheep carrying capacity	289	172	63	138	909

[a] Preferred site series (in descending order):
Columbia Lake – SW, AW, ES, DJ
Premier Ridge – all; would normally be assumed to be AW & CF (as at Columbia Lake and Bull River), but none of those exist in the preferred regional habitat at Premier Ridge
Bull River – AW, CF, NV
Mount Broadwood – AF, WS, DB, NV, SB, LS
Polygons having non-vegetated type (ES, NV) as leading site series included only if that type forms <5/10ths of the polygon (otherwise too little forage production to consider)
Preferred structural stages (in descending order):
Columbia Lake – 2, 3, 1
Premier Ridge – 2, 3, 1 (as at Columbia Lake; coding system different at Bull River)
Bull River – 3a, 2
Mount Broadwood – 1, 2, 4

[b] grass proportion in winter diet for Premier Ridge assumed to be mean of Columbia Lake and Bull River values, as no diet analysis done at Premier Ridge

Appendix 6-3. Forage production on forested sites in the Interior Douglas-fir zone.

Forage production was estimated in grassland and grass-shrubland (Chapter 5). These sites reflected preferred habitat, but other plant communities would also have contributed to carrying capacity. Understanding forage production on forested sites allows more detailed calculations of carrying capacity, and this information is also useful in assessing gains to be made by restoring ingrown forest to grassland or open forest.

Tisdale (1950) reported that the principal herbaceous species in the IDF zone is pinegrass. It commonly comprises 40-50% of the ground cover and 50-70% of the forage yield (Tisdale 1950, Tisdale and McLean 1957). However, the understory vegetation cover is strongly affected by tree canopy cover, age of the stand and tree species (Tisdale and McLean 1957). Several studies in the Interior Douglas-fir (IDF) zone have measured herbaceous growth under different forest types or canopy closures (Table 9). The study by Dodd et al. (1972) relating tree-crown cover to grazing value was conducted in forests with relatively even Douglas-fir crown cover, and without evident clumpiness, tree regeneration or other tree species. Therefore, caution must be used in extrapolating between regions or even between sites.

Table 9. Herbage production (kg/ha) in different forest types and canopy closures within the IDF zone (citations in main Literature Cited section for Chapter 6).

Study	Forest Type					Canopy Closure
	Trembling Aspen	Aspen - Conifer	Lodgepole Pine	Immature Douglas-fir	Mature Douglas-fir	
Tisdale (1950)	724	376	465	114	193	
Tisdale and McLean (1957)	720		465		201	
McLean et al. (1971)					672	
McLean (1979)					273	
Wikeem and Strang (1983)	720				180	
Stout and Quinton (1986)				67	292	
Dodd et al. (1972)					677	5
					660	10
					629	15
					598	20
					555	25
					511	30
					475	35
					440	40
					410	45
					380	50
					344	55
					307	60
					263	65
					219	70
					190	75
					161	80

Stocking rates vary from 0.08 animal unit months (AUMs) per ha on dense grass stands to ≤0.01 AUMs depending upon such factors as distance from water, accessibility, topography, fencing, crown closure of trees, soils, site productivity, etc. On average, Douglas-fir-lodgepole pine forests with interspersed openings can be stocked at about 0.02 AUMs/ha (Stout and Quinton 1986).

Appendix 6-4. Livestock grazing regime on the Bull River winter range at the time research was conducted there.

The Bull River study area is located primarily within the Power Plant range unit, although a portion of Peckham's range unit to the west is also included in the study area. Within the Power Plant unit, a herd of 114 cow/calf pairs and 5 bulls was allowed on the range by May 20th. The herd was rotated through 7 pastures (Table 10) and removed from the range in mid-September. The assigned carrying capacity was 356 animal unit months (AUMs). The rotation between pastures changed between years depending upon the management issues (e.g. prescribed burns). Only Whitetail Pasture was grazed consistently in the spring to use the tame forage. This forage is more nutritional at this time, and grazing it rather than more native areas during spring allows the native range to produce more forage throughout the rest of the growing season and to produce seed.

Table 10. Pasture rotation of livestock within the Power Plant range unit.

Pasture	Days	Grazing Rotation Order		
	Grazed	1999	2000	2001
Big Bull	12	3	2	3
Bighorn	14	rested for burn	7	4
Little Bull	14	1	3	1
Lower Fontane - south	26	4	4	7
Power Plant	24	6	5	6
Upper Fontane - north	27	5	6	5
Whitetail	7	2	1	2

Within the Peckham's Range Unit, bighorn sheep wintered in the vicinity of the old quarry on an exposed south-facing rock outcrop and cliffs. This area is located within Big Hill Pasture and was subjected to rotational livestock grazing for 21 days. It was used mid-season in 2000 and was the first pasture used in 2001. Forage production and utilization data for this area were not acquired.

Chapter 7: Candidate Areas for Habitat Restoration on the Columbia Lake, Premier Ridge, Bull River and Mount Broadwood Bighorn Sheep Winter Ranges

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1. Introduction

Carrying capacities of the 4 winter ranges are low relative to current and desired bighorn sheep populations (Chapter 6). Ecosystem restoration methods being applied within the Rocky Mountain Trench are recommended as a means of enhancing forage availability (Chapter 5). The goal of this chapter is to identify areas where the restoration of open-range habitats would most benefit bighorns using the Columbia Lake, Premier Ridge, Bull River and Mount Broadwood winter ranges. Candidate restoration areas presented here are based entirely on analyses developed in earlier chapters of this report. See Section 3.5 for a discussion of potential limitations.

2. Methods

I identified potential sites for restoration based on TEM mapping available for each herd (JMJ Holdings Inc. 1994, Ketcheson et al. 1996, Marcoux et al. 1998, Kernaghan et al. 2000), using the following general criteria as successive screens. All candidate restoration areas were:

1. Within potential sheep habitat, i.e. having terrain features conducive to sheep occupancy. The regional habitat model (Chapter 4) defined this.
2. Within or near areas of known bighorn sheep activity. The intent was to maximize the likelihood of sheep finding and using restored sites. I considered only areas that were within:
    a. the composite winter home range of radiocollared ewes (Figure 1 of Chapter 6) and
    b. 1 km of winter radiolocations.
3. Within TEM polygons where the most common site series is one locally preferred by sheep (as defined through micro-habitat modeling in Chapter 3).
4. Within TEM polygons where the most common site series occurs at mid to late structural stages, i.e. pole-sapling, young forest, mature forest, old forest. These stages are typically avoided (Chapter 3), are expected to include areas of conifer ingrowth, and typically have low forage production.
5. Within TEM polygons that are predominantly on land that is Crown (including parks) or owned by a conservation organization.

It was necessary to modify the above criteria in several situations.

1. For Bull River, all of the TEM mapping polygons dominated by preferred site series were classified as being predominantly at early structural stages already. Therefore, site series preferred when occurring as the second-most common type in a polygon (Chapter 3) were considered instead.
2. At Mount Broadwood, the majority of land initially indicated to be suitable for restoration was on steep slopes in the Elk River canyon. Logistics may limit restoration activity there so I secondarily relaxed criterion 3 above to consider TEM polygons dominated by any site series, provided the other criteria were met.
3. At Premier Ridge, no telemetry was conducted as part of this study. A composite home range was determined from translocated sheep moved to Premier Ridge after fieldwork for this study was completed (Chapter 6). However, I did not consider the individual locations of those sheep to be representative enough of residents to limit the identification of

restoration areas to sites within 1 km of them. Therefore, for Premier Ridge, I eliminated criterion 2b. I also dropped criterion 3, as no micro-habitat modeling was conducted for that winter range.

3. Results and Discussion

3.1 Columbia Lake

TEM mapping was available for the entire winter composite home range except for some private land in the Village of Canal Flats north of Columbia Lake (Figure 1). Within areas identified as habitat under the regional model, preferred site series[20] occur in clusters just north of Canal Flats, near Armstrong Bay, and in the vicinity of Columbia Lake Provincial Park and District Lot 48 (Figure 1). Consequently, mid- to late-seral TEM polygons dominated by preferred site series occur widely through the winter range. For the first several kilometres north of Canal Flats, potential restoration sites (Figure 2) are mainly on steep, rocky ground, some of which has limited potential for forage production. This area experienced the greatest winter use by collared ewes (Figure 3) and includes a parcel owned by The Nature Trust of BC (TNT). TNT also owns several parcels south and southeast of Armstrong Bay on gentle to moderate slopes. These lots and some surrounding land were used relatively little by collared ewes but appear to have good potential for restoration. The same is true for provincial Crown land east and north of Armstrong Bay. Potential restoration sites in and above Columbia Lake Provincial Park experienced some use by collared sheep and are on gentle to steep slopes.

