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Habitat use and ecologically sustainable carrying capacity for elk (*Cervus elaphus*) in the Takhini Valley, Yukon

by

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The undersigned certify that they have read, and recommend to the Faculty of Environmental Design for acceptance, a Master's Degree Project entitled *"Habitat use and ecologically sustainable carrying capacity for elk (Cervus elaphus) in the Takhini Valley, Yukon"* submitted by Jesse Helen Sarah Chambers in partial fulfilment of the requirements of the degree of Master of Environmental Design.

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ABSTRACT

HABITAT USE AND ECOLOGICALLY SUSTAINABLE CARRYING CAPACITY FOR ELK (*Cervus elaphus*) IN THE TAKHINI VALLEY, YUKON

by

Jesse Helen Sarah Chambers

Prepared in partial fulfilment of the requirements for the degree of Master of Environmental Design in the Faculty of Environmental Design, The University of Calgary

Supervisor: Dr. Wayne Strong

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Population growth of a (re)introduced elk (*Cervus elaphus*) herd (n = 144) in the Takhini Valley, southwest Yukon, has increased the need to determine an ecologically sustainable carrying capacity for the primary range. Elk telemetry data, aerial photographs, and contour maps were used to define the study area (95 km^2), which represented 56% of the total local range used in 2007 and 2008. Plot sampling, plant community classification, and air-photo mapping were used to determine the composition and areal extent of vegetation types, each of which was used to evaluate forage availability. Seven treed and five nontreed types were recognized, with treed forest types representing 68% of the area. Nontreed vegetation produced more forage (279–652 kg/ha) than all treed types, except *Populus tremuloides/Rosa acicularis-Arctostaphylos uva-ursi* vegetation (438 kg/ha), which was the second-most common type in study area (15% of area). No significant differences ($P \leq 0.05$) were found between crude protein amounts among vegetation types, though graminoids were lower in crude protein than either forbs or shrubs (*P* ≤0.001). Different carrying capacity scenarios were developed based on cumulative assumptions. These included considerations of forage quantity, availability and preference, horse (*Equus ferus caballus*) and mule deer (*Odocoileus hemionus*) requirements, and diet similarities with elk. Winter was the most limiting season because forage was senesced. The most conservative scenario included ecologically sustainable safe-use factors, and resulted in an estimated winter carrying capacity of 72–144 elk for the study area. The assessment of carrying capacity was most sensitive to browse consumption and competition with horses. These factors require further investigation to refine the estimated ecologically sustainable carrying capacity.

Keywords: *Cervus elaphus*, ecologically sustainable carrying capacity, elk, forage, range ecology and management, Yukon.

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INTRODUCTION

Elk (*Cervus elaphus*)[1] have historically ranged over much of North America (Bryant and Maser 1982). During the Wisconsonian glaciation, they traveled across the Bering Strait (Geist 1971), and there is evidence for elk being hunted in the Yukon during the early Holocene (MacNeish 1964). In northern British Columbia, near the border with southeastern Yukon, native elk populations are increasing in size and expanding their ranges. Elk have been encountered in this area since the early 20th century (Anonymous 1934). However, they were introduced further to the northwest in 1951 (Yukon Elk Management Planning Team 2008). The first releases were of animals relocated from Elk Island National Park in Alberta, and aimed at increasing opportunities for hunting in the area (McCandless 1985). Nineteen elk were released near Braeburn Lake, about 100 km north of Whitehorse, in the first introduction and 30 more were released in 1954. The elk from these releases formed two distinct populations, with some moving into the Takhini Valley west of Whitehorse after a major wildfire in 1958 (Florkiewicz 1994). Population growth was slow (Youngman 1975) and poor recruitment levels were thought to be a factor in the low population numbers observed in 1967, at which time the Braeburn population was the larger (Pearson 1967). By 1988, both the Braeburn and Takhini Valley populations contained approximately 50 animals (Florkiewicz 1994). Elk
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[1] Taxonomy based on the Integrated Taxonomic Information System (ITIS Partners 2009), full species names in Appendix I.

introductions began again in the early 1990s, mainly from the local Midnight Sun Farm near Whitehorse, which resulted in an additional 18 elk being released in the Takhini Valley and 101 in the Braeburn-Hutshi area (Yukon Elk Management Planning Team 2008). The majority of these newly released elk were male yearlings. The final introductions were conducted in 1994 (Yukon Elk Management Planning Team 2008). The Takhini population is now the larger of the two, with an estimated 144 elk in September 2007 (Florkiewicz et al. 2007).

A management plan was created in 2007 to address issues surrounding elk, including the impact of the populations on the land, other wildlife, and humans. For instance, elk foraging along the Alaska Highway has been a concern; there, they often gather in large groups and have the potential to cause collisions with vehicles that may result in human and elk injuries. Between 2001 and 2008, 27 elk mortalities occurred along the portion of the Alaska Highway that runs through the study area (Yukon Department of Environment, 2008, unpublished data). Other concerns surrounding the growing elk population include more time spent in the agricultural fields that border the range, negatively affecting crop production (Yukon Elk Management Planning Team 2008). Since 2007, management of the Takhini elk population has occurred, including tick control and more recently, a limited harvest. The ultimate goal of the elk management program is to maintain the Takhini Valley population at a “healthy” herd size of 175 animals (Yukon Department of Environment 2009). Development of a carrying capacity estimate would assist in determining the maximum number of elk that can be ecologically sustained on the range based forage availability, and then could be modified to take into account other pressures such as agricultural conflicts.

Carrying capacity is a general concept with many meanings (Sayre 2008). In range management, carrying capacity usually refers to herbivore densities that are in equilibrium with plant productivity (Sayre 2008). The definition of carrying capacity used in this study is based on an "ecologically sustainable stocking rate" (Alberta Sustainable Resource Development 2004). This represents the number of animals (primarily cattle) that can be sustained in an area without degradation of rangeland. In the context of this study, it is the number of elk that can be maintained within the study area without causing negative effects on plant communities as a result of grazing. Determination of an ecologically sustainable carrying capacity requires knowledge of elk diets, the amount and distribution of forage, and an understanding of how elk use the landscape (Olsen and Hansen 1977). Diet overlap with other species (Hobbs et al. 1981) and forage safe-use factors are also important considerations.

Elk are generalists (Collins and Urness 1983; Irwin and Peek 1983; Kirchhoff and Larsen 1998), a trait that is important in areas with low richness of potential forage species (Collins and Urness 1983). The composition of their diet depends on location, growing-degree-days, growing conditions, and available vegetation. Winter diets are limited by decreased nutrient availability in forage and browse (Hobbs et al. 1981). These dietary constraints make the quantity and quality of winter forage one of the main determinants of carrying capacity (Cook 2002). Therefore, winter nutrients must be obtained from a larger area than used during summer (Anderson et al. 2005).

Based on a review of 72 studies of elk diets in North America, Christianson and Creel (2007) reported that winter diets were on average 29% browse, usually obtained within 1–2 m above the ground (Rounds 1979). This is similar to the amount of browse consumed by elk in southwestern Yukon, 22% and 25% in 1988 and 1989, respectively (Florkiewicz 1994). Greater browse consumption is also associated with increasing snow depth (Cook 2002). Elk not only browse leaves and twigs from trees and shrubs, but also eat leaves licked from the ground surface such as *Populus tremuloides* (trembling aspen), *Salix* spp. (willows), and *Dasiphora fruticosa* (shrubby cinquefoil). These leaves are often found at the base of trees and shrubs where they are protected from snow in winter (Hobbs et al. 1981). Forbs comprise on average <5% of an elk's winter diet, mainly because they are unavailable during winter due to senescence and snow cover. Graminoids are selected for during winter, and are more likely to be available through snow cover (Christianson and Creel 2007). Important dietary graminoids include *Calamagrostis* spp. (reedgrasses), *Bromus* spp. (bromes), *Poa* spp. (bluegrasses), and *Carex* spp. (sedges) (Hobbs et al. 1981).

Summer diets are much higher in forbs than winter diets (Baker and Hobbs 1982). Forbs often green-up before graminoids, and are important sources of protein in the early spring. Graminoids are a very important component of the elk summer diet, but as they decrease in crude protein availability over the season, elk tend to consume more browse (Collins and Urness 1983).

The majority of feeding is conducted at dawn and at dusk (Green and Bear 1990), preferably in open areas, which commonly have greater amounts of forage than forests

(Cook 2002; Anderson et al. 2005). Elk tend to rest close to where feeding occurs, often moving into forested habitats (Collins et al. 1978; Collins and Urness 1983). Snow depth is a very important factor in determining winter habitat selection by elk, particularly where snow (>50 cm) constrains elk movement (Poole and Mowat 2005). Snow depth varies with vegetation characteristics including stand density and cover (Visscher et al. 2006)

Little quantitative information exists on the plant communities found in the Takhini Valley, particularly within the range of the elk herd. A more comprehensive understanding of local plant communities and their forage production might be helpful in managing the elk population. Forage production varies not only among tree overstory types, but also understory type. A more detailed classification of vegetation within the study area would allow for a more precise estimate of forage production. The study area has undergone significant changes in vegetation cover, shifting from a *Picea glauca* (white spruce) - dominated area to a mixture of nonforest vegetation with stands of *Populus tremuloides*, after the July 1958 fire (Burn 1998). The elk population has also increased substantially in size during the past 20 years, since the initial elk carrying capacity research in the area by Florkiewicz (1994), and appears to be expanding its range. The purpose of this study was to estimate an ecologically sustainable carrying capacity for elk in the selected study area within the Takhini Valley, west of Whitehorse in southern Yukon. The objectives were to:

i) *Determine plant species composition and percent cover of different vegetation types in the study area;*

ii) *Determine the abundance of growth-forms (graminoids, forbs, shrubs) and aspen litterfall (kg/ha) in different vegetation types;*

iii) *Assess seasonal variation in protein and fibre content of key forage species;*

iv) *Determine the seasonal distribution and abundance of forage and nutrient availability in different vegetation types;*

v) *Determine seasonal habitat use in different vegetation types by elk;*

vi) *Create a series of carrying capacity estimates based on cumulative assumptions;* and

vii) *Provide recommendations for managing current and future elk populations in an ecologically sustainable manner with respect to range health.*

The following chapters outline the approaches taken to classify vegetation within the study area and to determine the carrying capacity by season based on forage quantity and quality, and elk forage preference (Methods); the results of the analysis (Results); and a discussion of the outcomes (Discussion). The final chapter provides management options for maintaining an ecologically sustainable elk population within the study area.

STUDY AREA

The study area is located in the Takhini Valley, 50 km west of Whitehorse, Yukon (Figure 1)[2]. It extends from the Takhini River bridge in the east to 2.5 km west of the Kusawa Lake road, and is centred along 20 km of the Alaska Highway (Highway 1). The southern boundary is the Takhini River, whereas the northern boundary follows stream courses on the eastern and western edges and the height of the foothills in the centre. The width of the study area is from 3–5 km and covers 95 km^2. The approximate centre of the area is 60°49'N, 135°56'W. Elevations range from 650 m near the Takhini River up to 1,000 m on the foothills in the northwest corner. Topography south of the foothills is generally flat, with a few small hills. The area is part of the Kwanlin Dun First Nation, the Ta'an Kwachan Council, and Champagne and Aishihik First Nations traditional territories'.

The Takhini Valley is part of the Boreal Cordillera ecozone, which, within Yukon, extends from Dawson south to the British Columbia border. The area is a combination of plateaus (Lewes, Nisutlin, and Teslin) and rolling hills (Ecological Stratification Working Group 1995). Drainage of the Takhini Valley is through the Yukon River watershed. Subhumid to semiarid climatic conditions occur, because the area is in the rain shadow of the St. Elias Mountains to the southwest (Ecological Stratification Working Group 1995). Mean yearly rainfall between 1971 and 2000 was 63 mm, and mean yearly snowfall was 455

[2] Study area selection criteria are presented in Methods.

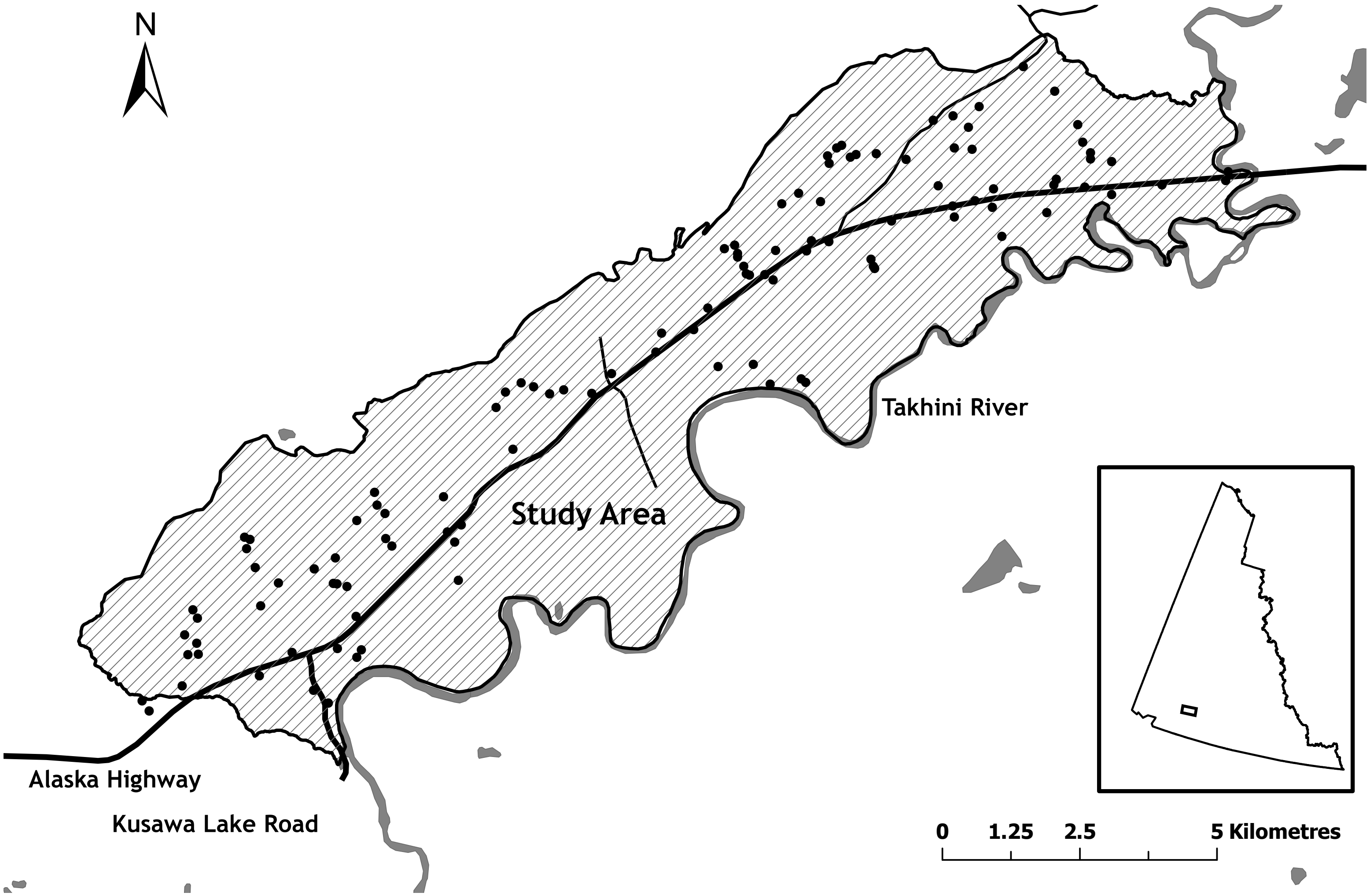

Figure 1. The approximate location of the study area within the Takhini Valley, southwest Yukon (see inset). Dots identify the location of vegetation sampling plots within the study area (hatched).

145 cm (1 cm of snow approximately equates to 1 mm of precipitation). Mean daily winter (November to March) temperature is -12.5°C, and the mean daily temperature through June, July, and August is 12.8°C based on the Whitehorse Airport weather station (ID 71964, Meteorological Service of Canada 2009). Though summers are short, the long daily sunlight creates more growing-degree-days above 5°C than would be expected with the short summer season (Sproule 1996).

The Takhini Valley was glaciated by Cordilleran ice during the late Wisconsonian advance (Jackson et al. 1991; Gilbert and Desloges 2005). The parent materials left by the retreating glacier, which cover the valley bottom, are mainly glacial lacustrine and glacial fluvial deposits (Mougeot and Smith 1992). Upper elevations along the north side of the study area have shallow moraine deposits over bedrock (Mougeot and Smith 1992). The dominant soil subgroup in the Takhini Valley is Orthic Eutric Brunisol (Mougeot and Smith 1992). There is a thin (0–2 cm) layer of White River volcanic ash in the upper soil horizons throughout most of the valley (Keenan and Cwynar 1992).