The largest contiguous areas of potential restoration land are near Armstrong Bay. While winter activity by collared ewes was limited there, this should change with restoration activity. Enhancing habitat in that relatively remote location may also benefit sheep by shifting winter range away from potential harassment near settlements.

[20] pasture sage – bluebunch wheatgrass or saskatoon – bluebunch wheatgrass, and antelope-brush – bluebunch wheatgrass, Douglas-fir – Rocky Mountain juniper, and exposed soil

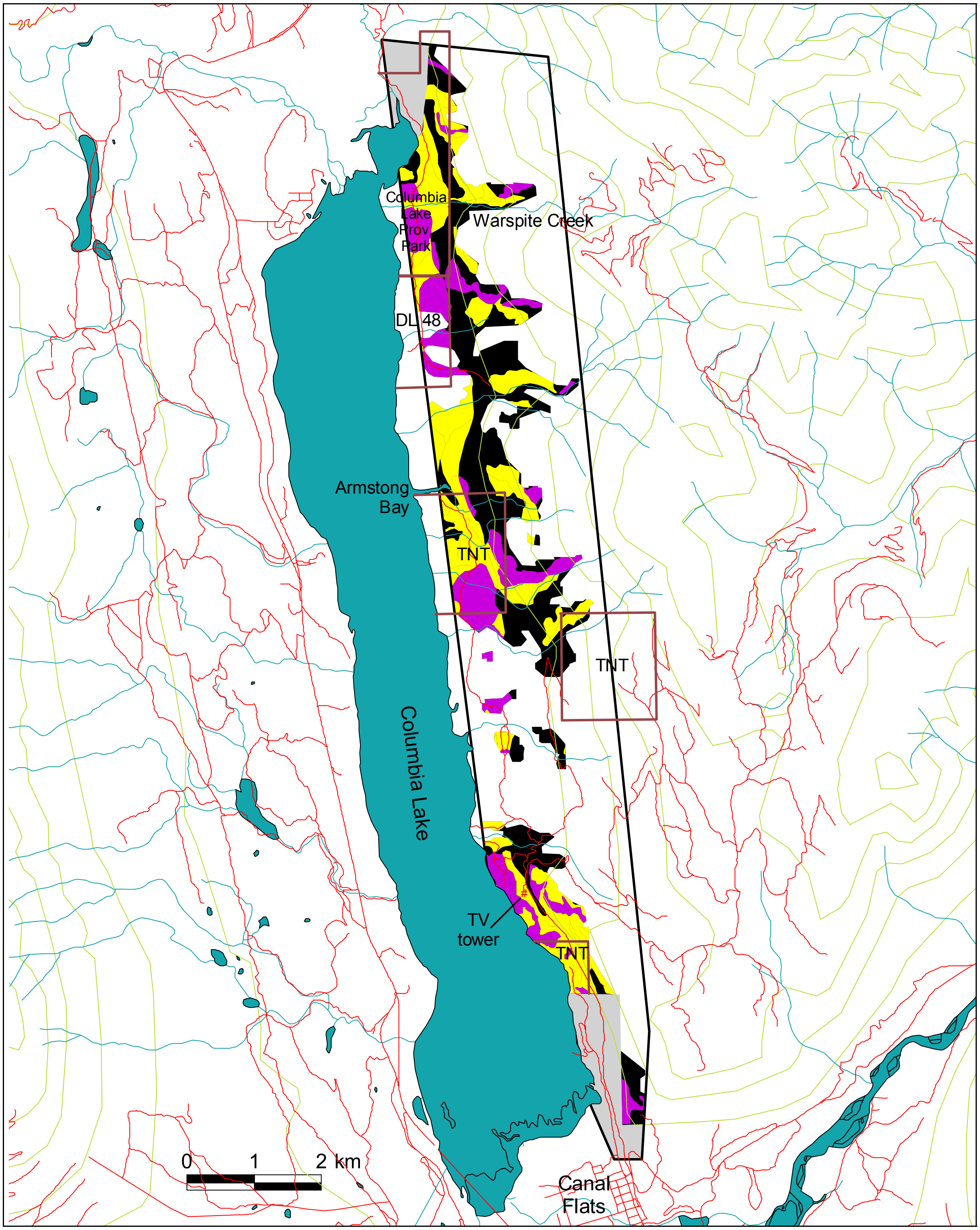

Figure 1. Location of preferred TEM site series of older structural stages (yellow) and younger structural stages (purple) within areas identified as potential habitat through regional modeling (blsvl), for the winter composite home range of collared ewes at Columbia Lake. Areas lacking TEM mapping are shown in grey. Contour interval = 200 m. TNT = The Nature Trust of BC.

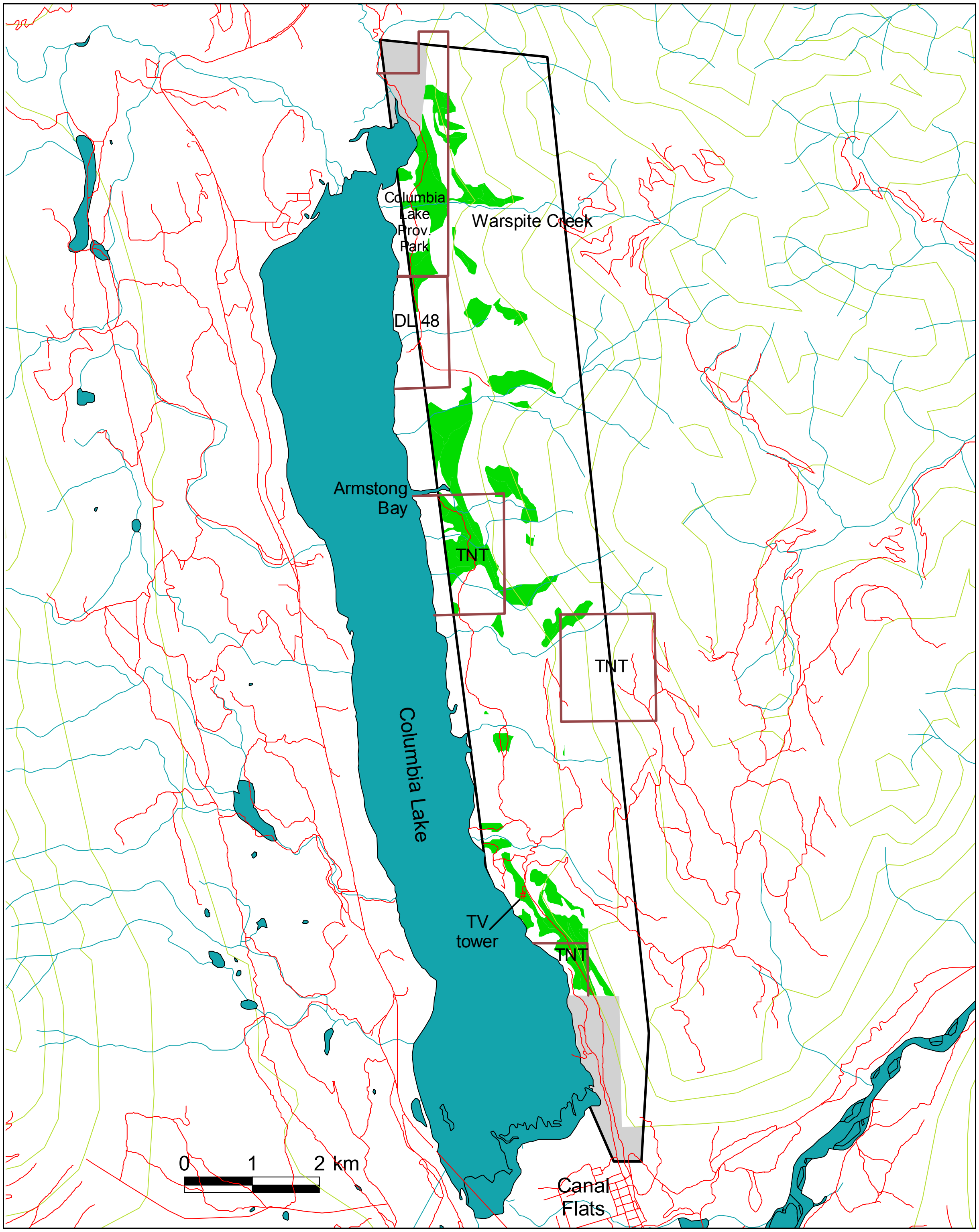

Figure 2. Candidate sites for restoration (green) on the Columbia Lake bighorn sheep winter range. Areas lacking TEM mapping are shown in grey. Contour interval = 200 m. TNT = The Nature Trust of BC.

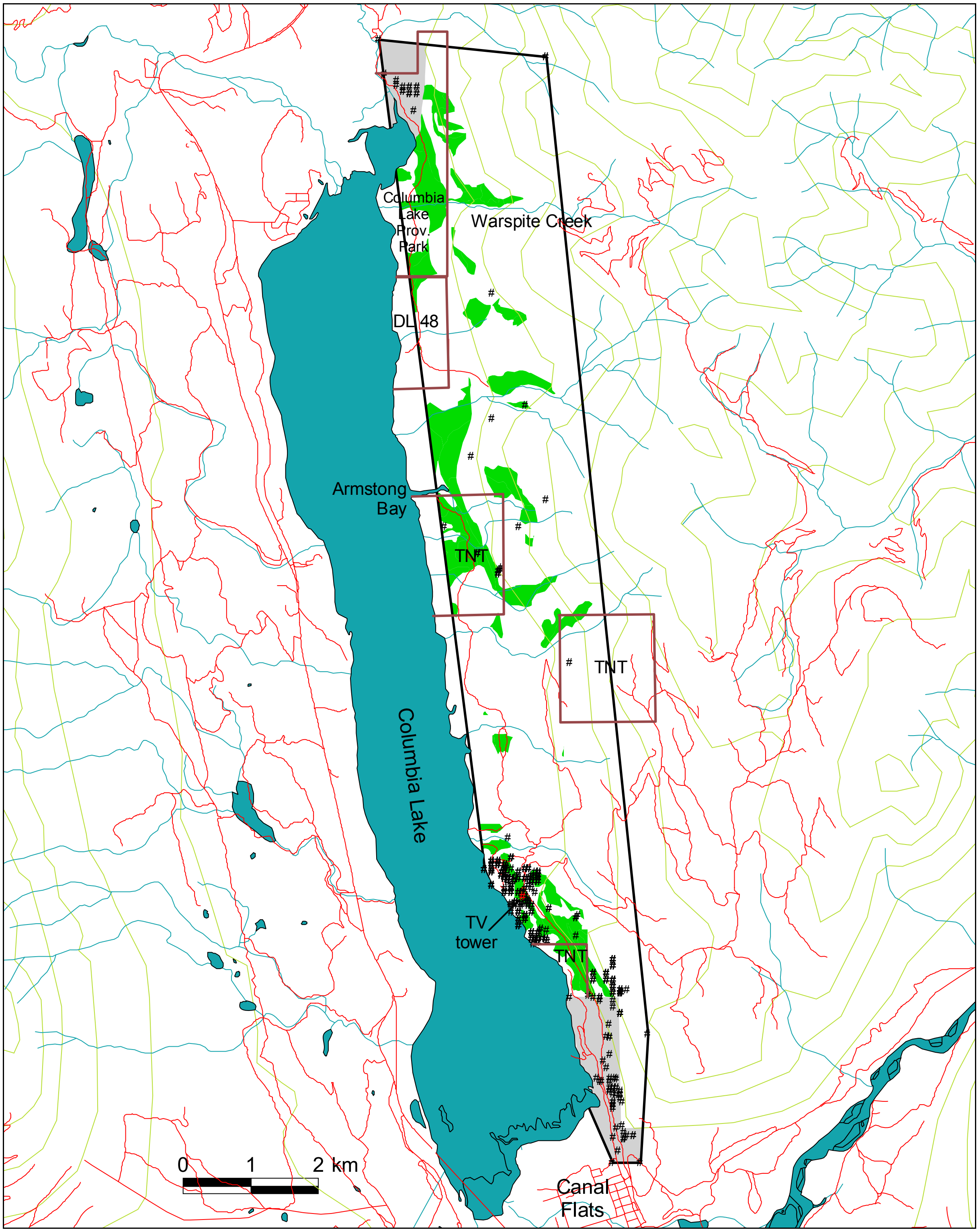

Figure 3. Candidate sites for restoration (green) on the Columbia Lake bighorn sheep winter range in relation to winter telemetry locations. Areas lacking TEM mapping are shown in grey. Contour interval = 200 m. TNT = The Nature Trust of BC.

3.2 Premier Ridge

TEM mapping was not available for Premier Lake Provincial Park, private land north of the park on the lake's east side, or south of Wasa Creek (Figure 4). Within areas identified as habitat under the regional model, mid- to late-seral structural stages occur along the face of the Rockies south of Diorite Creek, above Canuck Lake, above Quartz Lake, on both sides of Wolf Creek east and south of the park, and to a very limited extent on the southeast edge of Premier Ridge (Figure 4, Figure 5). Many of these sites abut the park or Wasa Creek, so it is almost certain that similar opportunities for restoration occur in areas where TEM mapping is lacking.

Almost none of the area identified for restoration is on Premier Ridge itself. The regional habitat model indicated a lack of suitable habitat within the composite home range of translocated sheep, likely relating to the general lack of steep terrain. The regional model does indicate a patch of suitable habitat on the far southwestern edge of the ridge (Figure 4 of Chapter 4), and that area was also identified in the past as the center of winter activity by resident sheep (Hudson et al. 1976). Had the composite home range of translocated sheep extended farther west, potential restoration sites likely would have been identified on the southwestern edge of Premier Ridge. In evaluating the possibility or restoring habitats there, managers will need to monitor whether current sheep activity is concentrated more on the ridge or on the face of the Rockies, and whether the ridge offers sufficiently rugged terrain. The value of Premier Ridge may be limited during periods of high predator numbers by the lack of escape terrain (I. Teske, Ministry of Environment, Cranbrook, pers. comm.), in comparison to the mountain faces. Over the long term, sheep may benefit more from restoration on or adjacent to the face of the Rocky Mountains than on Premier Ridge, particularly if translocated sheep and their descendents continue to focus their activity on the mountainsides.