Open *Picea glauca* forests represent the climax vegetation in the region (Orloci and Stanek 1979). *Pinus contorta* (lodgepole pine) grow on well drained sites and *Populus tremuloides* grow on warmer sites with fine, silty soils (Orloci and Stanek 1979). *Populus tremuloides* and *Pinus contorta* are both early successional species after fire (Lausi and Nimis 1985). Unlike other parts of the boreal forest, *Picea mariana* (black spruce) is not common in the southwest Yukon (Farrar 1995). Hogg and Wein (2005) stated that the Takhini Valley more closely resembles the intermixed grass areas and *Populus tremuloides* stands of the aspen parkland south of the boreal forest, which occurs in a broad arc from southern Manitoba to central Alberta, than more typical boreal forest vegetation. Burn (1998) suggested this might be due to the aridity of the Takhini Valley. Patches of grassland are frequent on southfacing slopes and in valley bottoms (Oswald and Senyk 1977). Common shrubs in the Takhini Valley include *Salix* spp., *Rosa acicularis* (wild rose), *Arctostaphylos uva-ursi* (bearberry), *Shepherdia canadensis* (buffaloberry), and *Juniperus communis* (common juniper) and *J. horizontalis* (ground junipers). Common forbs include *Oxytropis* spp. (locoweed), *Penstemon gormanii* (Gorman's penstemon), and *Solidago simplex* (goldenrod). *Calamagrostis purpurascens* (purple reedgrass) is the most common graminoid; others include *Poa* spp., *Festuca* spp., and *Carex* spp. (Florkiewicz 1994).

Fauna common to the region are grizzly bears (*Ursus arctos*), wolves (*Canis lupus*), coyotes (*Canis latrans*), Arctic ground squirrels (*Spermophilus parryii*), and moose (*Alces americanus*) (Ecological Stratification Working Group 1995). Other large and medium-sized mammalian herbivores found in the Takhini Valley include mule deer (*Odocoileus hemionus*), semi-feral to feral horses (*Equus ferus caballus*), snowshoe hare (*Lepus americanus*); and elk (T.S. Jung, Yukon Department of Environment, 2009, pers. comm.).

The area is used for hunting, recreation, tourism, and agriculture (Ecological Stratification Working Group 1995).

METHODS

Study area selection

Study area boundaries were determined based on discussions with Yukon Department of Environment, an evaluation of elk radio telemetry data, and a review of aerial photographs and contour maps. Elk radio telemetry data collected weekly, between 1000 and 1400 hrs from April 2007 to May 2008 (Yukon Department of Environment, 2008, unpublished data), was used to estimate range size. Elk locations to the south of the Takhini River were excluded due to lack of access roads and steep river banks. Locations to the east of the Takhini River bridge and west of the Kusawa Lake road were also excluded because elk generally occurred only on road sides and in disturbed areas (including private agricultural lands). Aerial photographs were used to determine the northern boundary of the study area, following natural topographic breaks in the landscape, i.e., stream courses and heights of land. This study area also included the research area used by Florkiewicz (1994). Due to exclusions of inaccessible areas, the final study area incorporated 56% of the area used by radio-collared elk in 2007 and 2008 (Environment Yukon, unpublished data).

Vegetation Sampling and Analysis

Plot Selection

Aerial photographs at a scale of 1:40,000 from September 2004 (Geographical Air Survey Ltd., G0408058 121 – 127) were interpreted for vegetation composition. Areas with a similar tone, texture, and vegetation structure were delineated as separate polygons. Ground-truthing was carried out in late May and early June 2008 to identify what types of plant communities occurred in the area. Approximately 75% of the mapped polygons were visited. General site geomorphology and tree physiognomy, as well as overstory trees, and the dominant shrub and herb species were used to initially classify the polygons. Polygons were assigned a cover type based on similarities in dominant plant species. Initially, eight cover types were identified *via* mapping and ground-truthing: Pine, Spruce/moss; Spruce/forb; Aspen/bearberry; Aspen/buffaloberry; south slope (sedge); meadow; and roadside. The desired number of vegetation sampling plots per cover type was 12, and sampling locations were chosen from among accessible polygons.

Vegetation Polygon Sampling

Vegetation composition sampling was carried out to provide species cover data for vegetation type classification. Vegetation composition sampling followed the design used by Redburn et al. (2008). A 30-m transect was run through the centre of a 20-m × 30-m plot parallel to the slope contour. Plots for sampling the roadside vegetation (n = 12) were run perpendicular to the edge of the pavement. Five sets of nested quadrats were placed along each transect at 5-m intervals beginning at the 5-m mark. The nested sampling design consisted of a 2.5-m × 2.5-m quadrat within which the percent canopy cover of plants 1–2.5-m tall (tall shrub stratum) were estimated by species. Canopy cover of species <1 m in height (low shrub and herb stratum) were estimated in a 1-m × 1-m quadrats, placed within each of the larger quadrats. Canopy cover of trees and tall shrubs

>2.5-m (tree stratum) was estimated within the 20-m × 30-m plot. This was done through estimates at six points, three evenly spaced on each side of a transect. Ocular estimates were used to estimate plant canopy cover (*sensu* Daubenmire 1968, pp. 42-43) values of all species. For analysis purposes, percent cover for each species within the five 1-m × 1-m, and the five 2.5-m × 2.5-m quadrats were combined to determine mean percent cover by plot. Vascular plants, bryophytes, and lichens were primarily identified using Cody (2000); Flora of North America Editorial Committee (2007), Lawton (1971), and Conrad (1979); and Brodo et al. (2001), respectively. Appendix I contains the scientific names for all encountered plant species.

Tree densities were estimated by the point-centred quarter method as described by Mueller-Dombois and Ellenberg (1974, p. 110). Point-centered quarter density requires measuring of distance to the nearest tree in each of the four ordinal quadrants from a fixed point. These points were located at 0, 15 and 30 m along the vegetation sampling transect. The heights of two representative trees in each vegetation sampling plot were measured using a clinometer and measuring tape, and stem diameters were taken at breast height (1.3 m). The ages of these trees were determined by counting annual rings from core samples taken 30 cm above the forest floor. The oldest age determined from core samples was used to represent the stand age.

Soil characteristics were described at each plot by digging a soil pit, usually 50 cm deep. The assessed characteristics included: humus form (Green et al. 1993); soil subgroup (Strong and Limbird 1981), with updates consistent with the Soil Classification Working Group (1998); depth to mottles and the water table; and parent material, drainage class, nutrient regime, and moisture regime (Beckingham and Archibald 1996). Slope gradient, aspect, and topography (level, rolling, inclined) were also recorded. The sampling form used for the above characteristics is presented in Appendix II.

Biomass Sampling

Exclosures were placed in five different cover types (Southfacing slopes, Open aspen, Dense aspen, Grassy areas, Conifer stands) and along roadsides. The exclosures were made of wire mesh that was folded into a box shape, 130 cm × 130 cm and 60 cm tall. The top edges of the wire were folded over to prevent animals from foraging within the exclosures. They were anchored to the ground using 25 cm long galvanized nails. Six exclosures were placed on southfacing slopes within the study area on 5 April 2008. From May 4–8, 19 exclosures were placed in other habitats. An additional four exclosures were subsequently located within the Alaska Highway right-of-way on June 7, due to a delay in receiving permission from Yukon Department of Highways and Public Works. The purpose of the exclosures was to provide a control where no foraging by ungulates could occur for comparison to forage abundance along biomass sampling transect at the end of the growing season.

Peak biomass sampling was conducted from August 4–22. Biomass sampling was conducted adjacent to all exclosures and on 41 additional sites, all of which had been previously sampled for species composition. The latter plots were chosen to provide approximately equal representation among the eight cover types used in vegetation sampling.

Species known to be elk forage (Kufeld 1973; Florkiewicz 1994; Cook 2002) and 2–250 cm tall were clipped from five 0.5-m × 1-m quadrats, along a transect located in approximately the same position as the vegetation sampling plots, to estimate biomass availability. If a sufficient sample (>15 g) could not be obtained, 1-m × 1-m quadrats were used. The collected biomass was separated into graminoids, forbs, and shrubs; and then placed in separate paper bags. Exclosures were sampled for biomass in the same manner, but a single 1-m × 1-m quadrat was placed in the centre of each exclosure. All biomass samples were initially air-dried, then placed in a drying oven at 60°C for 48–72 hours and subsequently weighed using a Sartorius MC1 Laboratory LC 6200D (Model: 10603783) balance with a precision of 0.01 g.

Leaf litterfall biomass from deciduous trees was collected with leaf traps placed in 14 *Populus tremuloides* vegetation sampling plots. Three cardboard boxes (30 cm × 38 cm, and 25 cm tall), used as leaf traps, were placed at 10-m intervals along biomass sampling transects and anchored to the ground with 25 cm long galvanized nails. These boxes were placed at the beginning of fall, prior to the leaves turning colour or dropping off the trees, and collected approximately one month later, after all of the leaves had fallen. The leaves in individual boxes were collected separately, oven-dried at 60°C for 48–72 hours and then weighed.

Nutrient analysis

Crude protein and fibre content were analyzed as an indicator of the value of forage biomass and common plant species. Plant samples for nutrient analysis were collected at the same locations on a monthly basis, i.e., at the end of May, June, July, and August 2008, to assess seasonal variation in protein and fibre content. Five species were sampled: *Bromus inermis*; *Calamagrostis purpurascens*; *Salix glauca*; *Populus tremuloides*; and *Carex supina*. These species were chosen for analysis based on research by Florkiewicz (1994), which suggested these were among the most common species consumed by elk in the Takhini Valley. Samples were bagged, and air- and oven-dried at 60°C for three days. Twenty samples were analyzed for protein content, neutral detergent fibre, and acid detergent fibre at a commercial lab (Sandberg Labs, Lethbridge, Alberta).

A subset of the forb, shrub, graminoid, and leaf litter biomass samples was also analyzed for protein content, neutral detergent fibre, and acid detergent fibre. Samples were arbitrarily chosen from each sampled type (Pine, Spruce/moss, Spruce/forb, Aspen/bearberry, Aspen/buffaloberry, South slope (sedge), Meadow, and Roadsides), though only those that met the minimum weight requirement (15 g) were sent for analysis. In total, 60 biomass samples from 24 plots were analyzed.

Vegetation plot classification and analysis

A classification of vegetation sampling plots, based on all species present, was conducted to provide an understanding of the variation in vegetative composition and forage availability. Vegetation plot analyses were conducted based on total combined percent cover, i.e., percent cover of a species from all three sampling strata. Treed and nontreed vegetation plots were analyzed separately to avoid the grouping of treed and nontreed plots with similar composition, except tree cover, and to simplify comparisons between groups. Treed plots were grouped using cluster analysis based on STATISTICA software (Statsoft 1995), with squared Euclidean distance as the distance (dis)similarity measure and Ward's method as the group linkage method. Nontreed plots were grouped using PC-ORD 4.25 cluster analysis software (McCune and Mefford 1999), based on relative Euclidean distance and Ward's methods. Two different software programs were used because squared Euclidean distance and relative Euclidean distance methods were not available within one statistical software package. These combinations of methods provided the least amount of chaining among groups and provided the most interpretable results. Cluster analysis groupings were named based on stratal dominance and were referred to as "vegetation types" (Strong et al. 1990). A slash between species names indicates a different stratum and two slashes indicate that there is no dominant species within an intermediate stratum. A dash between species represents co-dominance.

Constancy was defined and calculated as the percent occurrence of a plant taxon within a vegetation type. Richness was defined as the total number of taxa present among plots within a vegetation type. Dominance concentration (D_w, Strong 2002) was calculated to assess the degree of abundance uneveness among plant taxa within communities:

$$D_w = \max_i \left[\frac{b_i}{Q} - \frac{i}{n} \right] \qquad \text{Equation 1}$$

Where: b_i = the sequential cumulative totaling of the ith species abundance values ranked from largest to smallest

i = the ith species in the dataset, where i = 1 through n

$\max_i$ = the largest calculated ith value, where i = 1 through n

n = the number of species in a sample
Q = sum of the kth species abundance values, where k = 1 through n

D_w values range from 0–1, with a value of 1 indicating that the vegetation is dominated by one species.

Detrended Correspondance Analysis (McCune and Mefford 1999) was used to illustrate trends in vegetation composition among plots. Treed and nontreed plots were separately analyzed. When necessary, extreme outliers were excluded from ordinations. Variance explained by the ordination was determined using Euclidean distance. Axes with the greatest explained variance were used for displaying the ordination.

Statistical Analysis

All data used for statistical analysis were tested for normality based on skewness (± 0.9) and kurtosis measures (-0.4 – +1.8) (Wetherill 1981, p. 9). As the data were typically not normal, nonparametric Kruskal-Wallis tests were used to identify significant differences among groups. Statistical Package for Social Sciences (SPSS Inc. 2007) was used for Kruskal-Wallis tests. Scheffé rank tests were used to distinguish statistically different groups within Kruskal-Wallis tests. Scheffé rank tests were conducted manually (Miller 1966, p. 166, formula 110):

$$\left|\overline{\mathrm{R}}_i - \overline{\mathrm{R}}_{i'}\right| \leq \sqrt{\chi^2_{\alpha 0.05}} \times \sqrt{\left(N(N+1)\right)/12} \times \sqrt{\frac{1}{n_i} + \frac{1}{n_{i'}}}$$

Equation 2

Where: R = mean rank of a group derived from Kruskal-Wallis test
χ^2 = chi-square for number of groups – 1 (df) at the α 0.05 level

N = total number of samples ($n_1 + n_2 \ldots. n_n$)
n = number of samples in a group
i = group 1 of comparison pair
i' = group 2 of comparison pair

Regression analysis was used to display the relationships between plot variables. Regression modeling was conducted using Microsoft EXCEL (Microsoft 2007). Exclosure and plot biomass were compared using Wilcoxon rank-sum tests (SPSS Inc. 2007). Throughout the text, "significant" refers to a statistical result where the probability level (P) is <0.050.

Habitat Selection

Habitat selection by elk was investigated to determine preferred and less preferred vegetation types, and to further understand the foraging preferences of elk. Relative preference for vegetation types by elk was determined using Bonferroni simultaneous confidence intervals (Neu et al. 1974; Byers et al. 1984). If the expected use of the vegetation type was less than the confidence interval, the type was preferred and vice versa. The confidence intervals were calculated at different probability levels to provide an indication of how strongly observed and expected values deviated.

To calculate habitat use, 51 winter, 59 spring, 135 summer, and 65 fall female elk locations were used from 12 elk. Each location was buffered (Rettie and McLoughlin 1999) to a 250 m (i.e., the estimated standard error of the telemetry locations) and a 500 m radius. This was done to include areas that elk may have been in relative to the measured location, whereas the 500 m buffer provided a more general determination of habitat use. These buffers were overlaid on the vegetation map in ArcGIS (ESRI Inc. 2006) to determine the proportion of each vegetation type that occurred within the individual buffers. The resulting values were observed use. Expected use was determined based on the proportion of each vegetation type in the study area.

Elk pellet groups (Collins and Urness 1981; Edge and Marcum 1989) were counted along a 5-m wide belt transect that ran the length of the biomass sampling plot, a method similar to that used by Forester et al. (2007). Groups were identified based on similar exterior pellet colour and texture, and formed a distinct cluster. Pellets were not assigned a relative age as decay rates vary among habitat types, and there were no control pellets of known ages (Prugh and Krebs 2004).

Forage Assessment

Forage Index

A forage index (FI) similar to that used by Sachro et al. (2005) and Redburn et al. (2008) was calculated to provide an indication of forage quality and quantity. This index incorporated forage preference and percent canopy cover values:

$$\mathrm{FI}_c = \frac{\sum C_i R_i}{\sum C_i} \qquad \text{Equation 3}$$

Where:
- FI_c = Forage Index Value
- c = based on percent canopy cover
- C_i = percent canopy cover of ith species
- R_i = forage preference rating (0–3) of ith species (Table 1)

Table 1. Elk forage preference ratings for vascular plants present within vegetation sampling plots from the Takhini Valley.