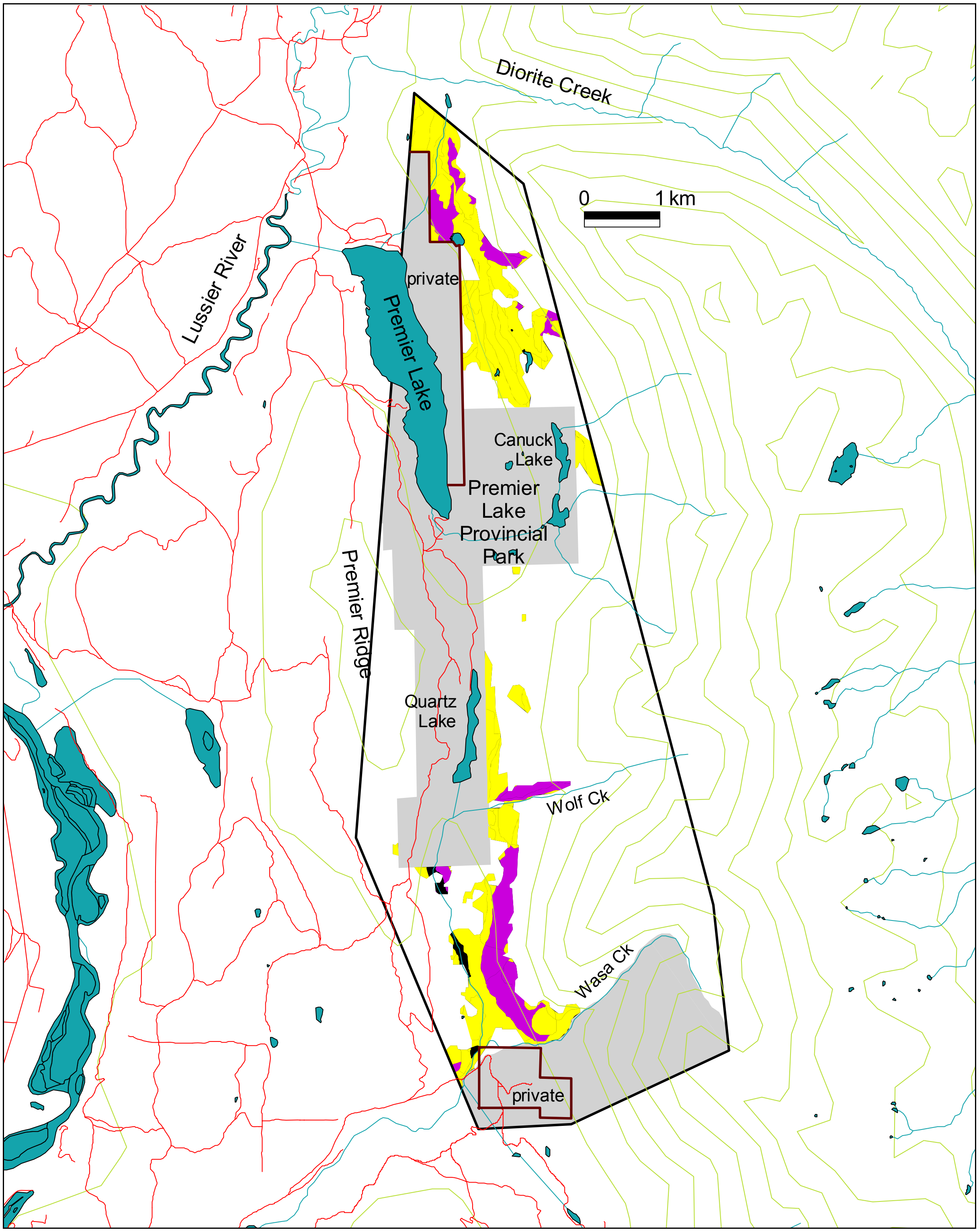

Figure 4. Location of older structural stages (yellow) and younger structural stages (purple) within areas identified as potential habitat through regional modeling (black), for the winter composite home range of translocated ewes at Premier Ridge. Areas lacking TEM mapping are shown in grey. Contour interval = 200 m.

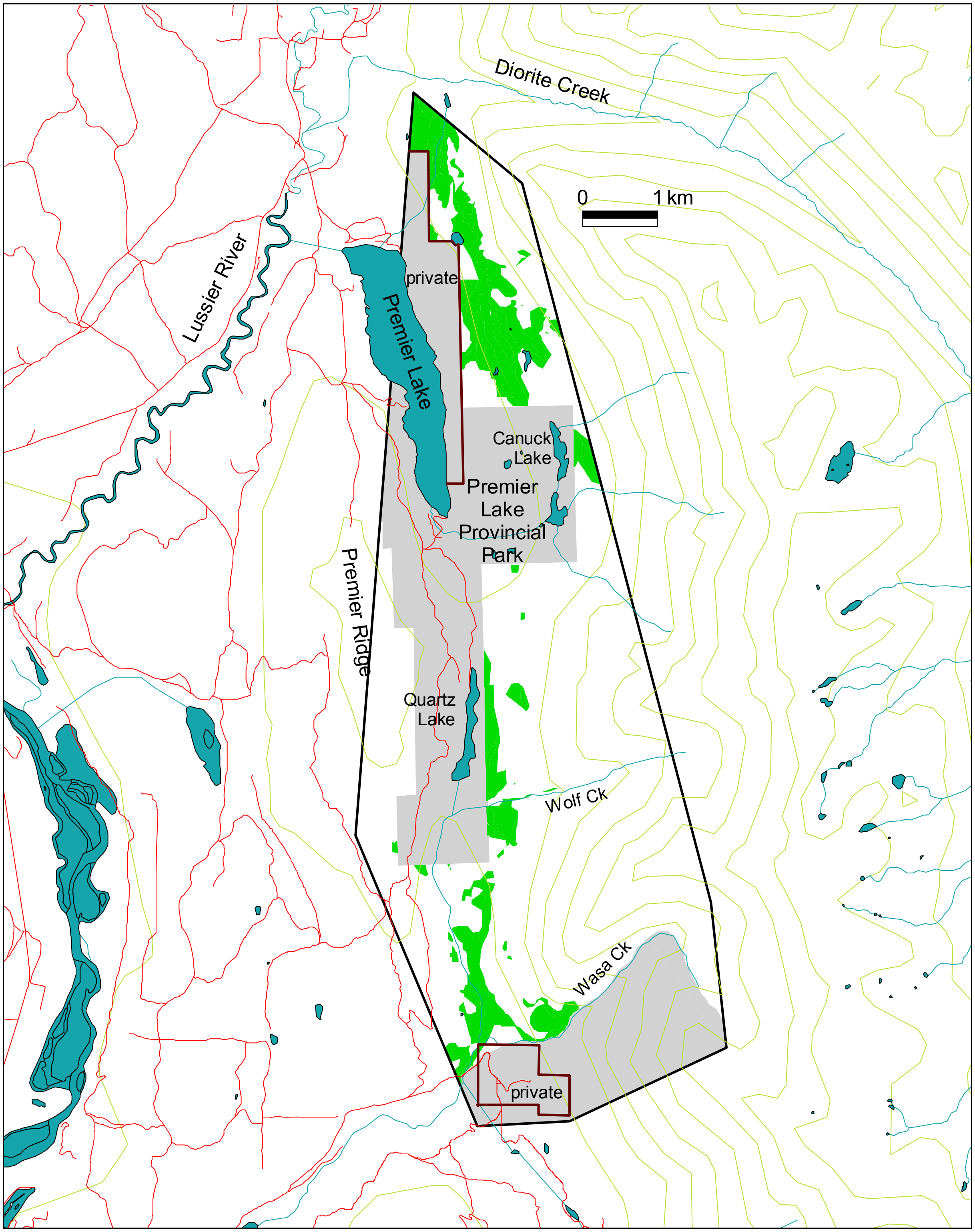

Figure 5. Candidate sites for restoration (green) on the Premier Ridge bighorn sheep winter range. Areas lacking TEM mapping are shown in grey. Contour interval = 200 m.

3.3 Bull River

TEM mapping was lacking for the north-central portion of the winter composite home range (Figure 6), most of which is on private land. Within areas identified as habitat under the regional model, preferred site series[21] lie above the Bull River from the trout hatchery upstream nearly to the powerline crossing, along the south end of the hills north of the hatchery (west of Wardner – Ft. Steele Road), and on the southwest edge of Bull Mountain (Figure 5). Private land covers some of the mid- to late-seral TEM polygons dominated by preferred site series, but provincial Crown land or lots owned by The Nature Trust of BC or the Ministry of Environment include several potential restoration sites (Figure 7).

The area immediately west of the junction of Bull River Road and Wardner – Ft. Steele Road had no collared-sheep activity (Figure 8), though there was some nearby, and this site offers the potential to link foraging areas to the north and southwest. The small site along the western edge of the TNT property would aso facilitate movement among foraging areas is restored. There was considerable use by sheep on the terrace extending from the Ministry of Environment lot northeastward, both within and adjacent to the candidate restoration area there. A few sheep locations were recorded at the southwestern base of Bull Mountain, and restoration there would create a larger block of good habitat and offer an opportunity to disperse winter sheep activity. The same is true of the 2 sites in the hills west-northwest of the hatchery. The small stand on a steep slope immediately above the river downstream of the powerline crossing is likely less suitable for restoration as there would probably be issues with logistics, soil stability and the potential desire to maintain forest cover near the river for biodiversity values.

[21] As noted under Methods, preferred leading site series were all at early structural stages already, so the analysis was based on preferred second-leading site series, including antelope-brush – bluebunch wheatgrass, talus, and Douglas-fir/lodgepole pine – pinegrass – twinflower.

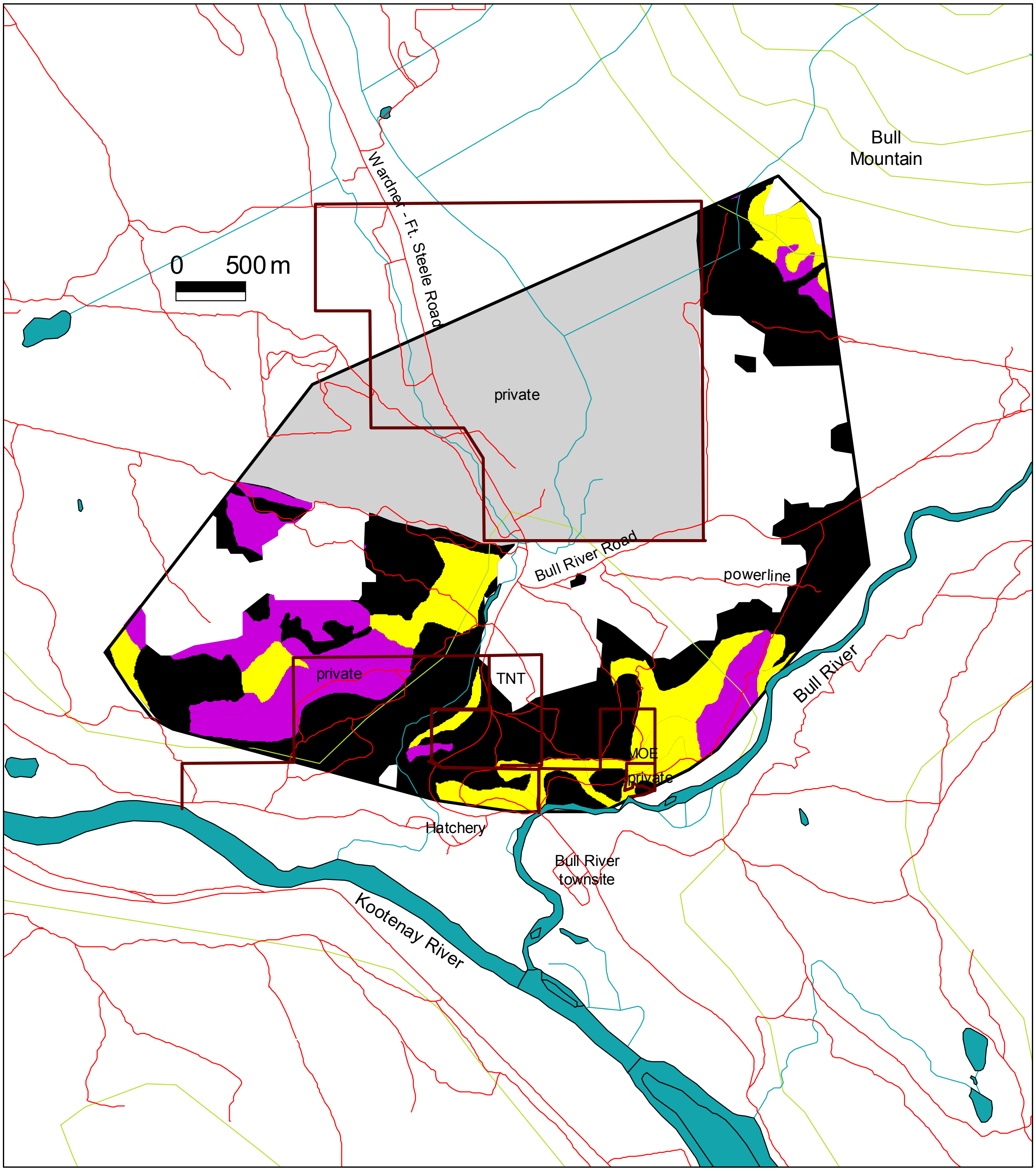

Figure 6. Location of preferred TEM site series of older structural stages (yellow) and younger structural stages (purple) within areas identified as potential habitat through regional modeling (black), for the winter composite home range of collared ewes at Bull River. Areas lacking TEM mapping are shown in grey. Contour interval = 200 m. TNT = The Nature Trust of BC; MOE = Ministry of Environment ownership.

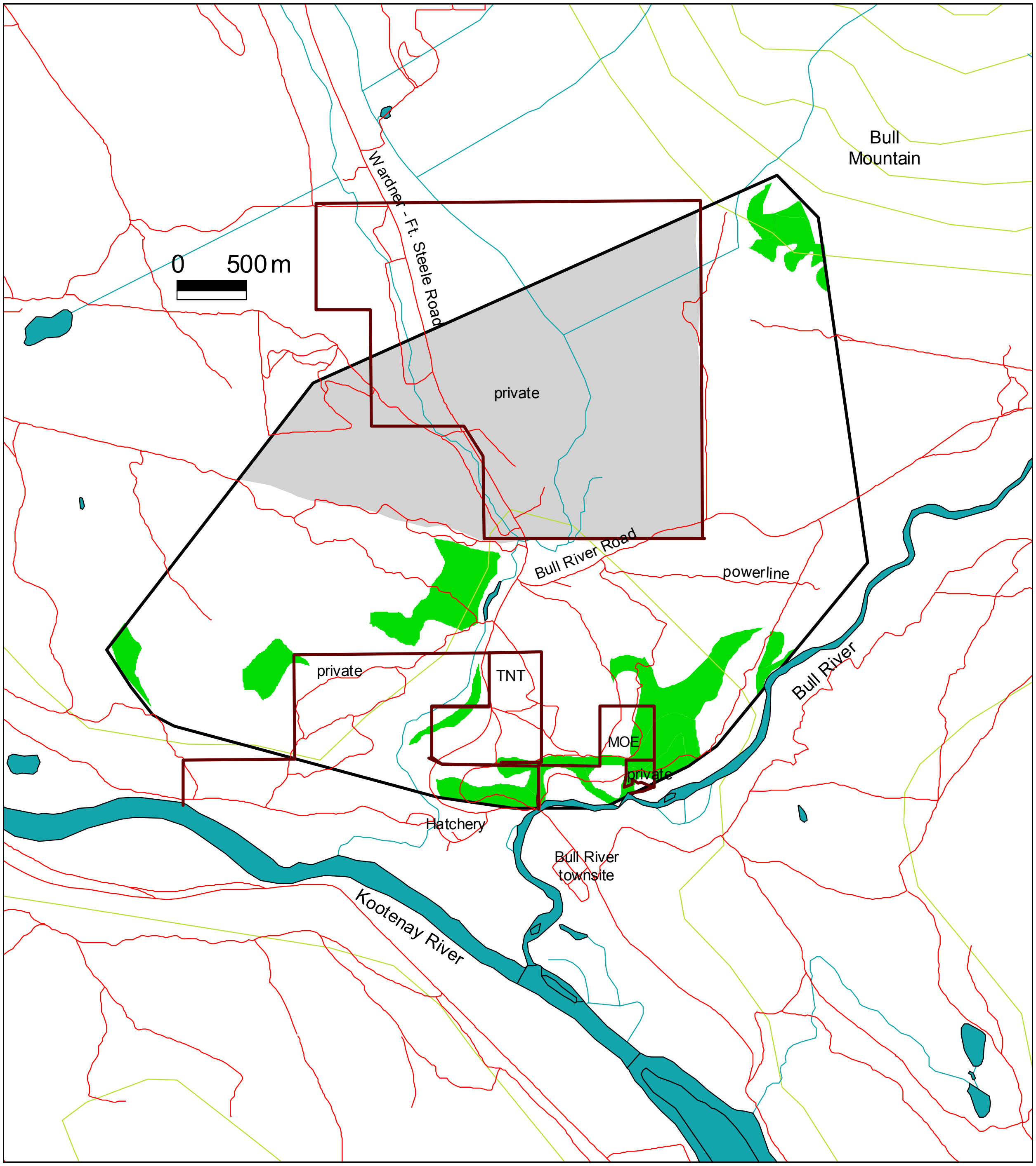

Figure 7. Candidate sites for restoration (green) on the Bull River bighorn sheep winter range. Areas lacking TEM mapping are shown in grey. Contour interval = 200 m. TNT = The Nature Trust of BC; MOE = Ministry of Environment ownership.