Taxa	Forage Preference Rating[§] Winter	Spring	Summer	Fall	Taxa	Forage Preference Rating Winter	Spring	Summer	Fall
Achillea millefolium	1.3	0	1*	1*	*Geum aleppicum*	0	0	0	0
Androsace septentrionalis	0	0	0	0	*Hedysarum alpinum*	0	0	0	0
Anemone multifida	0	0	0	0	*Helictotrichon hooker*	0	0	0	0
Antennaria microphylla	1*	1	1*	1*	*Hordeum jubatum*	0	0	0	0
Antennaria rosea	1*	0	0	0	*Juncus balticus*	0	0	3	0
Aquilegia brevistyla	0	0	0	0	*Juniperus communis*	1	0	0	1
Arabis drummondii	0	0	0	0	*Juniperus horizontalis*	1	0	0	1
Arabis hirsute	0	0	0	0	*Lappula squarrosa*	0	0	0	0
Arabis holboellii	0	0	0	0	*Linnaea borealis*	1	0	0	0
Arctostaphylos rubra	0	0	0	0	*Linum lewisii*	0	0	0	0
Arctostaphylos uva0ursi	1	1	0	1.7	*Lupinus arcticus*	0	2	1	2
Arnica cordifolia	0	0	2*	0	*Mertensia paniculata*	0	0	0	0
Artemisia campestris	0	0	0	0	*Minuartia rubella*	0	0	0	0
Artemisia frigida	2	2	0	0	*Moehringia lateriflora*	0	0	0	0
Astragalus agrestis	1.5*	2[†]	3	2*	*Orthilia secunda*	3	0	0	1
Astragalus alpinus	1.5*	0	3	2*	*Oxytropis borealis*	0	2*	1	0
Astragalus bodinii	1.5*	0	3	2*	*Oxytropis campestris*	0	2*	1	0
Bromus inermis	3	2*	2	2	*Oxytropis deflexa*	0	2*	1	0
Bromus pumpellianus	1	0	1.8	2	*Packera paupercula*	1.5	2	1	0
Calamagrostis purpurascens	2*	3*	3*	1.5*	*Pedicularis labradorica*	0	2[†]	0	0
Carex concinna	2	1.3	1.9	1.8	*Penstemon gormanii*	1	1.5	1	0
Carex duriuscula	2	1.3	1.9	1.8	*Penstemon procerus*	0	0	1	0
Carex rossii	2	1.3	1.9	1.8	*Picea glauca*	1	0	0	0
Carex supina	2	1.3	1.9	1.8	*Pinus contorta*	1.5	1	0	1.3
Carex tahoensis	2	1.3	1.9	1.8	*Poa glauca*	1.7	2.4	1.9	2.5
Chamaerhodos erecta	0	0	0	0	*Poa palustris*	1.7	2.4	1.9	2.5
Chamerion angustifolium	3	2[†]	2	2	*Poa secunda*	2	2	2.3	3
Deschampsia caepitosa	2	2[†]	3*	0	*Polemonium pulcherrimum*	0	0	2	1
Elymus calderi	0	0	0	0	*Populus balsamifera*	2	0	0	0
Elymus trachycaulus	0	0	0	0	*Populus tremuloides*	2.3	2.3	1.7	2.5
Empetrum nigrum	0	0	0	0	*Potentilla bimundorum*	0	1.3	1.3	1.5
Erigeron compositus	0	2	1.5	2	*Potentilla hookeriana*	0	1.3	1.3	1.5
Erysimum cheiranthoides	0	0	0	0	*Potentilla pensylvanica*	0	1.4	1.3	1.5
Eurybia sibirica	2*	2*	2*	1.5*	*Pyrola chlorantha*	3	0	0	1
Festuca altaica	2.4*	2	3	2	*Rosa acicularis*	1	2[†]	3	3
Festuca brachyphylla	0	2	3	2	*Salix arbusculoides*	2.1	2	1.8	2.3
Festuca saximontana	0	2	3	2	*Salix bebbiana*	2.1	2	1.8	2.3
Fragaria virginiana	1.5	2	1	1	*Salix glauca*	2.1	2	1.8	2.3
Galium circaezans	1	0	0	0	*Salix planifolia*	2	1.5	1	2
Gentianella propinqua	0	0	0	0	*Salix scouleriana*	3	2[†]	0	0
Geocaulon lividum	0	0	0	0	*Saxifraga tricuspidata*	0	0	0	0

Table 1. Concluded.

Taxa	Forage Preference Rating: Winter	Spring	Summer	Fall	Taxa	Forage Preference Rating: Winter	Spring	Summer	Fall
Sedum lanceolatum	0	0	0	0	*Stipa nelsonii*	2.3	2.5	2	2
Senecio lugens	1.5	2	1	0	*Taraxacum officinale*	1	1.8	2.2	2
Senecio strepthanfollius	1.5	2	1	0	*Trisetum spicatum*	0	0	2*	2*
Shepherdia canadensis	2	0	1	1.5	*Vaccinium vitis-idaea*	2*	0	1*	1*
Solidago simplex	1	0	0	0	*Viburnum edule*	0	0	0	0
Stellaria longipes	1	0	0	0	*Zigadenus elegans*	0	0	0	0

Ratings from Cook et al. (2000); *Kufeld (1973); and †R. Florkiewicz and R.M.P. Ward (Yukon Department of Environment, 2009, pers. comm.).
§ Ratings scale: 0 = no rating; <1 = least preferred; 1-2 = preferred; >2 = most preferred.

Forage ratings were derived from values presented by Kufeld (1973) and Cook (2002), and discussed with local biologists (R.M.P. Ward and R. Florkiewicz, pers. comm.). The rating terminology was as follows:

>2 – "Most preferred" species were consumed in excess of their proportional occurrence in the vegetation, or were a major part of the diet;

1-2 – "Preferred" species were sought and consumed, but not to the extent of more preferred species, or were a moderate part of the diet; and

<1 – "Least preferred" species were consumed in smaller proportions than occurred on the range and were a minor part of the diet.

Twenty-eight of the 149 recorded species did not have a forage preference rating. Species without ratings were included in the index calculations, but were given a rating of

0 to obtain a conservative FI value. The average cover of the unranked species was 0.09% (sd 0.22). Forage index values were calculated for each plot and averaged by vegetation types. These were calculated by season (spring, April and May; summer, June–August; fall, September and October; and winter, November–March). The winter FI value excluded forbs and shrubs from the calculation because only grasses are accessible during this season as forage.

Forage Carrying Capacity

A multi-step process was used to develop different carrying capacity scenarios based on various assumptions. An initial carrying capacity for the study area was calculated based on peak biomass availability divided by the amount of biomass required by an elk per year. Ungulates consume 2-4% of their body weight in forage per day to maintain their physical condition (Kuzyk and Hudson 2007). Mule deer, horses and elk were assumed to consume an average of 3% (Baker et al. 1998; Gedir and Hudson 2000) of their body weight in forage per day. Elk average body weight was based on 320 kg for males, 225 kg for females, and 135 kg for calves (Florkiewicz 1994; Crane et al. 1997). The population distribution was assumed to be 58 bulls : 100 cows : 24 calves, respectively (Florkiewicz et al. 2007). This gross carrying capacity was refined based on the following assumptions:

1. Biomass available by season was a proportion of peak forage abundance. Leaf litterfall was only available for consumption during fall.

2. In winter, browse formed an average of 29% of an elk's diet (Christianson and Creel 2007), so forage requirements were accordingly reduced. To accommodate potential uncertainty regarding current browse consumption in the study area, rates ±10% of the average were also considered as part of the analysis.

3. The average weight of a horse was typically 450 kg (Marlow et al. 1992). The average weight of mule deer was 88 kg (Kuzyk and Hudson 2006; Yukon Department of Environment, 2008, unpublished data).

4. Approximately 15 horses and 30 mule deer resided in the study area (T. Jung, Yukon Department of Environment, 2009, pers. comm.).

5. Horses typically consumed the same forage species as elk especially when forage supply was low (Hansen and Clark 1977; Olsen and Hansen 1977; Salter and Hudson 1980). Mule deer also foraged many of the same species, but relied on browse for 72% of their diet (Hansen and Clark 1977; Bartmann et al. 1982).

6. A constant number of elk, horses, and mule deer remained within the study area at all times and equally used all vegetation types.

7. Forage values for elk were weighted by forage index preference ratings.

8. Forbs were inaccessible or physically disintegrated during fall and winter.

9. Ecologically sustainable safe-use factors for grazing were 25% of total biomass for treed areas, and 50% for nontreed areas based on data from Alberta rangelands (Alberta Sustainable Resource Development 2004). Forage consumption at or

below these values allows for sufficient remaining biomass to perform necessary ecological services and functions.

RESULTS

Sampling of 112 plots occurred between June 23 and July 24, 2008; the mid-summer growing period (Figure 2). Ninety-six vascular and 56 nonvascular species were identified during vegetation sampling. Appendix III contains the cover data. Four tree species occurred within the plots: *Populus tremuloides*; *Picea glauca*; *Pinus contorta*; and *Populus balsamifera*. The latter was present in only one plot. Ten shrub species were present in the vegetation sampling plots; the most common were *Rosa acicularis*, *Shepherdia canadensis*, and *Salix glauca*. The latter occurred occasionally in the tree stratum (>2.5 m tall). *Rosa acicularis* had the highest constancy (75%) of all species that occurred in the sampled plots. Of the 61 forb species that were present, low-growing taxa (<15 cm) were the most common. These included *Anemone multifida*, *Achillea millefolium*, *Chamerion angustifolium*, *Fragaria virginiana*, *Galium circaezansi*, and *Linnaea borealis*. *Calamagrostis purpurascens* and *Bromus pumpellianus* were the most common graminoid taxa. *Peltigera rufescens*, a ground lichen, occurred in >20% of the plots, which was the only nonvascular taxon to do so. Lichens typically had <10% constancy among plots.

Vegetation types

Plots were classified as treed (n = 72) and nontreed (n = 40) that had little to no overstory cover >2.5 m tall. Classification of the plots by cluster analysis after sampling increased the number of vegetation groups from eight cover types to 12 vegetation types, reducing the average number of plots from 12 to nine per type (Figure 2).

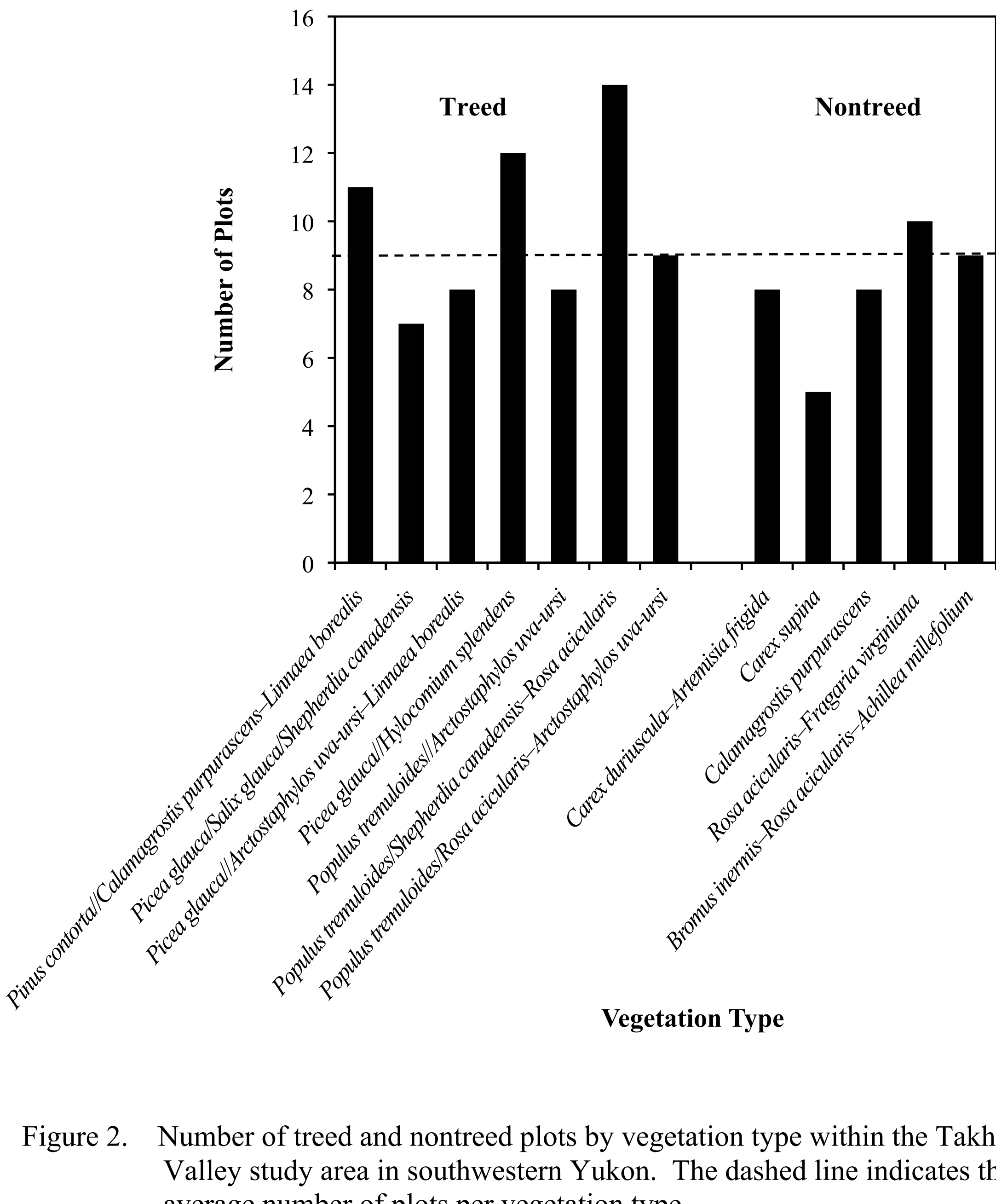

Figure 2. Number of treed and nontreed plots by vegetation type within the Takhini Valley study area in southwestern Yukon. The dashed line indicates the average number of plots per vegetation type.

Treed Vegetation Types

Seven vegetation types were identified within a cluster analysis dendrogram of treed plots (Figure 3). A break-point (i.e., plot amalgamation discontinued) was chosen where distinct clusters based on species composition were formed, with the least amount of grouping error. The grouping error at the break-point was <10%. One cluster group (C3) was divided into two more homogenous groups based on species composition and cover differences (C2) (Figure 3). Three *Pinus contorta* plots were moved from B2, a *Picea glauca* group, to the *Pinus contorta* group (A) based on dominant species cover values. Three *Picea glauca* plots (P35, P53, and P59), also from B2, were removed from further analysis because their species composition and cover values did not fit any of the recognized cluster analysis groups. They were also different from each other, so did not in combination form a separate group. No value for percent chaining was available for the treed cluster analysis, but it appeared to be low based on the structure of the dendrogram.

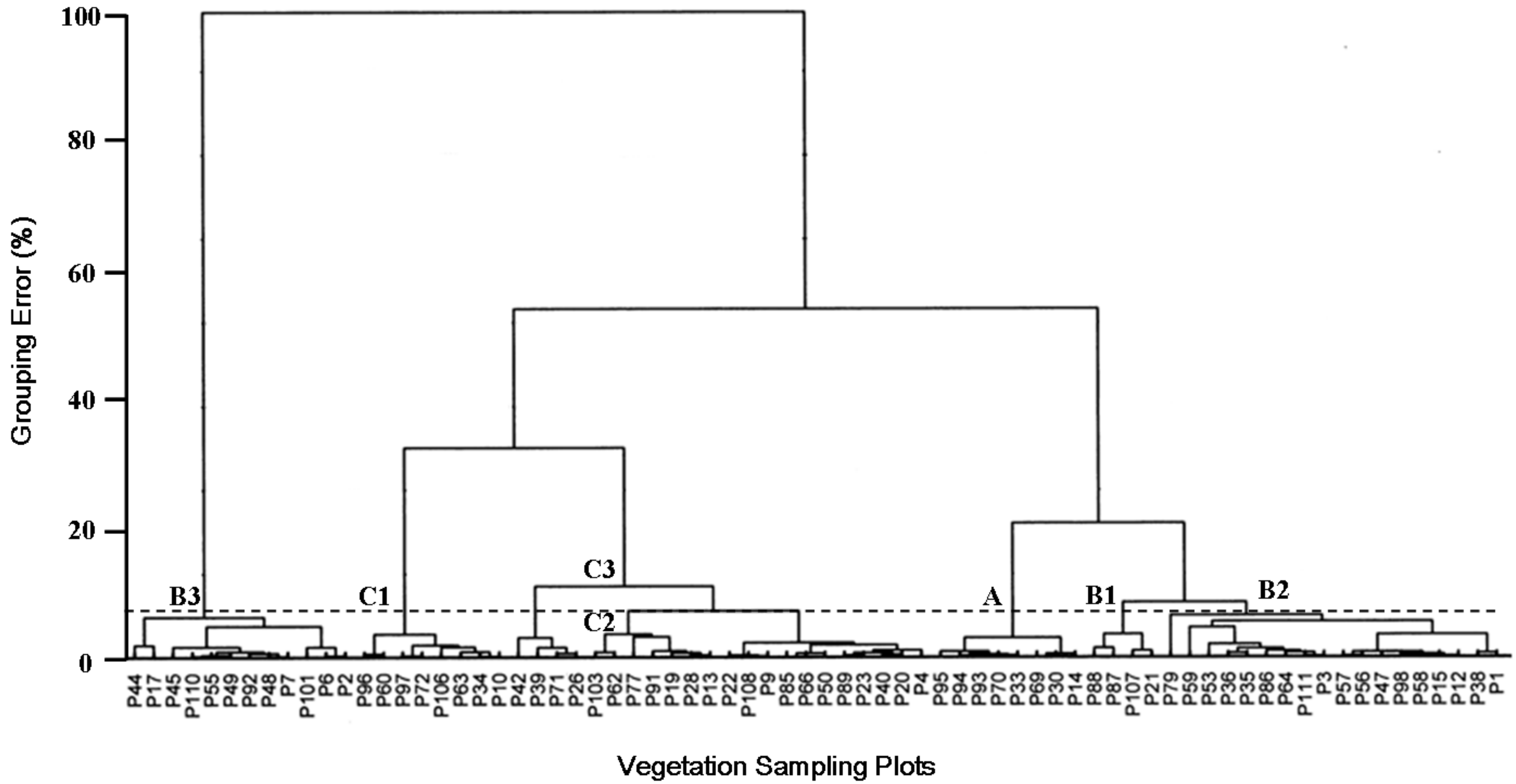

Figure 3. Cluster analysis dendrogram of treed vegetation sampling plots based on species composition and abundance from the Takhini Valley study area. The dashed line indicates the break-point where grouping was discontinued.