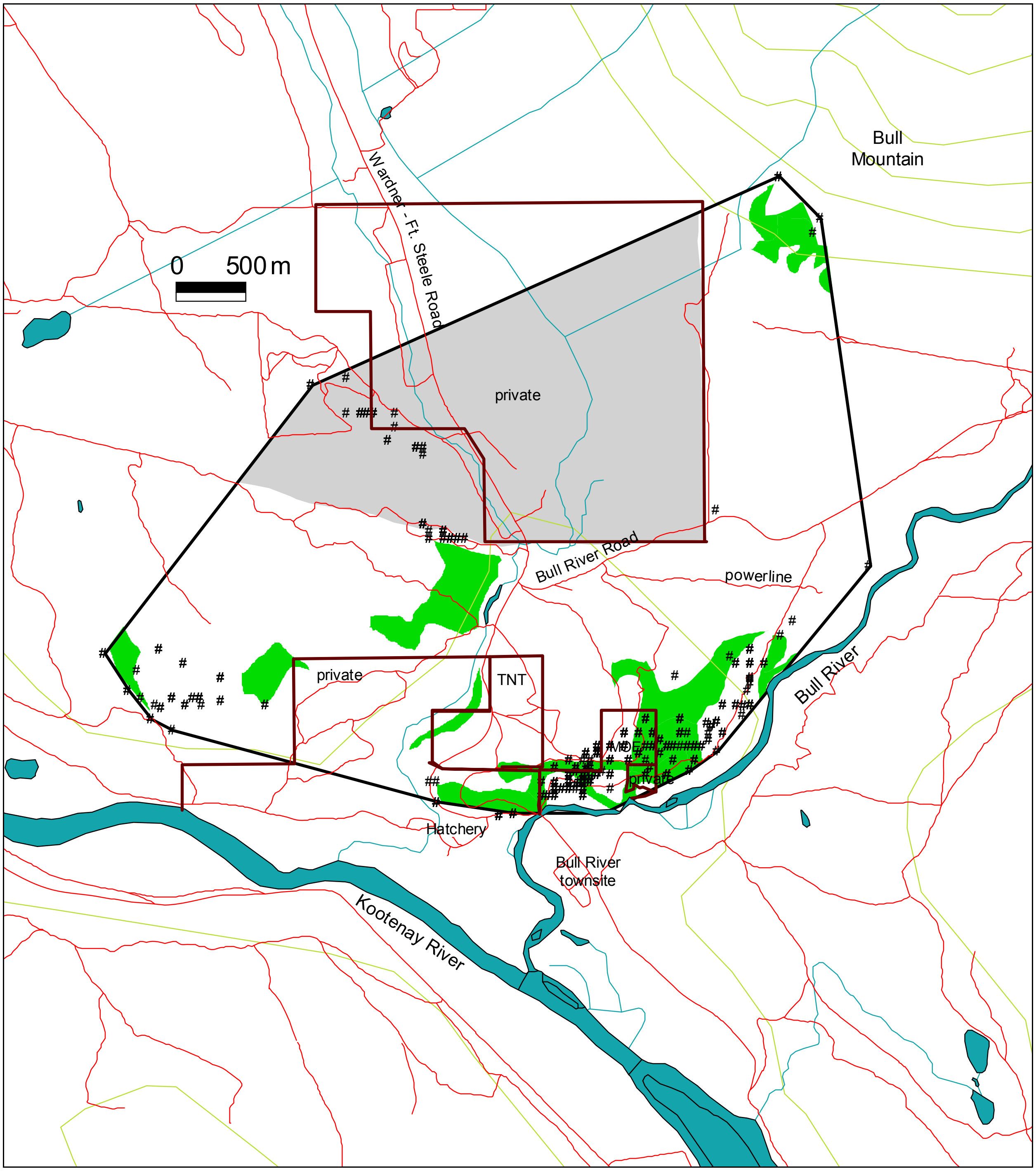

Figure 8. Candidate sites for restoration (green) on the Bull River bighorn sheep winter range in relation to winter telemetry locations. Areas lacking TEM mapping are shown in grey. Contour interval = 200 m. TNT = The Nature Trust of BC; MOE = Ministry of Environment ownership.

3.4 Mount Broadwood

TEM mapping was available for the area east of the Elk River, but not west (Figure 9). Within areas identified as habitat under the regional model, preferred site series[22] fall mainly in an arc along the east side of the Elk River and north side of the Wigwam River, with a smaller extension eastward on a south slope toward the south end of the Silver Spring Lake draw (Figure 9). Land owned by BC Hydro covers some of the mid- to late-seral TEM polygons dominated by preferred site series immediately southeast of Elko, but potential restoration sites on Crown land include the steep slopes on the east side of the Elk River north of the pipeline crossing, a portion of the terrace above those slopes south of the pipeline and a small portion of the terrace above the Wigwam River (at the south edge of Wigwam Flats), and several small patches on south slopes or in a draw north of the pipeline (Figure 10).

The majority of the potential restoration sites identified above are on very steep terrain above the river, so logistical and site-stability concerns may limit restoration there. Additionally, some of the sites on terraces appear to already be relatively open, so there may be only modest incremental gains to be made in restoring them. Considering all mid- to late-seral sites (regardless of site series) within areas identified as regional habitat, potential restoration areas may also include those shown in Figure 11. These mainly lie adjacent to the Elk River south of the pipeline and in the Silver Spring valley. Considering sites identified through both of these means, it initially appears that the best candidates for restoration lie along the southern, western and northern fringes of Wigwam Flats and on the BC Hydro property. Those on the south and west sides of Wigwam Flats are on terraces adjacent to areas of earlier seral stages that had considerable activity by collared sheep (Figure 12), so restoration of them should allow a natural extension of sheep activity there. North of Wigwam Flats (on the south aspect north of the pipeline) little sheep activity was recorded. This may have been due to the older forest found there, and restoration would potentially create a second link toward the draw south of Silver Spring Lake. Just to the north, the valley in which those lakes lie shows potential for restoration, and may help to restore long-term movement down that draw to the north, to the Elk River above Elko and the Lizard Range farther north. The high recreational values of the Silver Spring Lake may have some effect on the ability to conduct restoration, however. The Elk River canyon north of the pipeline is likely too precipitous to allow restoration, although it may be possible in the vicinity of the pipeline crossing. If it is possible to conduct activities on the BC Hydro property, 2 potential restoration areas occur there in areas known to be used by sheep (Figure 12). One of these is in the canyon and the other is on a hill.

The most obvious large block of forest within the winter composite home range is east of the ponds in the center of the home range polygon. However, it is not considered to be habitat, based on the regional model (Figure 9). This is most likely due to the gentle terrain and generally northeastern aspect there. The general low quality of escape terrain nearby would likely limit its use by sheep, even if restored, although portions of it may be close enough to steep terrain to the south or east to encourage use (some use has been recorded to the east). This is probably not the highest-priority site for restoration. However, if open habitats were created there it might disperse sheep activity somewhat and enhance the ability of sheep to move away from the heavily-used strip along the Elk and Wigwam rivers toward potential habitat in the draw south of Silver Spring Lake.

[22] abandoned field, Douglas-fir – bluebunch wheatgrass, snowberry – balsamroot, and western larch – snowberry