Pinus contorta//Calamagrostis purpurascens–Linnaea borealis vegetation type (A)

This vegetation was an intermediate height (3–15 m), open-canopied (25–60% cover), evergreen forest type[3] (Photograph 1a) that occupied 4% of the study area (Table 2). *Pinus contorta//Calamagrostis purpurascens–Linnaea borealis* vegetation occurred mainly in the southeastern portion of the study area and on the north aspects of hills north of the Alaska Highway (Figure 4). The tree stratum was dominated by *Pinus contorta*, which had an average canopy cover of 30% (Table 3). *Pinus contorta* average height was 14.6 m (sd 3.5) and average diameter at breast height (DBH) was 13 cm (sd 3). Average stand age was 44 years. Stands older than 50 years (i.e., pre-1958 burn) occurred in two of the 11 sampled plots, they were 59 and 70 years old. Both of these plots occurred on northfacing slopes. Tree densities averaged 2,990 stems/ha. A shrub stratum (<2.5 m tall) of *Picea glauca* was present in half of the plots, with an average cover of 2%. Two high (>75%) constancy understory species occurred; *Linnaea borealis* and *Calamagrostis purpurascens* both had <4% cover. This vegetation had the second lowest amount of forb (13%) and shrub (6%) cover (Table 3) among treed vegetation types. Bryophyte and lichen cover averaged 2% and 8%, respectively. Richness averaged 14 (sd 4) species among plots and species cover totaled 61%. All but one plot occurred on sites with 5–36% slopes. This vegetation type occurred on moderately well drained soils, with poor to medium nutrient regimes and mesic moisture regimes. The most common parent

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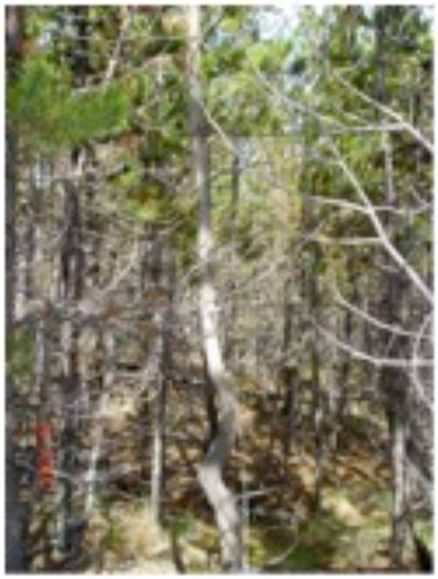
[3] Vegetation physiognomic criteria based on the Canadian System of Vegetation Classification (Strong et al. 1990).

(a)



(b)

(c)

(d)

Photograph 1. A representative example looking along the 30-m transect through a vegetation sampling plot (a) *Pinus contorta//Calamagrostis purpurascens–Linnaea borealis*, (b) *Picea glauca/Salix glauca/Shepherdia canadensis*, (c) *Picea glauca/Arctostaphylos uva-ursi–Linnaea borealis*, and (d) *Picea glauca//Hylocomium splendens* treed vegetation types.

Table 2. Areal extent of vegetation types and percent occurrence in the Takhini Valley study area, southwestern Yukon.

Vegetation Type	**Hectares**	**Percent Study Area**
Pinus contorta//Calamagrostis purpurascens–Linnaea borealis	394	4.1
Picea glauca/Salix glauca/Shepherdia canadensis	1,152	12.1
Picea glauca//Arctostaphylos uva-ursi–Linnaea borealis	627	6.6
Picea glauca//Hylocomium splendens	779	8.2
Populus tremuloides//Arctostaphylos uva-ursi	888	9.3
Populus tremuloides/Shepherdia canadensis–Rosa acicularis	1,626	17.0
Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi	1,439	15.1
Carex duriuscula–Artemisia frigida	709	7.4
Carex supina	267	2.8
Calamagrostis purpurascens	428	4.5
Rosa acicularis–Fragaria virginiana	362	3.8
Bromus inermis–Rosa acicularis–Achillea millefolium	113	1.2
Farmland	564	5.9
Disturbances	100	1.0
Eroding slopes	96	1.0
Total	9,543	100.0

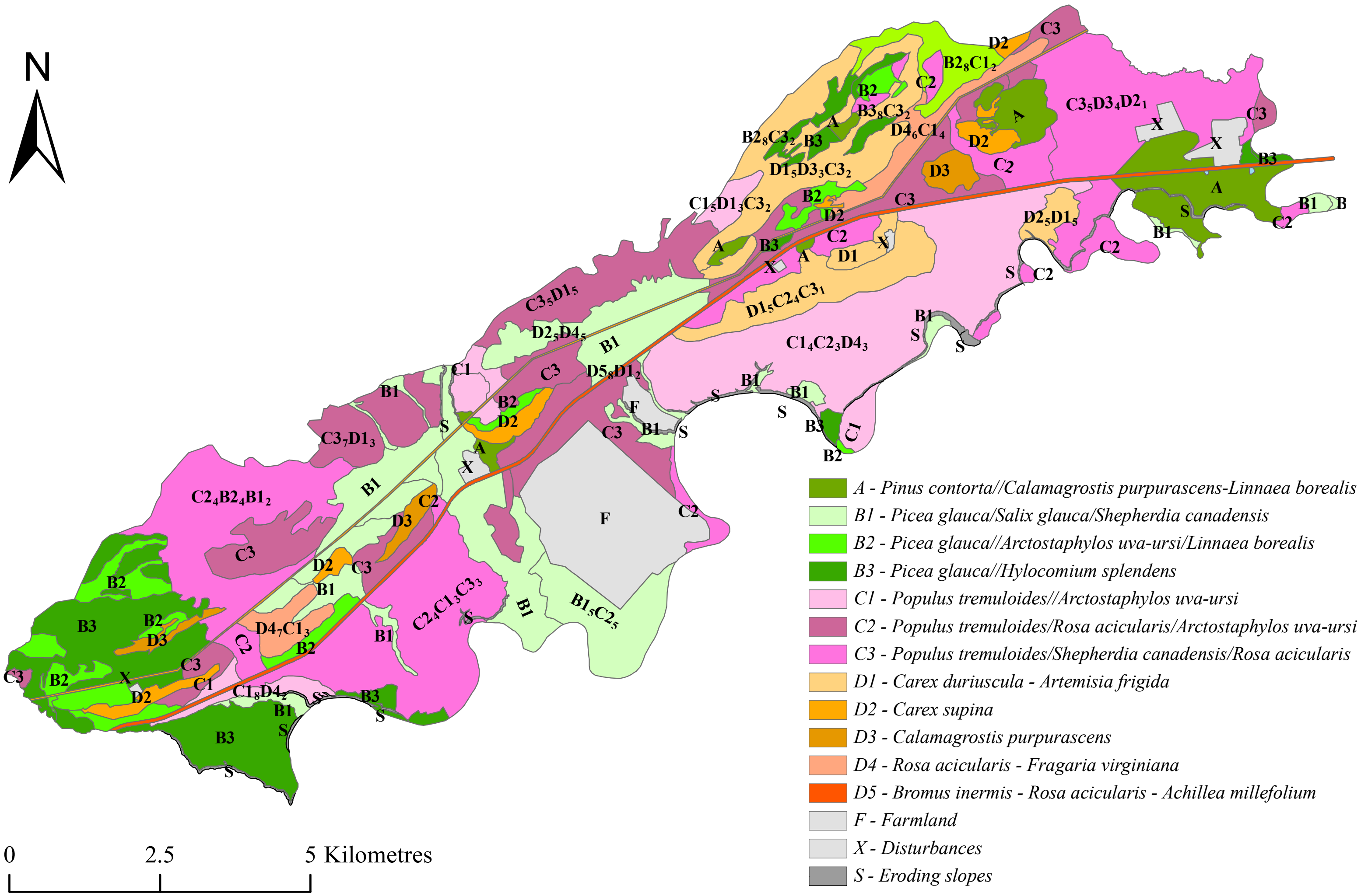


Figure 4. Distribution of vegetation types within the Takhini Valley study area, southwestern Yukon. Subscripts indicate proportion of the polygon represented by the vegetation type

Table 3. Plant species composition and characteristics of treed vegetation types within the Takhini Valley study area, southwestern Yukon. Mean percent cover values for vegetation types were compared using Kruskal-Wallis tests and differences were identified using Scheffé rank tests. Species values underlined have a high (>75%) constancy, and a cover value >2%.

Variables	**Vegetation Types** *Pinus contorta// Calamagrostis purpurascens – Linnaea borealis*	*Picea glauca/ Salix glauca/ Shepherdia canadensis*	*Picea glauca// Arctostaphylos uva-ursi – Linnaea borealis*	*Picea glauca// Hylocomium splendens*	*Populus tremuloides/ Shepherdia canadensis– Rosa acicularis*	*Populus tremuloides/ Rosa acicularis– Arctostaphylos uva-ursi*	*Populus tremuloides// Arctostaphylos uva-ursi*	*P*
	Percent cover[standard deviation]constancy class*							
Trees								
Picea glauca	2.3[2.2]6ab†	9.7[5.0]10abc	23.0[5.6]10bc	32.1[14.6]10c	0.5[0.8]4a	1.5[3.1]3a	0.2[0.3]4a	<0.001
Pinus contorta	28.3[15.6]10b	0a	+[0.1]1ab	0a	0.7[2.6]1a	0a	0a	<0.001
Populus balsamifera	0a	0a	0a	0.1[0.2]1a	0a	0a	0a	1.000
Populus tremuloides	1.0[1.4]4a	0.2[0.3]3a	3.6[5.0]6ab	0.6[1.1]3a	34.3[11.3]10bc	37.9[14.5]10c	15.9[11.0]10abc	<0.001
Shrubs								
Arctostaphylos uva-ursi	2.4[5.2]4ab	6.6[9.2]4ab	13.3[10.3]10ab	1.8[5.4]4a	1.1[1.7]4a	19.7[7.8]10ab	47.3[11.0]10b	<0.001
Juniperus communis	0a	+[0.1]1a	0a	0a	+[0.1]1a	0a	0.1[0.1]1a	0.553
Juniperus horizontalis	0a	0.3[0.9]1a	0.8[2.3]2a	0.2[0.3]2a	+[0.1]1a	1.0[3.1]1a	1.6[3.0]2a	0.547
Rosa acicularis	1.4[2.1]5a	0.9[1.5]3a	6.2[7.6]7ab	1.1[1.2]6a	9.9[7.4]9ab	19.0[15.5]10b	6.5[6.0]9ab	<0.001
Salix arbusculoides	0a	0a	0a	0a	0a	+[0.1]1a	0a	0.353
Salix bebbiana	0a	0.2[0.5]1a	1.3[2.8]4a	0a	+[+]1a	0.3[1.0]1a	0a	0.065
Salix glauca	0.5[1.51a	20.3[11.9]10b	1.5[1.7]6ab	0a	0.6[1.7]2ab	0.6[1.7]1ab	0a	<0.001
Salix planifolia	0.1[0.2]1a	0a	0a	0a	0a	+[0.1]1a	0a	0.541
Salix scouleriana	0.2[0.4]2a	0.3[0.6]3a	0a	0a	0.6[2.1]1a	0a	0a	0.165
Shepherdia canadensis	4.8[8.4]6ab	7.1[6.6]10ab	3.6[3.0]7ab	0.2[0.5]2a	16.2[15.3]9b	5.1[6.5]8ab	3.2[8.5]5ab	<0.001
Viburnum edule	0a	0a	0a	0a	0a	+[+]1a	0a	0.547
Forbs								
Achillea millefolium	+[+]1ab	0.2[0.2]9ab	0.3[0.5]5ab	0a	0.4[0.5]6ab	0.8[1.0]9b	0.5[0.4]9b	<0.001
Androsace spetentrionalis	0a	0a	0a	0a	+[+]1a	+[+]1a	0a	0.628
Anemone multifida	1.3[1.9]6a	0.4[0.6]4a	0.5[1.0]5a	0.1[0.2]2a	1.0[0.8]9a	1.4[1.0]8a	1.5[0.8]9a	0.002
Antennaria microphylla	0a	0.1[0.2]1a	0a	0a	0.1[0.3]1a	0.1[0.2]2a	0a	0.285
Aquilegia brevistyla	+[+]1a	0a	0a	0a	0a	0a	0a	0.509
Arabis drummondii	0a	++[]1a	0a	+[0.1]1a	+[0.1]1a	0a	+[0.1]1a	0.682
Arctostaphylos rubra	0a	0.4[1.1]1a	0a	0a	0a	0a	0a	0.182

Table 3. Continued.

Variables	*Pinus contorta*// *Calamagrostis purpurascens* – *Linnaea borealis*	*Picea glauca*/ *Salix glauca*/ *Shepherdia canadensis*	*Picea glauca*// *Arctostaphylos uva-ursi* – *Linnaea borealis*	*Picea glauca*// *Hylocomium splendens*	*Populus tremuloides*/ *Shepherdia canadensis*– *Rosa acicularis*	*Populus tremuloides*/ *Rosa acicularis*– *Arctostaphylos uva-ursi*	*Populus tremuloides*// *Arctostaphylos uva-ursi*	*P*
	Vegetation Types — Percent cover[standard deviation]constancy class*							
Arnica cordifolia	0.1[0.2]1a	0a	0.3[0.8]1a	0a	0a	0a	0a	0.474
Artemisia frigida	0a	0a	0a	0a	0a	0.1[0.3]1a	0a	0.353
Astragalus agrestis	0a	0.9[2.3]1a	0a	0a	+[0.2]1a	0a	0a	0.476
Astragalus alpinus	0a	0.1[0.2]1a	0a	0.1[0.2]1a	0.1[0.4]1a	0.9[2.7]1a	0a	0.791
Chamerion angustifolium	0.5[1.4]3a	0.9[1.0]7a	1.3[1.9]6a	0.1[0.2]2a	3.1[2.9]8a	1.8[2.2]8a	1.2[2.2]2a	0.005
Empetrum nigrum	0a	0a	0a	3.5[6.8]3a	0a	0a	0a	0.003
Equisetum scirpoides	0a	0a	0.1[0.2]1a	0a	0a	0a	0a	0.267
Erysimum cheiranthoides	0.1[0.5]1a	0a	0a	0a	+[+]1a	0a	0a	0.606
Eurybia sibirica	0a	0.1[0.3]1a	0a	+[+]1a	0.1[0.3]2a	0.1[0.4]1a	0.3[0.9]2a	0.498
Fragaria virginiana	0a	1.6[1.3]9a	0.4[0.8]4a	+[0.1]1a	4.0[6.3]6a	5.7[11.2]6a	5.9[6.8]5a	0.002
Galium circaezans	+[+]1a	0.1[0.3]1a	0.1[0.1]1a	+[0.1]3a	0.4[0.6]6a	0.3[0.5]6a	0.3[0.3]7a	0.010
Gentianella propinqua	0a	0a	0a	0a	+[0.1]1a	0.7[2.1]1a	0a	0.633
Geocaulon lividum	0.4[1.2]2a	0.3[0.7]1a	1.4[2.5]2a	0.4[0.6]4a	0a	0a	0a	0.052
Hedysarum alpinum	0a	0a	0.1[0.1]1a	0.1[0.3]1a	0a	0a	0a	0.516
Linnaea borealis	3.6[2.9]8a	4.2[8.1]4a	8.0[5.2]9a	3.4[5.8]6a	1.1[2.7]2a	2.5[3.3]4a	0.1[0.3]1a	0.002
Linum lewisii	0a	0a	0a	0a	+[+]1a	+[+]1a	+[+]1a	0.650
Lupinus arcticus	0a	0a	0.3[1.0]1a	0.2[0.4]2a	0a	0.5[1.5]1a	1.2[3.3]1a	0.575
Mertensia paniculata var. *arctica*	0a	0a	0a	0a	0.2[+]+a	0a	0a	0.186
Mertensia paniculata	0a	0a	0.4[0.8]2a	0a	0a	0a	0a	0.017
Moehringia lateriflora	0a	0a	0a	0a	0.1[0.2]1a	+[0.1]1a	0a	0.686
Orthilia secunda	0a	0a	0.2[0.4]2a	+[+]2a	0a	0.1[0.2]1a	0a	0.043
Oxytropis campestris	0a	0a	0a	0a	+[0.1]1a	0a	0a	0.622
Packera paupercula	0a	0.1[0.2]1a	0a	0a	+[0.1]1a	+[0.1]2a	+[+]1a	0.443
Pedicularis labradorica	0a	0a	2.0[4.3]2a	+[+]1a	0a	0.2[0.4]2a	0a	0.090
Penstemon gormanii	0a	0a	0a	0.1[0.2]+a	0a	0a	0a	1.000
Penstemon procerus	0a	0a	0.2[0.7]1a	0a	0.8[1.7]4a	0a	0.7[1.3]4a	0.047

Table 3. Continued.