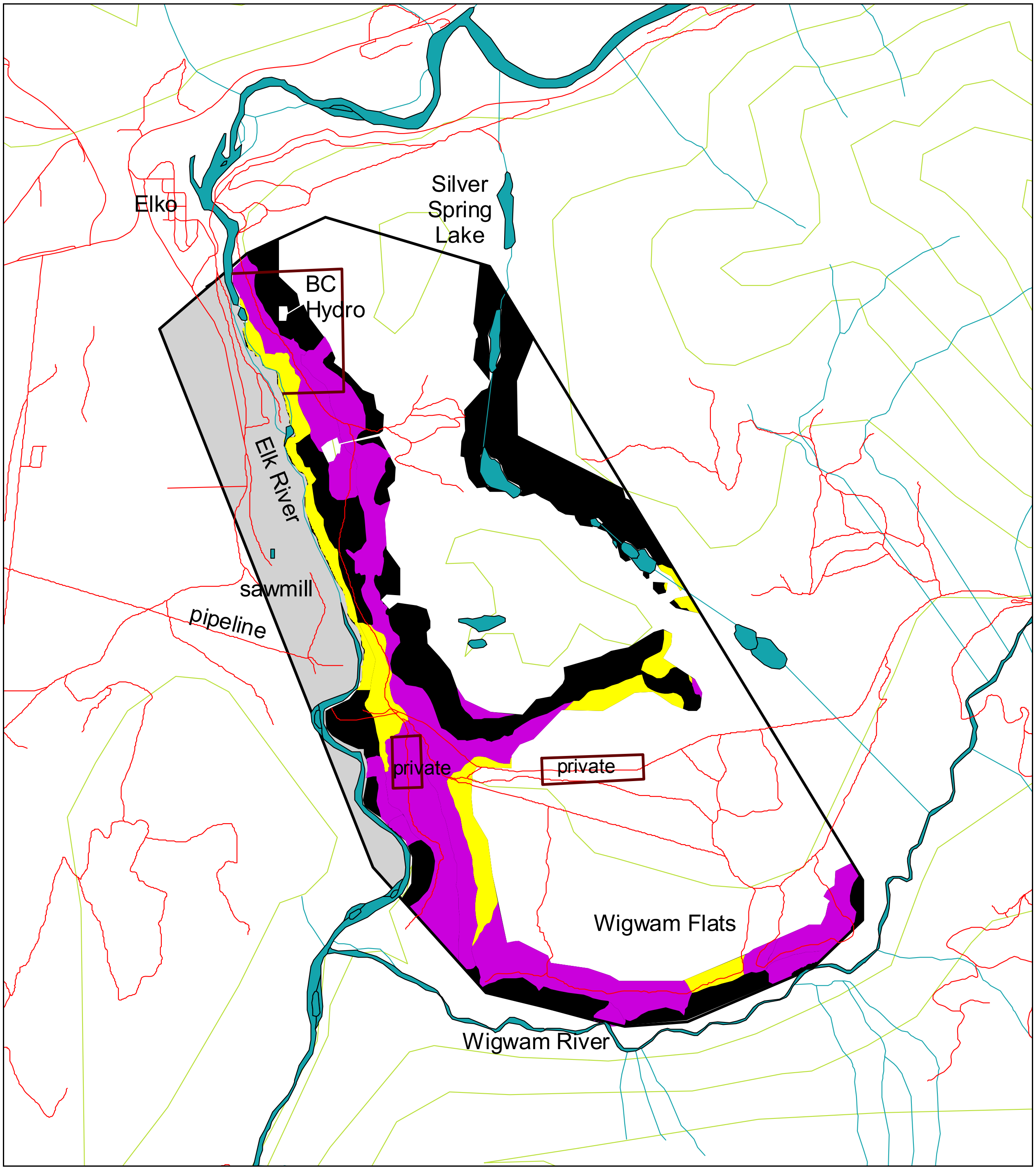

Figure 9. Location of preferred TEM site series of older structural stages (yellow) and younger structural stages (purple) within areas identified as potential habitat through regional modeling (black), for the winter composite home range of collared ewes at Mount Broadwood. Areas lacking TEM mapping are shown in grey. Contour interval = 200 m. Configuration of private land may not be accurate.

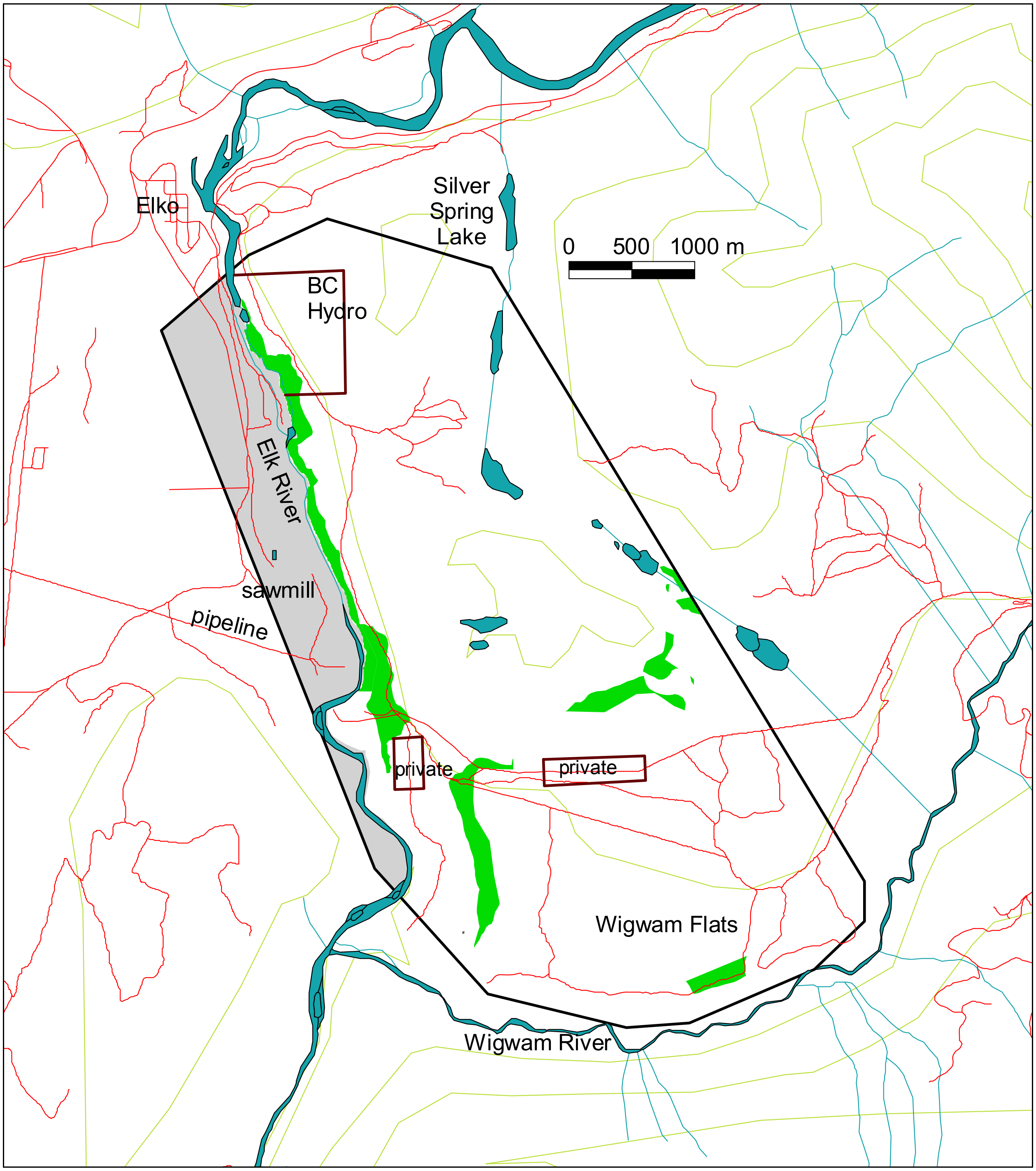

Figure 10. Candidate sites for restoration (green) on the Mount Broadwood bighorn sheep winter range, considering only preferred site series. Areas lacking TEM mapping are shown in grey. Contour interval = 200 m. Configuration of private land may not be accurate.

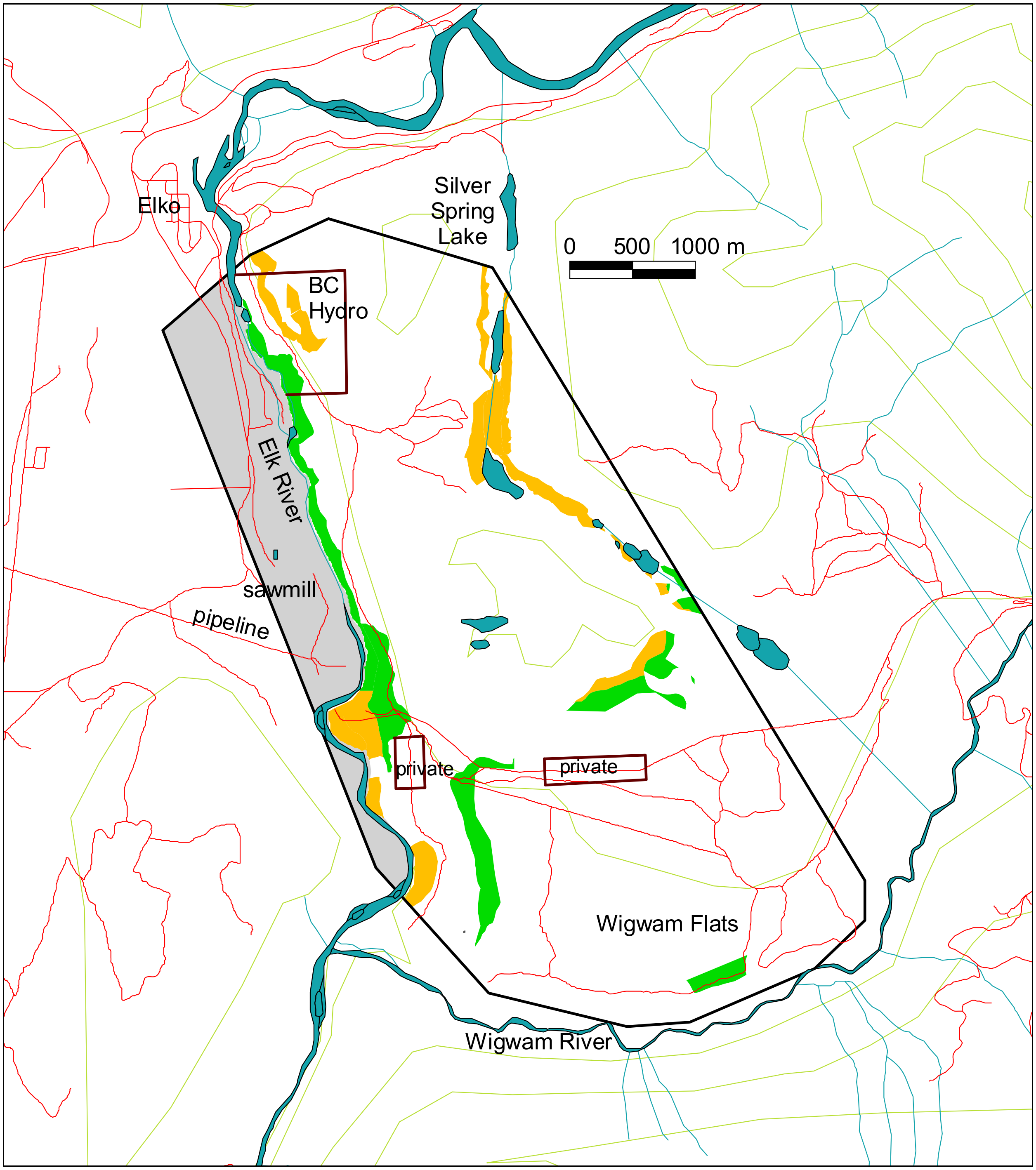

Figure 11. Candidate sites for restoration on the Mount Broadwood bighorn sheep winter range, considering preferred site series (green) and other site series (orange). Areas lacking TEM mapping are shown in grey. Contour interval = 200 m. Configuration of private land may not be accurate.

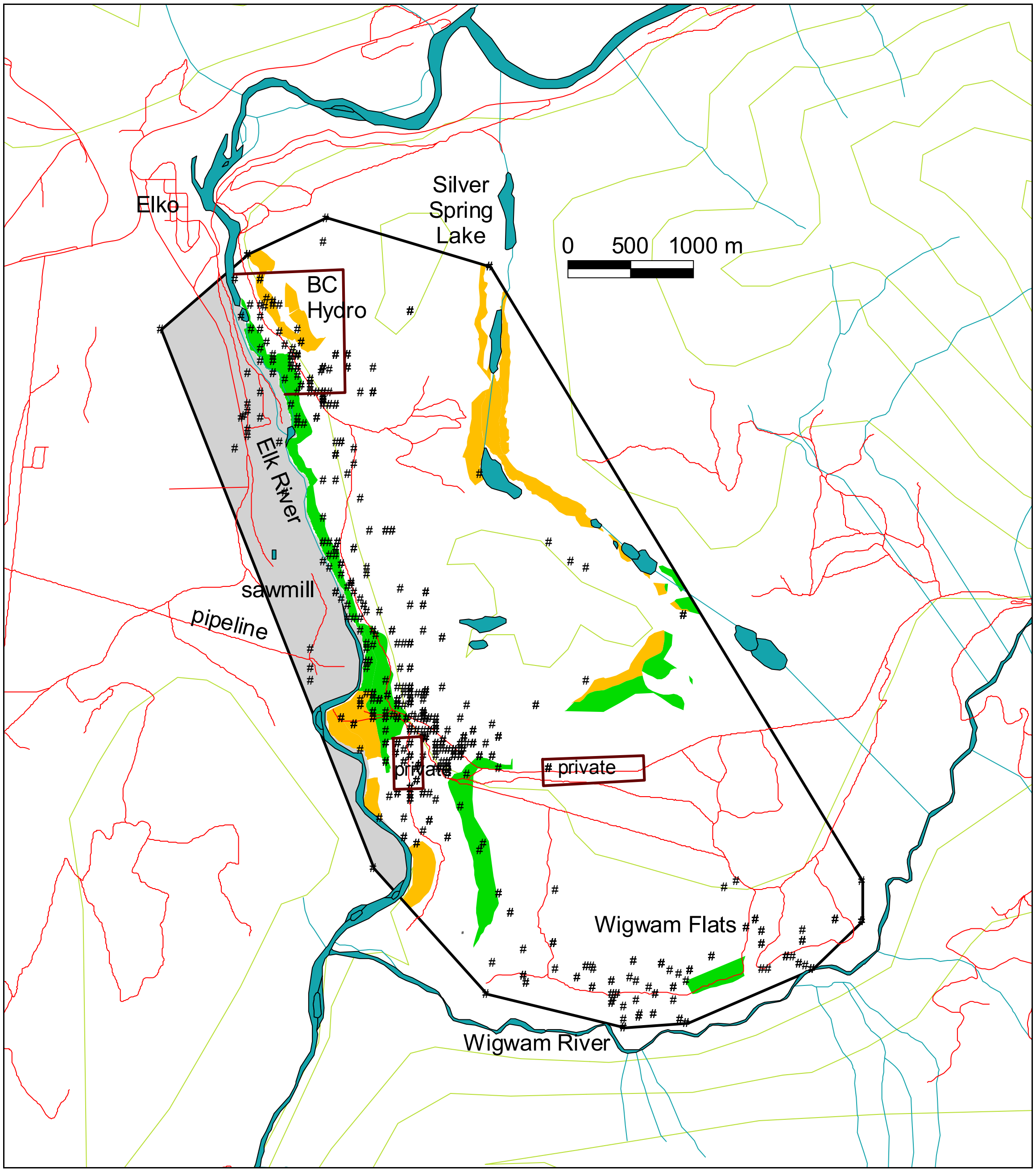

Figure 12. Candidate sites for restoration on the Mount Broadwood bighorn sheep winter range, considering preferred site series (green) and other site series (orange) in relation to winter telemetry locations. Areas lacking TEM mapping are shown in grey. Contour interval = 200 m.

3.5 Limitations of Analysis

Candidates for restoration activity have been identified here at an overview level only. It is essential that any further planning for restoration be preceded by ground-truthing or at least examination of more detailed and recent map sources. There are a number of reasons for this.

1. The TEM mapping on which this analysis was based is now 10 to 15 years old, so it is possible that some areas mapped as being at an early structural stage have now grown in to a state where restoration may be worthwhile. Conversely, some areas shown as being at later structural stages have probably been commercially logged or undergone ecosystem restoration already, and may not need further work.
2. More broadly, the analysis was in most cases based on the leading component per TEM polygon. Because each polygon contains up to 3 components, the dominant site series and structural stage may constitute as little as 40% of any polygon. As a result, polygons identified as candidates for restoration may include significant areas of non-preferred site series or early structural stages. For the same reasons, polygons not identified as candidates may include significant areas whose site series and structural stage make them suitable for restoration.
3. None of the 4 winter ranges was completely covered by TEM mapping, and identified candidates commonly abutted the unmapped portions.
4. Private land map layers may not be entirely accurate, and purchases by conservation organizations of some private land on these winter ranges may occur in the future.
5. Some potential limitations to restoration on steep slopes, as related to logistics and slope stability, have been noted for several of the winter ranges, but this is very difficult to assess accurately from mapping alone. In addition, components of the biodiversity on winter ranges relating to the presence of forests have not been evaluated. Old-growth forest and stands containing a deciduous component may support rare elements of each winter range's biodiversity, but have not been considered in this assessment.
6. Polygons were identified as candidates for restoration based on their structural stage. However, stands at older structural stages have not always experienced ingrowth by conifers. Some of the candidate locations likely include old, open-growing stands with relatively forage-rich understories. Manipulating those types of sites will provide far less benefit to sheep than would activity aimed at densely stocked stands.
7. A potentially overriding consideration in determining restoration sites is whether such activity will contribute to the spread of weeds (Chapter 5). A great deal of weed control has taken place since the fieldwork was conducted (I. Teske, Ministry of Environment, Cranbrook, pers. comm.), but exotic plant species are still well established at all winter ranges. Even where the removal of conifer ingrowth is feasible and likely to benefit bighorn sheep, the potential for weed invasion should be assessed. Restoration activities should not begin unless weed concerns are very slight or weed control is part of the management prescription.

4. Literature Cited

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