Variables	*Pinus contorta// Calamagrostis purpurascens – Linnaea borealis*	*Picea glauca/ Salix glauca/ Shepherdia canadensis*	*Picea glauca// Arctostaphylos uva-ursi – Linnaea borealis*	*Picea glauca// Hylocomium splendens*	*Populus tremuloides/ Shepherdia canadensis– Rosa acicularis*	*Populus tremuloides/ Rosa acicularis– Arctostaphylos uva-ursi*	*Populus tremuloides// Arctostaphylos uva-ursi*	*P*
	Vegetation Types – Percent cover[standard deviation]constancy class*							
Polemonium pulcherrimum	0a	0.3[0.7]3a	0a	+[0.1]+a	+[0.2]1a	0a	+[+]1a	0.133
Potentilla bimundorum	0a	0a	0a	0a	+[0.1]1a	0a	0a	0.686
Pyrola chlorantha	0a	0a	0a	0.2[0.4]1a	0a	0a	0a	0.576
Saxifraga tricuspidata	+[+]1a	0a	0a	0a	0a	0a	0a	0.536
Senecio lugens	0a	0a	0.1[0.2]1a	0a	0a	0a	0a	0.267
Senecio strepthanfollius	0a	0a	0a	0a	+[0.1]1a	0.8[2.2]2a	0a	0.177
Solidago simplex	+[+]2a	+[+]1a	0.1[0.1]2a	+[+]1a	+[0.1]1a	0a	0.1[0.3]1a	0.950
Stellaria longipes	0a	+[+]1a	0a	0a	0.1[0.2]2a	0a	0a	0.122
Taraxacum officinale	0a	0.1[0.2]1a	0a	0.6[2.1]+a	+[+]1a	0a	0a	0.476
Vaccinium vitis-idaea	0.4[1.1]2a	0a	0a	+[+]1a	0a	+[0.1]1a	0a	0.288
Zigadenus elegans	0.1[0.2]3a	+[+]1a	0.2[0.4]4a	+[+]1a	0a	0a	+[+]1a	0.099
Graminoids								
Bromus inermis	0a	0a	0a	0a	0.5[1.9]1a	0.1[0.4]1a	0a	0.686
Bromus pumpellianus	0a	0.1[0.4]1a	1.0[2.8]1a	+[0.1]+a	0.5[0.7]5a	0a	0.8[1.5]4a	0.018
Calamagrostis purpurascens	3.9[3.2]9a	0.7[1.8]3a	0.8[1.2]5a	+[+]2a	3.1[5.9]6a	0a	5.6[6.0]9a	0.003
Carex concinna	+[0.1]1a	0.1[0.1]4a	0.3[0.5]5a	0.7[2.3]2a	0a	3.7[4.3]7a	0a	0.005
Carex duriuscula	0a	0a	0a	0a	+[0.1]1a	0.4[1.1]1a	0.2[0.5]1a	0.358
Carex supina	0a	0a	0a	0a	0a	+[+]1a	0.4[1.1]2a	0.082
Carex tahoensis	0a	0a	0a	0a	0a	0a	0.1[0.2]1a	0.396
Deschampsia caepitosa	0a	0a	0.5[1.1]2a	0a	0a	0a	0a	0.017
Elymus trachycaulus	0a	0a	0a	0.6[1.4]+a	0a	1.0[2.0]3a	0a	1.000
Festuca altaica	0a	0.9[2.4]1a	0.4[1.2]1a	+[+]4a	0a	+[+]1a	2.2[6.0]2a	0.086
Festuca brachyphylla	0.1[0.3]1a	+[0.1]1a	0a	0a	0a	+[0.1]1a	0a	0.537
Festuca saximontana	0a	0.1[0.2]1a	0a	0a	+[0.1]1a	0a	0a	0.471
Poa glauca	0a	+[0.1]1a	0a	0a	0.5[1.8]1a	0a	+[+]1a	0.147

Table 3. Continued.

Variables	*Pinus contorta// Calamagrostis purpurascens – Linnaea borealis*	*Picea glauca/ Salix glauca/ Shepherdia canadensis*	*Picea glauca// Arctostaphylos uva-ursi – Linnaea borealis*	*Picea glauca// Hylocomium splendens*	*Populus tremuloides/ Shepherdia canadensis– Rosa acicularis*	*Populus tremuloides/ Rosa acicularis– Arctostaphylos uva-ursi*	*Populus tremuloides// Arctostaphylos uva-ursi*	*P*
	Vegetation Types — Percent cover[standard deviation]constancy class*							
Poa palustris	0a	0a	0a	0a	0a	0.4[0.6]3a	0a	1.000
Lichens								
Cetraria ericetorum	0a	0a	+[+]1a	0a	0a	0a	0a	0.267
Cladonia cornuta	0.1[0.2]4a	0a	0.2[0.4]4a	0.1[0.5]1a	0.1[0.5]1a	0a	0a	0.052
Cladonia rangiferina	0a	0a	0a	+[0.1]1a	0a	0a	0a	0.576
Cladonia amaurocraea	0a	0a	0a	0.1[0.3]2a	0a	0a	0a	0.141
Cladonia botrytis	+[0.1]1a	0a	0a	0a	0a	0a	0a	0.509
Cladonia cariosa	0.1[0.2]1a	0.1[0.3]1a	0.1[0.1]1a	0a	+[0.1]1a	0a	0a	0.724
Cladonia cenotea	0a	0a	0a	+[0.1]1a	0a	0a	0a	0.576
Cladonia chlorophaea	0a	0a	0a	0a	+[0.1]1a	0a	0a	0.240
Cladonia ecmocyna	0.1[0.2]2a	0a	0.2[0.5]1a	0.1[0.2]2a	0a	0a	0a	0.354
Cladonia fimbriata	0a	0.1[0.2]1a	0a	0a	0.1[0.4]1a	0a	0a	0.493
Cladonia gracillis	0.4[0.7]3a	0a	0.2[0.6]1a	0.1[0.3]3a	0a	0a	0a	0.051
Cladonia mitis	0a	0a	0.4[1.1]1a	0.2[0.6]2a	0a	0a	0a	0.077
Cladonia phyllophora	0a	0a	0a	0.1[0.2]1a	0a	0a	0a	0.576
Cladonia pyxidata	0.5[0.5]5a	0.4[1.0]3a	1.2[1.9]4a	0.1[0.3]1a	0.3[0.6]3a	0a	0a	0.039
Cladonia squamosa	0a	0.1[0.2]1a	0a	0a	0.5[1.4]1a	0a	0a	0.315
Cladonia ssp.	2.9[4.0]5a	4.1[7.2]3a	0a	0a	0a	0a	0a	<0.001
Flaviocetraria nivalis	0.3[0.6]3a	0.1[0.2]3a	0.6[1.8]1a	0.7[1.7]2a	0a	0a	0a	0.165
Parmelia sulcata	0a	0a	+[+]1a	0a	0a	0a	0a	0.267
Peltigera aphthosa	1.1[1.6]4a	0a	1.1[2.3]4a	2.0[2.3]7a	0a	0a	0a	<0.001
Peltigera canina	0.1[0.3]1a	0a	0a	0.4[1.0]2a	0.1[0.4]1a	0a	0.2[0.5]1a	0.705
Peltigera malacea	0.2[0.3]3a	0a	0.1[0.1]1a	0.3[0.7]2a	0a	0.2[0.5]2a	0a	0.210
Peltigera ponojensis	0.1[0.4]1a	0.1[0.2]1a	0.2[0.5]1a	0a	0.2[0.6]1a	0.2[0.6]2a	0a	0.671
Peltigera rufescens	0.5[1.3]3a	2.2[2.3]6a	2.0[2.2]6a	0.1[0.5]1a	1.1[2.4]5a	0.3[0.6]2a	0.4[0.7]4a	0.073
Peltigera ssp.	1.4[3.1]2a	5.2[9.9]3a	0a	0a	0a	0a	0a	0.045
Physconia muscigenia	0.1[0.3]1a	0a	+[+]1a	0.1[0.3]1a	0a	0a	0a	0.683

Table 3. Continued.

Variables	Vegetation Types							*P*
	Pinus contorta// Calamagrostis purpurascens – Linnaea borealis	*Picea glauca/ Salix glauca/ Shepherdia canadensis*	*Picea glauca// Arctostaphylos uva-ursi – Linnaea borealis*	*Picea glauca// Hylocomium splendens*	*Populus tremuloides/ Shepherdia canadensis– Rosa acicularis*	*Populus tremuloides/ Rosa acicularis– Arctostaphylos uva-ursi*	*Populus tremuloides// Arctostaphylos uva-ursi*	
	Percent cover[standard deviation]constancy class*							
Stereocaulon tomentosum	0.2[0.3]3a	0a	0a	0a	+[0.1]1a	0a	0a	0.058
Bryophytes								
Aulacomnium palustre	0a	0a	0a	0.1[0.3]1a	0a	0a	0a	0.576
Brachythecium salebrosum	0a	6.0[10]1a	0a	0a	0a	0a	0a	0.006
Bryum caespitosum	0a	0a	0a	0a	0a	0.1[0.3]1a	0a	0.353
Ceratodon purpureus	0.7[2.4]1a	0a	+[0.1]1a	1.2[2.4]2a	0.1[0.2]2a	0a	0a	0.363
Dicranum acutifolium	0.4[0.8]3a	6.9[1.1]a	+[+]1a	0.8[1.9]2a	0a	0.1[0.2]2a	0a	0.348
Dicranum brevifolium	0a	0a	0a	0a	0.1[0.2]1a	0a	0a	0.686
Dicranum elongatum	0.5[1.5]1a	0a	0a	0a	0a	0a	0a	0.509
Dicranum fuscescens	0a	0a	0.1[0.2]1a	0a	0a	0a	0a	0.267
Hylocomium splendens	0.2[0.5]3a	0a	1.2[2.2]4ab	51.4[17.3]10b	0a	0a	0a	<0.001
Hypnum cupressiforme	+[+]1a	0a	0a	0.5[1.7]2a	0.1[0.3]1a	0a	0a	0.566
Phascum cuspidatum	0a	0a	0a	0a	0a	0.1[0.3]1a	0a	0.353
Pohlia nutans	0a	0a	0a	0.2[0.7]1a	0a	0a	0a	0.576
Polytrichum juniperum	0a	0a	0a	0.3[0.7]2a	0.1[0.3]1a	0a	0a	0.317
Ptilidium pulcherrimum	0a	0.1[0.3]1a	0a	0a	0a	0a	0a	0.182
Rhytidium rugosum	0.1[0.3]1a	0a	0a	0a	0a	0a	0a	0.509
Thuidium abietinum	0a	0.2[0.5]1a	0a	0a	0a	0a	0a	0.182
Tortula ruralis	0a	0.5[1.3]1a	0.4[0.8]2a	0a	0a	0a	0a	0.062
Unknown moss	0a	0a	0a	0.1[0.2]1a	0a	0a	0a	0.576
Stand Characteristics								
Total Species Cover	61.5[15.0]a	85.6[27.2]ab	80.1[26.9]ab	105.9[24.9]b	83.3[19.9]ab	108.4[26.8]b	96.4[17.2]ab	<0.001
Total Tree Cover	31.6[15.5]ab	9.8[5.2]a	26.6[9.9]ab	32.8[14.6]ab	35.4[11.1]b	39.5[14.4]b	16.1[11.1]ab	<0.001
Total Salix Cover	0.7[1.6]ab	20.8[11.8]b	2.9[3.1]ab	0a	1.2[2.6]ab	1.0[2.7]ab	0a	<0.001
Total Shrub Cover	6.2[8.3]ab	8.0[6.5]ab	9.8[6.9]ab	1.3[1.3]a	26.1[18.8]b	24.2[15.0]b	9.71[1.6]ab	<0.001
Total Forb Cover	13.0[9.4]abc	18.7[15.0]abc	32.8[16.7]abc	12.5[12.6]a	17.6[8.1]ab	42.7[17.1]bc	7.0[12.8]c	<0.001

Table 3. Concluded.

Variables	*Pinus contorta// Calamagrostis purpurascens – Linnaea borealis*	*Picea glauca/ Salix glauca/ Shepherdia canadensis*	*Picea glauca// Arctostaphylos uva-ursi – Linnaea borealis*	*Picea glauca// Hylocomium splendens*	*Populus tremuloides/ Shepherdia canadensis– Rosa acicularis*	*Populus tremuloides/ Rosa acicularis– Arctostaphylos uva-ursi*	*Populus tremuloides// Arctostaphylos uva-ursi*	*P*
	Vegetation Types							
	Percent cover[standard deviation]constancy class*							
Total Graminoid Cover	4.0[3.2]ab	2.0[3.1]ab	3.1[2.2]ab	1.3[2.5]a	4.7[6.2]ab	5.5[4.4]ab	9.3[7.3]a	0.006
Total Bryophyte Cover	2.0[2.7]ab	13.6[19.0]ab	1.7[2.1]ab	54.9[17.2]b	0.4[0.5]a	0.3[0.6]a	0a	<0.001
Total Lichen Cover	8.0[7.4]a	14.7[18.2]a	6.2[6.7]a	4.4[3.1]a	2.5[3.3]a	0.8[1.2]a	0.6[1.0]a	<0.001
	Mean[standard deviation]							
D_w	0.52[0.1]ab	0.51[0.1]ab	0.47[0.1]a	0.61[0.1]b	0.59[0.1]ab	0.54[0.1]ab	0.55[0.1]ab	<0.001
Richness	13.6[3.4]a	14.9[4.8]a	16.4[3.6]a	12.5[4.3]a	14.1[2.7]a	14.0[2.5]a	11.6[3.1]a	0.159
Stand Age	43.7[12.5]ab	36.3[7.0]a	69.3[41.9]ab	120.8[62.0]b	36.7[12.9]a	29.2[17.5]a	46.6[12.4]ab	<0.001
Number of samples	11	7	8	12	8	14	9	

* Constancy classes: + [0-5%]; 1 [6-15%]; 2 [16-25%]; 3 [26-35%]; 4 [36-45%]; 5 [46-55%]; 6 [56-65%]; 7 [66-75%]; 8 [76-85%]; 9 [86-95%]; and 10 [96-100%].

† Letters denote the result of Scheffé rank test at the α 0.05 level, different letters by variable indicate which vegetation types differ significantly from each other.

materials were lacustrine and moraine deposits. Humus forms were leptomoder or did not occur. Soils were Eluviated Eutric Brunisol and Solonetzic Gray Luvisol.

Picea glauca/Salix glauca/Shepherdia canadensis vegetation type (B1)

This evergreen forest type was of intermediate height and had an open canopy (Photograph 1b). *Picea glauca/Salix glauca/Shepherdia canadensis* vegetation represented 12% of the study area (Table 2). The *Picea glauca* overstory had an average cover of 10%. *Populus tremuloides* was present in the overstory of 29% of plots. Average stand age was 39 years, and tree canopy heights varied from 4–11 m, but averaged 6.1 m (sd 1.9) with an average DBH of 9 cm (sd 3). Tree densities were 2,000 stems/ha. *Salix glauca* was the dominant species in the tall shrub stratum, with a cover of 20% (Table 3). *Shepherdia canadensis* had the greatest cover (7%) in the low shrub and herb stratum. Both *Salix glauca* and *Shepherdia canadensis* had 100% constancy (Table 3). Bryophyte and lichen covers were 14% and 15%, respectively. Richness averaged 15 (sd 5) species per plot, with total cover of 86%. All plots occurred on level ground. Soils were moderately well drained, with mesic moisture and medium nutrient regimes. The most common parent material was lacustrine deposits, the humus forms were rhizomull when they occurred, and the soils were Solonetzic Gray Luvisols.

Picea glauca//Arctostaphylos uva-ursi–Linnaea borealis vegetation type (B2)

This vegetation was an intermediate height, open-canopied evergreen forest type that represented 7% of the study area (Photograph 1c). The *Picea glauca//Arctostaphylos uva-ursi–Linnaea borealis* vegetation type typically occurred north of the Alaska Highway (Figure 4). *Picea glauca* in the overstory had an average cover of 23%, and averaged 7.6 m (sd 3.2) in height, with DBH of 11 cm (sd 4). Tree densities were similar to the *Picea glauca/Salix glauca/Shepherdia canadensis* type with 2,050 stems/ha. Stand ages ranged from 26–123 years. Three of the seven stands predated the 1958 fire. *Picea glauca* was the only species commonly found in the tall shrub stratum. *Arctostaphylos uva-ursi* occurred in all plots, with an average cover of ~30%. Other high constancy species in the low shrub and herb stratum were *Linnaea borealis* (8% cover), *Rosa acicularis* (6%), and *Shepherdia canadensis* (4%). Bryophyte cover was 2% and lichen cover was 6%. This vegetation type had richness of 16 (sd 4) species per plot. Total species cover was 80%. All but one plot occurred on slopes with inclines of 5–37%, unlike *Picea glauca/Salix glauca/Shepherdia canadensis* stands, which were all level. Soils were moderately well drained with medium nutrient regimes and mesic moisture regimes. Eluviated Eutric Brunisol soils formed over lacustrine parent material and the humus form was hemimor.

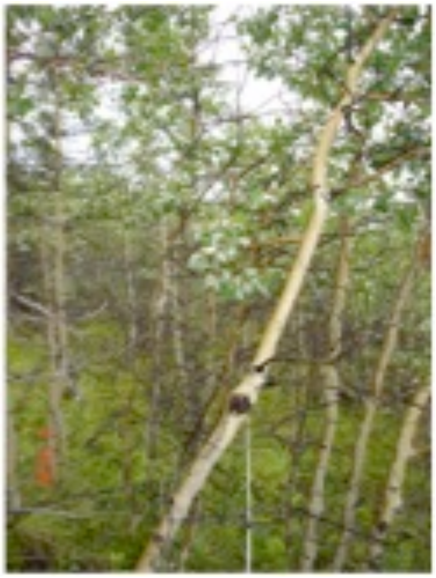
Picea glauca//Hylocomium splendens (B3)

This vegetation was the densest of the evergreen forest types, with an open canopy, and an intermediate height (Photograph 1d); and represented 8% of the study area (Table 2). Stands of the *Picea glauca*//*Hylocomium splendens* vegetation type occurred mainly in the western portion of the study area (Figure 4). *Picea glauca* canopy cover was 32%, with 100% constancy. Average tree height was 14 m (sd 16.4) with 17 cm (sd 13) DBH. Average stand age was 121 years, but ranged from 35–286 years. Tree densities varied from 1,230–12,860 stems/ha, but averaged 4,760 stems/ha. Within the tall shrub stratum *Populus tremuloides* occurred in 33% of plots. *Hylocomium splendens* was the only species other than *Picea glauca* with 100% constancy, and had an average cover of 51%; the greatest of any species among the 12 vegetation types (Tables 3 and 4). In the ground stratum, *Peltigera apathosa* had 75% constancy with 2% cover. This was the only type where either a lichen or bryophyte was a high constancy species. The dominance concentration was 0.61, significantly different than the other treed types except *Picea glauca/Salix glauca/Shepherdia canadensis*, and the greatest of all 12 vegetation types. Average species richness was 12 (sd 4) per plot and total cover was 106%. Half of the plots were on level terrain, and the others were on surfaces inclined 3–55%, all northfacing. Inclined and level sites were a mixture of imperfectly to moderately well drained soils, poor to medium nutrient regimes, and moisture regimes that were mesic to subhygric. Glacial moraine was common on inclines, and lacustrine deposits on level terrain. The common humus form was hemimor and the soils were Brunisolic Gray Luvisols.

Populus tremuloides//Arctostaphylos uva-ursi vegetation type (C1)

This vegetation was an open-canopied, deciduous forest type of intermediate height that occupied 9% of the study area (Photograph 2a; Table 2). *Populus tremuloides//Arctostaphylos uva-ursi* vegetation occurred through the central portions of the study area, and along the bank of the Takhini River (Figure 4). *Populus tremuloides* was the dominant overstory species and had 11% cover. Average tree height was 5.7 m (sd 1.8) and the DBH was 8 cm (sd 2). Stand ages averaged 46 years, and ranged from 21 to 69 years. Tree densities were 2,980 stems/ha, the least of the *Populus tremuloides* vegetation types. *Populus tremuloides* <2.5 m tall occurred in all but one of height plots. The most important species in the low shrub and herb stratum was *Arctostaphylos uva-ursi*, with 47% canopy cover and 100% constancy. Other high constancy species were *Rosa acicularis* (7% cover), *Calamagrostis purpurascens* (6%), *Anemone multifida* (2%), and *Achillea millefolium* (<1%). No bryophytes were present in this type and average lichen cover was 0.6%, the least of the treed types (Table 3). These plots had the fewest species of the treed vegetation types (12 sd 3 per plot). Total species cover was 96%. Half of the plots were on level terrain, and the others were on east to southeast inclines (7–38%). Soils were moderately well drained, nutrient regimes were medium, and moisture regimes were typically mesic. The most common parent materials were lacustrine deposits. The humus layer was absent on level sites, and leptomoder or mormoder formed on the inclined surfaces. Soils were classified as Brunisolic Gray Luvisols.

(a)



(b)

(c)

Photograph 2. A representative example looking along the 30-m transect through a vegetation sampling plot (a) *Populus tremuloides//Arctostaphylos uva-ursi*. (b*) Populus tremuloides/Shepherdia canadensis–Rosa acicularis*, and (c) *Populus tremuloides/Rosa acicularis–Arctostaphylos uva-urs*i treed vegetation types.

Populus tremuloides/Shepherdia canadensis–Rosa acicularis vegetation type (C2)

This vegetation, a deciduous forest of intermediate height with an open canopy (Photograph 2b), was the most extensive type (17%) in the study area (Table 2). It often occurred over large areas in the eastern and western portions of the study area (Figure 4). *Populus tremuloides* was the dominant tree species and formed 34% cover. They also represented the tallest (6.6 m, sd 2.6) and largest (9 cm sd 3 DBH) *Populus tremuloides* in the study area. Average stand age was 37 years, with ages ranging from 12–57 years. This vegetation type had the second greatest tree densities at 3,870 stems/ha. Like the previous type, *Populus tremuloides* was typically present in the tall shrub stratum, as was *Picea glauca*. Species with high constancy in the herb stratum included *Shepherdia canadensis* (16% cover), *Rosa acicularis* (10%), *Chamerion angustifolium* (3%), and *Anemone multifida* (1%). Bryophyte and lichen cover were <1% and 3%, respectively. Average species richness was 14 (sd 3) and total species cover was 83%. Five of the 14 plots occurred on level terrain, whereas the rest were on slopes inclined 6–22%. Soil conditions were similar on both inclined and level surfaces with moderately well drained, medium nutrient regimes, and mesic moisture regimes. Parent materials were lacustrine deposits, with Solonetzic Gray Luvisols and Eluviated Eutric Brunisol soils, and leptomoder humus.

Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi vegetation type (C3)

This vegetation was of intermediate height, had a closed canopy (Photograph 2c), and was a deciduous forest type that occupied 15% of the study area (Table 2). *Populus* *tremuloides* averaged 38% cover and was the dominant tree species. This vegetation had the greatest percentage of species cover (109%) of the treed types (Table 3), and also had the greatest tree densities (3,990 trees/ha). Average tree height was 5.7 m (sd 2.2) and average DBH was 7 cm (sd 2). Average stand age was 29 years and ranged from 25–47 years. Within the tall shrub stratum, *Populus tremuloides* occurred in 66% of the plots. *Rosa acicularis* and *Arctostaphylos uva-ursi* had 100% constancy within the low shrub and herb stratum and both had ~20% cover. Other high constancy species in the herb stratum included *Shepherdia canadensis* (5% cover), *Chamerion angustifolium* (2%), *Anemone multifida* (1% cover), and *Achillea millefolium* (1%). This and the *Populus tremuloides/ Shepherdia canadensis–Rosa acicularis* vegetation type shared a similar species composition and level of species richness, but they differed in the total canopy cover (Table 3). *Rosa acicularis* had 10% more cover in this vegetation type compared to the previous, whereas *Shepherdia canadensis* had 10% less cover. *Arctostaphylos uva-ursi* was more abundant than in the *Populus tremuloides/Shepherdia canadensis–Rosa acicularis* vegetation type (Table 3). Bryophyte and lichen cover were each <1%. Two of the plots were on level terrain; the remaining seven were on inclined 5–35% slopes, with west to southwest aspects. Soils were moderately well drained with medium nutrient regimes and mesic moisture regimes. The most common parent materials were lacustrine, but some moraine deposits occurred. Soils on lacustrine deposits had drier moisture regimes, but the same type of soil drainage (moderately well) and nutrient regime (medium), as the soils over moraine deposits. Humus forms were leptomoder and hemimor and soils were Solonetzic Gray Luvisols and Eluviated Eutric Brunisols.

Nontreed Vegetation Types

A cluster analysis containing only nontreed plots formed five groupings (Figure 5). The percent chaining within this cluster classification was 2%. The percent grouping error was 45% at the break-point (Figure 5). Group D1 had the least grouping error. No plots were excluded or moved between groups for the final analysis. The following provides a description of each of the vegetation types identified from the cluster analysis.

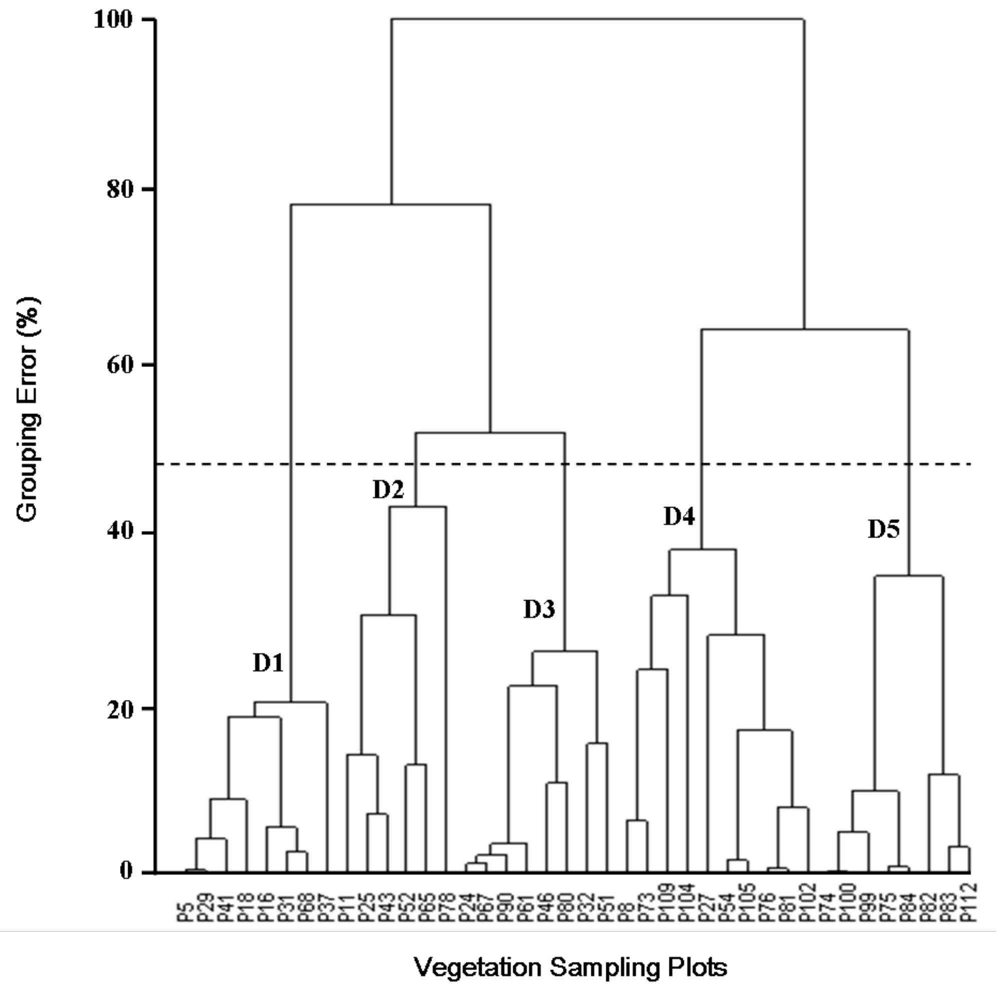


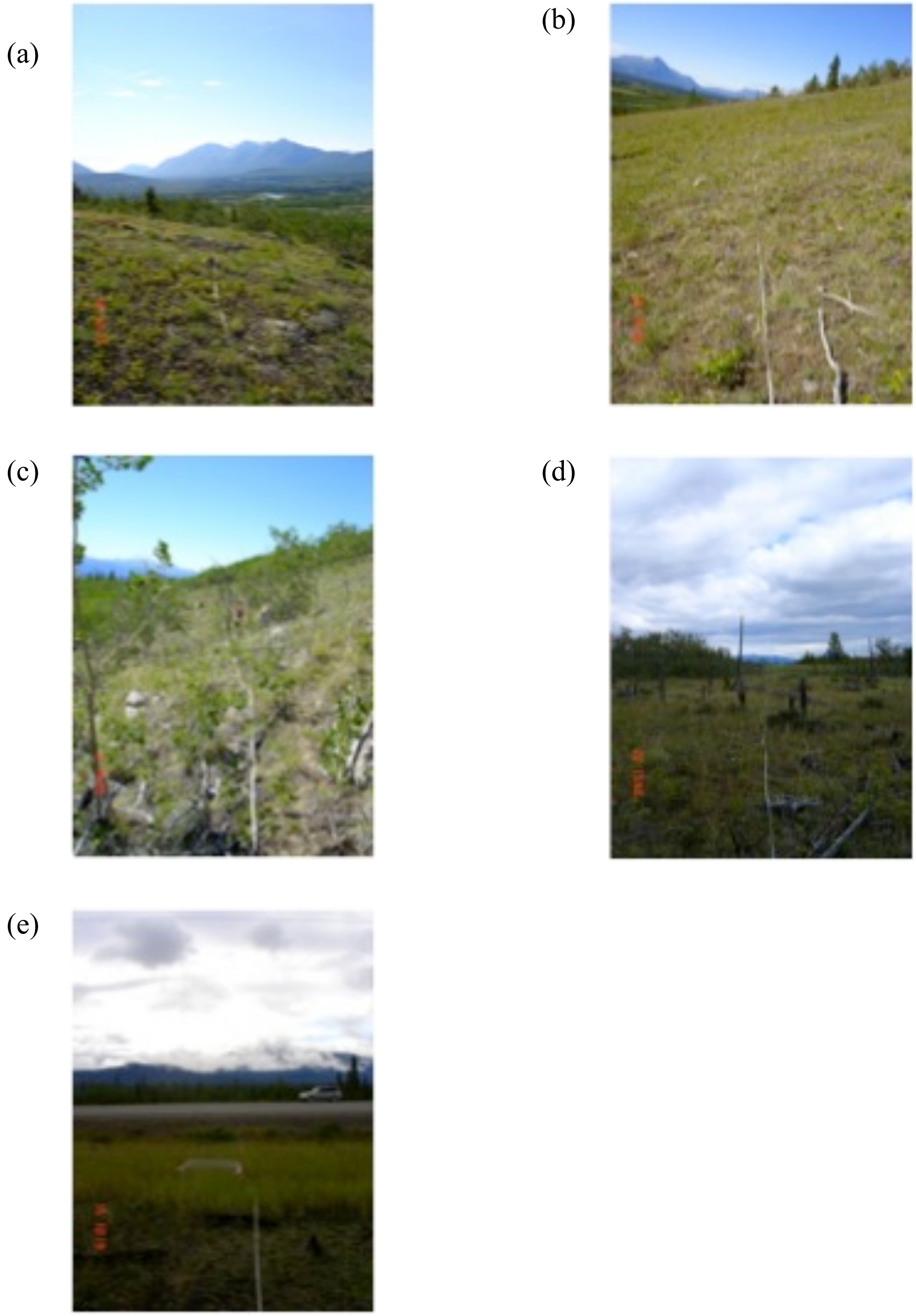
Figure 5. Cluster analysis of nontreed vegetation sampling plots based on species composition and abundance within the Takhini Valley study area. The dashed line indicates the break-point among groups.

Carex duriuscula–Artemisia frigida vegetation type (D1)

This open (25–60% cover), low (0.2–1 m) graminoid vegetation type (Photograph 3a) comprised 7% of the study area (Table 2). *Carex duriuscula* and *Artemisia frigida* both had 100% constancy; with average covers of 6% and 10%, respectively. *Calamagrostis purpurascens* (5% cover) and *Anemone multifida* (1%) had high constancies. No bryophytes occurred and lichen cover was sparse (2%). Species richness ranged from 5 to 22 with an average of 12 (sd 5). Total species cover was 51% (Table 4). Dominance concentration was 0.48, similar to those of the other nontreed types which, ranged from 0.48 to 0.52. Two of the plots were on level terrain and the others occurred on steep southfacing slopes (30–38% incline). Soils were moderately well to rapidly drained, nutrient regimes were medium, and moisture regimes were submesic (sloping sites) to mesic. The most common parent materials were lacustrine and moraine deposits. Inclined sites had no humus layer; level sites developed leptomoders. The associated soils were Eluviated Eutric Brunisols and Orthic Regosols.

Carex supina vegetation type (D2)

This low-growing, open graminoid vegetation type (Photograph 3b) represented 3% of the study area (Table 2). *Carex supina* had 100% constancy and was the species with the greatest cover (22%) in this vegetation type. *Anemone multifida* and *Achillea millefolium* also had 100% constancy, but <4% cover. Other high constancy species included *Calamagrostis purpurascens* (6% cover) and *Erysimum cherianthoides* (2%).



Photograph 3. A representative example of (a) *Carex duriuscula–Artemisia frigida*, (b) *Carex supina*, (c) *Calamagrostis purpurascens*, (d) *Rosa acicularis–Fragaria virginiana*, and (e) *Bromus inermis–Rosa acicularis–Achillea millefolium* nontreed vegetation types.

Table 4. Plant species composition and characteristics of nontreed vegetation types within the Takhini Valley study area, southwestern Yukon. Mean percent cover values for vegetation types were compared using Kruskal-Wallis tests and differences were identified using Scheffé rank tests. Species values underlined have a high (>75%) constancy, and a cover value >2%.

	Vegetation Type					
Variables	*Carex duriuscula–Artemisia frigida*	*Carex supina*	*Calamagrostis purpurascens*	*Rosa acicularis–Fragaria virginiana*	*Bromus inermis–Rosa acicularis– Achillea millefolium*	*P*
	Percent cover[standard deviation]constancy class*					
Trees						
Populus tremuloides	0.3[0.7]1a[†]	0.4[0.9]2a	1.5[2.7]4a	0.8[1.9]3a	2.0[3.3]4a	0.580
Picea glauca	0a	0a	0.1[0.2]1a	0.5[1.6]2a	0.2[0.7]2a	0.551
Pinus contorta	0a	0a	0.1[0.2]1a	0a	0a	0.406
Shrubs						
Arctostaphylos uva-ursi	3.0[6.2]4a	2.1[2.9]4a	4.4[5.7]6a	1.8[3.0]4a	0.4[0.9]3a	1.000
Juniperus communis	0a	0a	0a	0.1[0.4]1a	0a	0.558
Juniperus horizontalis	2.0[5.7]1a	0.4[0.9]2a	+[0.1]1a	0.7[1.8]2a	0a	0.732
Rosa acicularis	2.2[2.7]6a	5.2[6.8]6a	4.1[4.0]9a	10.6[8.0]10a	6.6[5.7]9a	0.066
Salix bebbiana	0a	0a	0.1[0.4]1a	0a	0a	0.406
Salix glauca	0a	0a	0a	0.1[0.3]1a	+[+]1a	0.686
Shepherdia canadensis	0a	0.9[2.1]2a	1.4[2.2]4a	1.7[5.4]1a	0.3[0.4]3a	0.326
Forbs						
Achillea millefolium	0.8[1.6]5a	3.2[5.0]10a	1.2[1.0]9a	1.4[1.2]10a	2.8[2.5]10a	0.091
Androsace spetentrionalis	0.2[0.4]4a	0.1[0.2]4a	0.1[0.1]5a	+[+]1a	+[0.1]2a	0.388
Anemone multifida	1.2[1.4]7a	1.9[0.5]10a	1.7[1.8]9a	2.4[1.7]10a	0.7[0.5]8a	0.027
Antennaria microphylla	0.1[0.2]1a	0.3[0.4]6a	+[+]2a	0.2[0.3]3a	0.2[0.6]2a	0.440
Antennaria rosea	0a	0.1[0.1]2a	0a	0a	0a	0.136
Arabis holboellii	+[+]2a	0a	0a	0a	0a	0.084
Arabis drummondii	0a	0a	0a	0.2[0.7]1a	0a	0.558
Arabis hirsute	0a	0.1[0.3]2a	0a	0a	0a	0.136
Artemisia campestris	0a	0a	0a	0a	0.2[0.6]1a	0.486
Artemisia frigida	6.1[5.5]10b	1.8[1.6]8ab	1.4[1.7]5ab	0a	0a	<0.001
Aster sibiricus	0a	0a	0a	1.0[2.8]2a	+[+]1a	0.387
Astragalus alpinus	0a	0.3[0.8]2a	0a	0a	0a	0.136
Astragalus bodinii	0a	0a	0a	+[0.1]1a	0a	0.558
Astragalus bodinii	0a	0a	0a	+[0.1]1a	0a	0.558

Table 4. Continued.

Variables	Carex duriuscula–Artemisia frigida	Carex supina	Calamagrostis purpurascens	Rosa acicularis–Fragaria virginiana	Bromus inermis–Rosa acicularis– Achillea millefolium	P
	Vegetation Type					
	Percent cover[standard deviation]constancy class*					
Chamaerhodos erecta	0.1[0.4]1a	0a	0a	0a	0a	0.406
Chamerion angustifolium	+[+]1a	0.1[0.3]2a	0.7[1.4]6a	0.7[0.7]7a	0.4[0.9]2a	0.053
Erigeron compositus	0.4[0.9]2a	0a	+[+]1a	0a	0a	0.215
Erysimum cheiranthoides	0a	0.1[0.2]8a	+[0.1]1a	0.1[0.1]4a	+[+]1a	0.013
Fragaria virginiana	0a	1.1[2.5]2a	1.0[1.9]4a	14.0[6.2]10b	3.7[5.0]7ab	<0.001
Galium circaezans	0.1[0.1]2a	1.5[1.6]6a	0.8[0.9]6a	0.6[0.6]8a	0.1[0.3]3a	0.056
Gentianella propinqua	+[0.1]1a	0a	0a	0a	0a	0.406
Geum aleppicum	0a	0a	0.1[0.4]1a	0a	0a	0.406
Hedysarum alpinum	0a	0a	0a	0.3[0.8]2a	0.7[2.0]2a	0.309
Helictotrichon hookeri	0a	0.6[1.3]2a	0a	0a	0a	0.136
Lappula squarrosa	+[+]2a	0a	0.1[0.1]1a	+[+]1a	0a	0.493
Linnaea borealis	0a	0a	+[+]1a	0a	0a	0.406
Linum lewisii	0.2[0.5]1a	0.9[0.9]6a	0.1[0.1]2a	+[0.1]3a	0.3[0.7]3a	0.301
Minuartia rubella	0.1[0.2]1a	0a	0a	0a	0a	0.406
Oxytropis deflexa	0a	0a	0a	0.6[1.8]1a	1.1[2.3]2a	0.345
Oxytropis borealis	0.3[0.8]1a	0a	0a	0a	0a	0.406
Packera paupercula	0a	0.1[0.1]4a	0.4[0.7]2a	1.0[1.4]5a	0.6[1.1]6a	0.129
Penstemon gormanii	0.9[1.3]5a	1.8[4.0]2a	0.9[1.5]4a	0a	0a	0.044
Penstemon procerus	1.0[1.8]2a	3.9[6.0]4a	0a	1.2[1.9]4a	0a	0.093
Polemonium pulcherrimum	0a	0a	0a	0.1[0.1]2a	0a	0.188
Potentilla hookeriana	0.1[0.1]1a	0a	0a	0a	0a	0.406
Potentilla pensylvanica	0.8[0.9]6a	0.3[0.5]4a	0.1[0.2]1a	0.2[0.6]2a	0.1[0.3]2a	0.133
Saxifraga tricuspidata	0.6[1.6]2a	0a	+[0.1]1a	0.4[1.3]1a	0a	0.457
Sedum lanceolatum	0a	0a	+[0.1]1a	0a	0a	0.406
Senecio strepthanfollius	0a	+[0.1]2a	0a	0.6[1.3]2a	0a	0.261
Solidago simplex	0.1[0.2]2a	0a	0a	0a	0a	0.084
Stellaria longipes	0a	0.1[0.1]2a	+[0.1]2a	0.2[0.3]3a	0a	0.250
Taraxacum officinale	0a	0a	0a	0.4[0.8]2a	+[+]1a	0.387

Table 4. Continued.

Variables	Carex duriuscula–Artemisia frigida	Carex supina	Calamagrostis purpurascens	Rosa acicularis–Fragaria virginiana	Bromus inermis–Rosa acicularis– Achillea millefolium	*P*
	Vegetation Type					
	Percent cover[standard deviation]constancy class*					
Graminoids						
Bromus inermis	0a	0a	1.5[4.2]1a	2.3[4.5]3a	18.6[7.3]10b	<0.001
Bromus pumpellianus	0a	0.5[0.7]6a	0.1[0.2]2a	0.6[0.8]5a	0a	0.015
Calamagrostis purpurascens	5.1[4.7]9ab	6.0[5.4]8ab	18.0[9.4]10b	1.3[2.1]4a	1.4[2.0]4a	<0.001
Carex concinna	0.1[0.3]2a	+[0.1]2a	0.1[0.2]2a	0.1[0.3]1a	0a	0.571
Carex rossii	0a	0a	0a	0a	+[0.1]1a	0.486
Carex duriuscula	21.4[9.7]10b	0.1[0.1]2ab	0.6[1.1]4ab	0.1[0.4]1a	0a	<0.001
Carex supina	1.3[1.5]6ab	21.7[14.1]10b	0.2[0.4]2a	0.2[0.5]1a	0a	<0.001
Carex tahoensis	0a	0.1[0.3]2a	0a	0.1[0.2]1a	0a	0.392
Elymus calderi	0.3[0.8]1a	0a	0a	0a	0a	0.406
Elymus trachycaulus	0a	0a	0.1[0.4]1a	0.7[1.3]3a	0.9[1.5]3a	0.217
Festuca brachyphylla	0.1[0.2]1a	0a	0.1[0.2]1a	0.6[1.8]1a	0.2[0.5]1a	0.960
Festuca saximontana	0a	0.1[0.2]2a	0.8[1.4]4a	1.8[3.9]2a	0.2[0.6]1a	0.416
Hordeum jubatum	0a	0a	0a	+[0.1]1a	+[0.1]1a	0.684
Juncus balticus	0.1[0.2]1a	6.4[13.6]4a	0a	0a	0a	0.037
Poa glauca	0.5[0.8]4a	0.1[0.3]2a	0.4[0.7]2a	0.8[1.7]4a	0.2[0.5]1a	0.615
Poa palustris	0a	0a	0a	0a	0.3[0.7]2a	0.132
Poa secunda	0.1[0.2]1a	0.2[0.4]2a	0a	0a	0a	0.320
Stipa nelsonii	0a	0a	0.1[0.3]1a	0a	0a	0.406
Trisetum spicatum	0a	0a	0a	0.5[1.0]2a	0a	0.188
Lichens						
Cetraria icelandica	0.1[0.4]1a	0a	+[0.1]1a	0a	0a	0.545
Cladonia pyxidata	0a	0a	+[0.1]1a	0.1[0.3]1a	0a	0.637
Cladonia ssp.	0a	0a	0a	0.4[1.3]1a	0a	0.558
Flaviocetraria nivalis	0.1[0.4]1a	0a	0a	0a	0a	0.406
Peltigera canina	0a	0a	0a	0a	0.1[0.3]1a	0.486
Peltigera ponojensis	0a	0a	0a	0.3[0.8]2a	0a	0.188
Peltigera rufescens	0a	0.4[0.9]2a	0.4[0.8]2a	0.5[0.7]4a	0a	0.133
Physconia muscigenia	+[0.1]1a	0a	0a	0a	0a	0.406
Xanthoparmelia chlorochroa	1.4[2.0]4a	0a	0a	0a	0a	0.130

Table 4. Concluded.

Variables	Carex duriuscula–Artemisia frigida	Carex supina	Calamagrostis purpurascens	Rosa acicularis–Fragaria virginiana	Bromus inermis–Rosa acicularis– Achillea millefolium	P
			Vegetation Type			
			Percent cover[standard deviation]constancy class*			
Bryophytes						
Brachythecium salebrosum	0a	0a	0a	1.0[2.3]2a	1.0[2.0]2a	0.309
Bryum caespitosum	0a	0a	0a	0a	+[0.1]1a	0.486
Ceratodon purpureus	0a	0a	0a	0a	0.2[0.7]1a	0.486
Dicranum acutifolium	0a	0a	0a	+[0.1]1a	0.6[1.7]1a	0.682
Dicranum elongatum	0a	0a	0.1[0.4]1a	0a	0a	0.406
Hypnum cupressiforme	0a	0a	0a	0.1[0.3]1a	0a	0.558
Leptobryum pyriforme	0a	0a	0a	0a	0.4[1.3]1a	0.486
Stand Characteristics						
Total Species Cover	51.1[12.1]a	63.4[21.8]a	42.7[9.5]a	53.2[15.5]a	46.0[10.9]a	0.280
Total Tree Cover	0.3[0.7]a	0.4[0.9]a	1.7[2.7]a	1.4[3.5]a	2.2[3.2]a	0.190
Total Salix Cover	+[+]a	+[+]a	0.1[0.4]a	0.1[0.3]a	+[+]a	0.815
Total Shrub Cover	2.2[2.7]a	6.1[8.8]a	5.5[4.3]a	12.3[10.0]a	6.8[5.8]a	0.060
Total Forb Cover	47.0[12.2]a	56.5[25.2]a	34.9[9.5]a	37.1[11.7]a	34.6[8.5]a	0.067
Total Graminoid Cover	29.0[8.7]b	35.4[25.2]b	22.0[9.0]ab	9.0[4.5]b	21.9[6.6]ab	<0.001
Total Bryophyte Cover	+[+]a	+[+]a	0.1[0.4]a	1.1[2.3]a	2.3[2.7]a	0.069
Total Lichen Cover	1.6[1.8]a	0.4[0.9]a	0.4[0.8]a	1.3[2.4]a	0.1[0.3]a	0.075
			Mean[standard deviation]			
Dominance Concentration	0.48[0.1]a	0.48[0.1]a	0.52[0.1]a	0.47[0.1]a	0.49{0.1]a	0.920
Richness	12.1[4.9]a	14.0[3.3]a	13.4[1.8]a	15.0[3.1]a	11.2[3.0]a	0.127
Number of samples	8	5	5	10	9	

* Constancy classes: + [0-5%]; 1 [6-15%]; 2 [16-25%]; 3 [26-35%]; 4 [36-45%]; 5 [46-55%]; 6 [56-65%]; 7 [66-75%]; 8 [76-85%]; 9 [86-95%]; and 10 [96-100%].

† Letters denote the result of Scheffé rank test at the α 0.05 level, different letters by variable indicate which vegetation types differ significantly from each other.

This vegetation type had the greatest average graminoid percent cover (35%) of the 12 vegetation types. No bryophytes occurred and average lichen cover was <1%. The average species richness was 14 (sd 3) and total cover was 63% (Table 4). Three of the five plots occurred on inclined southfacing surfaces in the western half of the study area, and two were on level terrain in the eastern portion of the study area (Figure 5). Soils were well drained with medium nutrient and mesic moisture regimes. The most common parent materials were lacustrine deposits. Humus layers were not present and the soils were Eutric Brunisols.

Calamagrostis purpurascens vegetation type (D3)

Calamagrostis purpurascens was a low-growing, open graminoid vegetation type (Photograph 3c) that occupied 5% of the study area (Table 2), typically on southfacing slopes. *Calamagrostis purpurascens* had an average cover of 18% and was the only species with 100% constancy (Table 4). *Rosa acicularis*, *Anemone multifida*, and *Achillea millefolium* had 88% constancy. Of these species, only *Rosa acicularis* had average cover >2%. Both bryophyte and lichen cover were <1%. Average species richness was 13 (sd 2). Total species cover was 43%, the majority of the ground surface was exposed soil or rock. Most plots occurred on south to southwest facing slopes with inclines of 5–38%. Plots on lacustrine deposits had more rapidly drained soil than those on moraine. The most common nutrient regime category was medium and the moisture regime was mesic. Humus forms, when present, were leptomoder and the soils were Eluviated Eutric Brunisols and Cumulic Regosols.

<u>*Rosa acicularis–Fragaria virginiana* vegetation type</u>

This open low-growing deciduous shrub vegetation type (Photograph 3d) covered 4% of the study area (Table 2). It was typically, interspersed among *Populus tremuloides* vegetation types south of the Alaska Highway, and on the power line right-of-way north of the Highway (Figure 4). *Fragaria virginiana* and *Rosa acicularis* were the dominant species with 14% and 11% cover, respectively. Two other species (*Anemone multifida* and *Achillea millefolium*) also had 100% constancy, but <2.5% cover. Average bryophyte and lichen cover were each <2%. Average species richness was 15 (sd 3) and total cover was 53% (Table 4). One plot was on a 32% incline, but nine occurred on level sites. Soils were moderately well drained with medium nutrient and mesic moisture regimes. The most common parent materials were lacustrine deposits. A rhizomull humus layer was present on three of the sites, and hemmior occurred on the remainder. Soil subgroups were Orthic Eutric Brunisols and Solonetzic Gray Luvisols.

<u>*Bromus inermis–Rosa acicularis–Achillea millefolium* vegetation type</u>

The *Bromus inermis–Rosa acicularis–Achillea millefolium* vegetation type was an open, low-growing mixed herb and shrub type composed of mainly introduced and disturbance tolerant species (Photograph 3e; Figure 4), and formed 1% of the total study area (Table 2). *Bromus inermis* had 100% constancy and averaged 19% cover. Two other high constancy species had cover values of 7% (*Rosa acicularis*) and 3% (*Achillea millefolium*). Average bryophyte and lichen cover values were <2%. This vegetation occurred along the Alaska Highway and followed a distinct pattern. The cleared right-of-way began 30 m from the edge of the highway, where there was 1–2 m of tree canopy cover (*Populus tremuloides* or *Picea glauca*), followed by 5–15 m of mixed forb and graminoid vegetation approaching the highway, and a 10–15 m strip of *Bromus inermis* immediately adjacent to the highway edge. Often an all-terrain vehicle path bisected the highway right-of-way with a 2 m disturbance zone. Average species richness was 11 (sd 3) and total cover was 46% (Table 4). The plots were all located on level ground. Soils were moderately well drained with medium nutrient regimes. The most common parent materials were lacustrine deposits. Humus layers were not present, and the soils furthest from the highway within the right-of-way were Eluviated Eutric Brunisols and Solonetzic Gray Luvisols. Soils closer to the highway had been excavated and were Orthic Regosols.

Other landscape types

Three anthropogenic landscape types occurred within the Takhini Valley study area; these were farmland, disturbances, and eroding slopes (Figure 4). A large bison (*Bison bison*) farm formed most of the farmland type. Other disturbances included a small housing subdivision, three gravel pits, and a communication tower site.

Ordination

Detrended correspondence analysis was used to illustrate the relative compositional relationships among vegetation types and to investigate their associated species patterns and site conditions (Figure 6). The ordination of treed plots (n = 69)

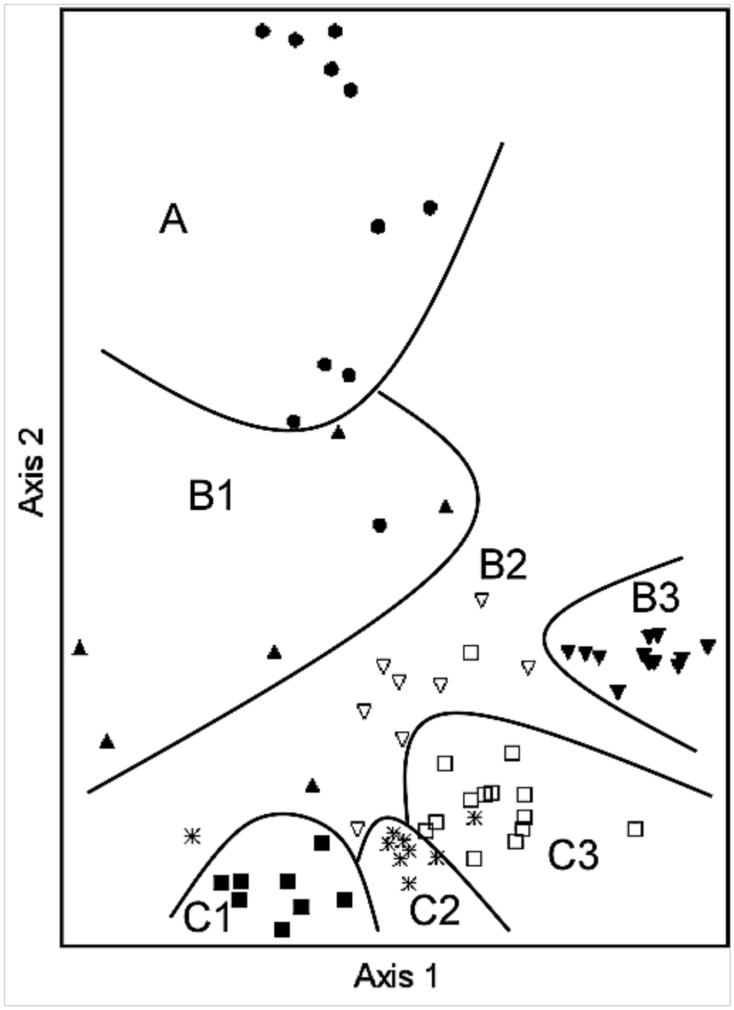


Figure 6. Detrended Correspondence Analysis of treed vegetation plots based on species composition and abundance: A – *Pinus contorta//Calamagrostis purpurascens–Linnaea borealis*; B1 – *Picea glauca/Salix glauca/Shepherdia canadensis*; B2 – *Picea glauca//Arctostaphylos uva-ursi–Linnaea borealis*; B3 – *Picea glauca//Hylocomium splendens*; C1 – *Populus tremuloides//Arctostaphylos uva-ursi*; C2 – *Populus tremuloides/Shepherdia canadensis–Rosa acicularis*; and C3 – *Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi* vegetation types.

resulted in spatially distinct groups of plots. Plot 79, a member of the *Picea glauca*/*Salix glauca*/*Shepherdia canadensis* vegetation type, was excluded from the ordination and subsequent analyses, because it was an extreme outlier. Axis 1 explained the most (22%) variance in plot distributions within the ordination. The second axis explained an additional 7% of the variation. *Populus tremuloides* was the dominant tree in the C groups that occurred along the bottom of axis 2, with the *Picea glauca* types (B) adjacent, and the *Pinus contorta* vegetation type (A) at the top left corner of the ordination (Figure 6). The *Picea glauca* vegetation types formed a compositional gradient in the ordination, *Picea glauca/Salix glauca/Shepherdia canadensis* to the left of axis 1, *Picea glauca//Calamagrostis purpurascens–Linnaea borealis* in the middle, and *Picea glauca//Hylocomium splendens*, the probable climax vegetation type on upland sites at the far right (Figure 6).

Stand age was strongly correlated with axis 1, as was total bryophyte cover. The vegetation type with the oldest stands and the greatest amount of bryophyte cover, *Picea glauca//Hylocomium splendens*, was on the far right of axis 1. Conversely, forb and *Salix* ssp. cover were negatively correlated with axis 1, though the only species moderately and negatively correlated with axis 1 was *Salix glauca* (Table 5). Total species cover was weakly and positively correlated to axis 1. Vegetation types B3 (*Picea glauca//Hylocomium splendens*) and C3 (*Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi*) had high species cover within the low shrub and herb stratum.

Table 5. Selected correlations (*r*) between stand characteristics and species, and axis 1 of the treed Detrended Correspondence Analysis ordination, *n* = 69.

Variable	***r***	***P* value**
Hylocomium splendens	0.706	<0.001
Total bryophyte cover	0.631	<0.001
Stand age	0.513	<0.001
Picea glauca	0.512	<0.001
Total tree cover	0.367	0.002
Total species cover	0.291	0.016
Total *Salix* ssp. cover	-0.317	0.008
Salix glauca	-0.384	0.001
Total forb cover	-0.411	<0.001
Arctostaphylos uva-ursi	-0.481	<0.001

Ordination explained 48% of the variance among nontreed plots (*n* = 40), with axis 1 explaining 44% (Figure 7). Axis 2 and axis 3 each explained 2% of the variation. The nontreed plots with large proportions of non-native species occurred furthest to the left in the ordination, whereas those on southfacing slopes (D1, D3), occurred on the right-side. Axis 1 was correlated with *Carex duriuscula* and *Artemisia frigida* abundance, both species with high cover values on southfacing slopes; and inversely correlated with *Rosa acicularis*, *Bromus inermis*, and *Fragaria virginiana* cover, which were species common to disturbed areas (Table 6). Shrub and bryophyte cover were negatively correlated with axis 1, these sites tended to be on level terrain or were within the highway right-of-way, as opposed to on southfacing slopes (Table 6). Forb cover followed the opposite trend, increasing towards the right-hand side of axis 1.

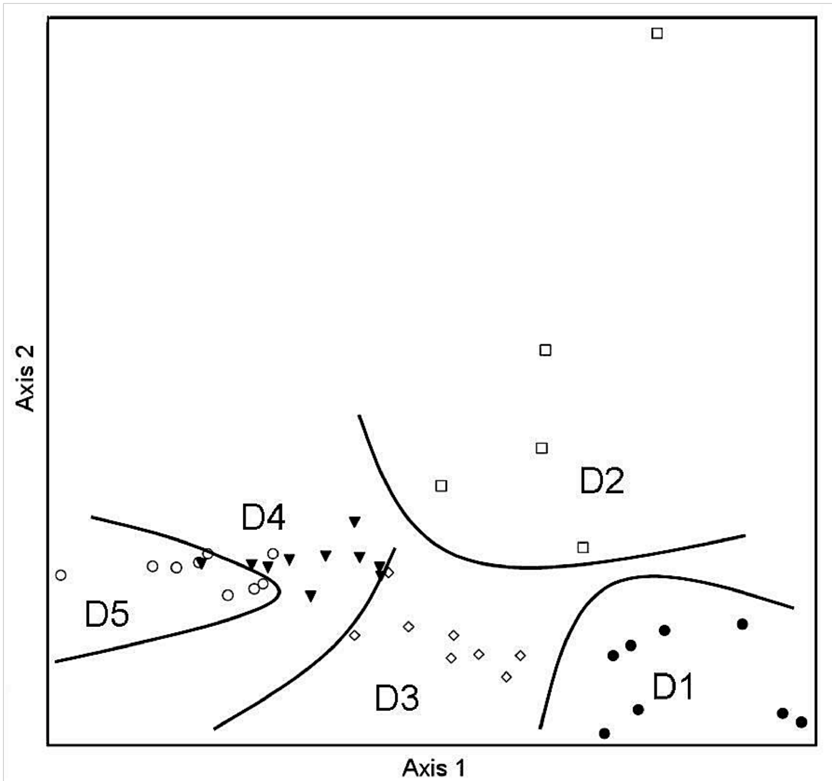


Figure 7. Detrended Correspondence Analysis of nontreed vegetation plots from the study area in the Takhini Valley, based on species composition and abundance D1 – *Carex duriuscula–Artemisia frigida*; D2 – *Carex supina*; D3 – C*alamagrostis purpurascens*; D4 – *Rosa acicularis–Fragaria virginiana*; and D5 – *Bromus inermis–Rosa acicularis–Achillea millefolium* vegetation types.

Table 6. Selected correlations (*r*) between stand characteristics and species, and axis 1 of the nontreed Detrended Correspondence Analysis ordination, *n* = 40.

Variable	***r***	***P* value**
Carex duriuscula	0.715	<0.001
Artemisia frigida	0.691	<0.001
Total forb cover	0.411	0.008
Carex supina	0.325	0.041
Total shrub cover	-0.337	0.033
Rosa acicularis	-0.376	0.017
Total bryophyte cover	-0.441	0.004
Fragaria virginiana	-0.493	0.012
Bromus inermis	-0.676	<0.001

Forage Quantity

Peak fall graminoid, forb, and shrub biomass in the study area totaled an estimated 2,072 tonnes. *Populus tremuloides/Rosa acicularis –Arctostaphylos uva-ursi* produced significantly (P <0.05) more biomass than the *Pinus contorta//Calamagrostis purpurascens–Linnaea borealis* and *Picea glauca/Hylocomium splendens* types (Table 7). Vegetation types with the most biomass tended to be located near the Alaska Highway and occurred on level terrain (Figure 8).

Graminoid biomass availability ranged from 7–499 kg/ha among the 12 vegetation types (Table 7). Graminoid weights were significantly different among tree-dominated vegetation types (P = 0.013; Table 7), but no differences were detected with Scheffé rank tests. The least amount of forb biomass (4 kg/ha) was produced in the *Pinus contorta//Calamagrostis purpurascens–Linnaea borealis* type (Table 7). *Pinus contorta//Calamagrostis purpurascens–Linnaea borealis* vegetation type produced significantly (P <0.001) less forb biomass than the *Populus tremuloides/Shepherdia canadensis–Rosa acicularis* and *Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi* types, with others having intermediate values. Shrub foliage weights differed only between *Picea glauca/Hylocomium splendens* and *Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi* among the treed types. *Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi* vegetation produced the greatest leaf litterfall with 1,697 kg/ha, which was >2.5 times the other two *Populus tremuloides* types (Table 7), though significant differences could not be calculated due to high variability within and among plots within vegetation types.

Table 7. Forage availability by vegetation type. Biomass (kg/ha) of vegetation types was compared using Kruskal-Wallis tests and differences identified using Scheffé rank tests.

Variables	*Pinus contorta// Calamagrostis purpurascens – Linnaea borealis*	*Picea glauca/ Salix glauca/ Shepherdia canadensis*	*Picea glauca// Arctostaphylos uva-ursi – Linnaea borealis*	*Picea glauca// Hylocomium splendens*	*Populus tremuloides// Arctostaphylos uva-ursi*	*Populus tremuloides/ Shepherdia canadensis– Rosa acicularis*	*Populus tremuloides/ Rosa acicularis– Arctostaphylos uva-ursi*	*P*
	Vegetation Type							
	Mean biomass (kg/ha) [standard deviation]							
Graminoid	23[22]a*	4[5]a	7[7]a	14[38]a	69[48]a	56[59]a	63[86]a	0.013
Forb	4[1]a	46[24]ab	30[27]ab	20[13]ab	93[104]ab	57[40]b	124[97]b	<0.001
Shrub	24[28]ab	72[49]ab	43[42]ab	10[12]a	51[31]ab	70[49]ab	251[394]b	0.004
Leaf	-	-	-	-	476a	751a	1259a	<0.001
Total weight without leaves	51[50]a	122[52]ab	80[32]ab	44[35]a	213[117]ab	183[104]ab	438[529]b	<0.001
Total weight with leaves	51[50]	122[52]	80[32]	44[35]	699[117]	934[104]	1697[529]	
Number of Samples	8	4	5	8	5	10	6	

Variables	*Carex duriuscula– Artemisia frigida*	*Carex supina*	*Calamagrostis purpurascens*	*Rosa acicularis– Fragaria virginiana*	*Bromus inermis–Rosa acicularis– Achillea millefolium*†	*P*
	Mean biomass (kg/ha) [standard deviation]					
Graminoid	212[142]ab	215[106]ab	215[131]ab	31[13]a	499[156]b	0.007
Forb	152[53]a	235[31]a	107[79]a	219[57]a	122[49]a	0.037
Shrub	18[30]a	60[88]a	35[39]a	28[11]a	30[21]a	0.813
Total weight	382[87]ab	510[79]ab	358[157]ab	279[77]a	652[115]b	0.010
Number of Samples	4	4	6	3	5	

* Letters denote the result of Scheffé rank test at the α 0.05 level, different letters by variable indicate which vegetation types differ significantly from each other.
† Area of the paved highway excluded from biomass calculations in roadside vegetation types.

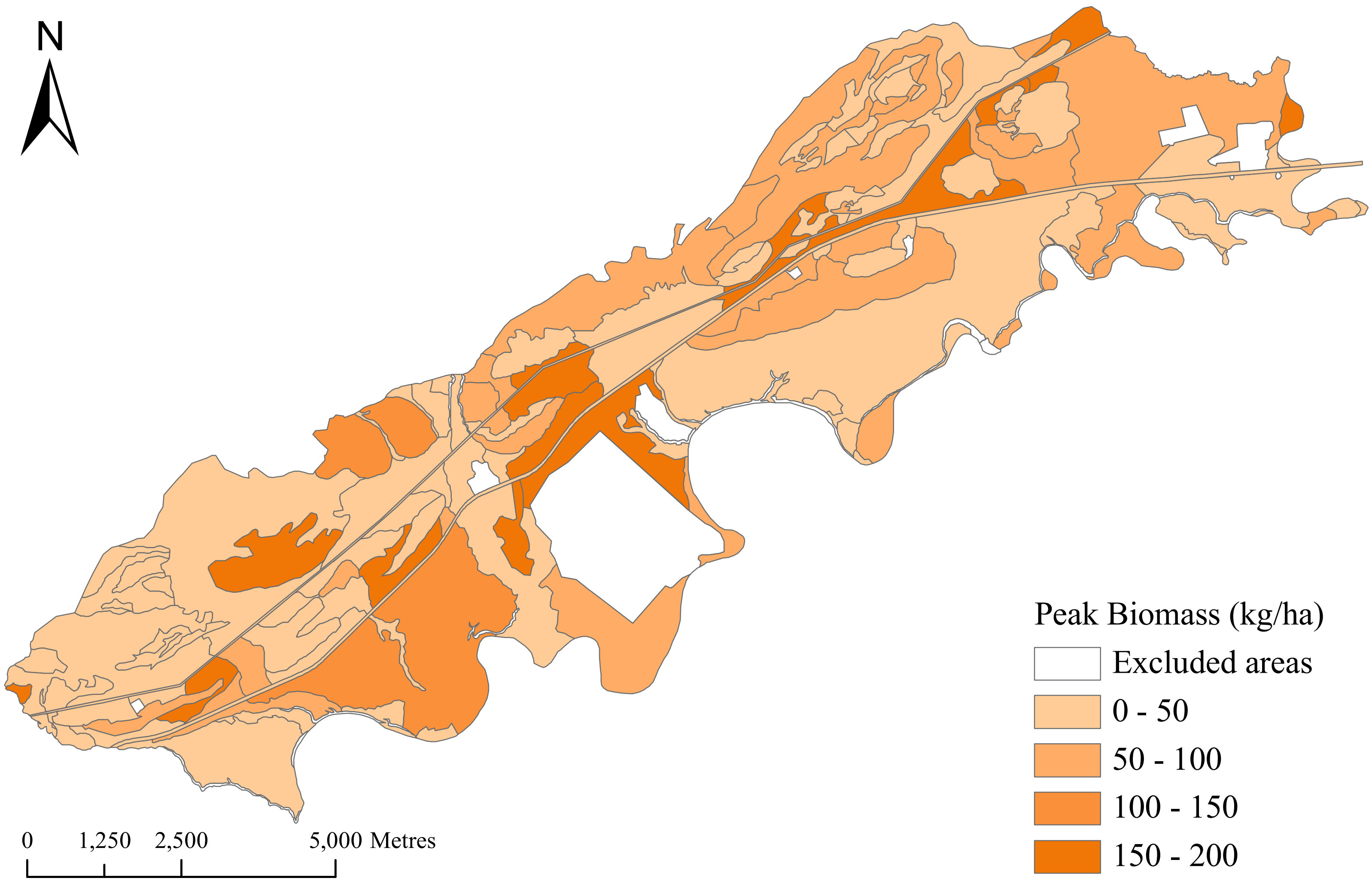


Figure 8. Peak biomass availability by vegetation types within polygons in the Takhini Valley study area, southwestern Yukon. Values are weighted by the proportion of each vegetation type within each polygon.

There were significant differences in graminoid, shrub, and total biomass weights among nontreed vegetation types (Table 7). The *Bromus inermis–Rosa acicularis–Achillea millefolium* vegetation had significantly more graminoid and total dry biomass weight than the *Rosa acicularis–Fragaria virginiana* vegetation type. No difference was identified among the other nontreed types (Table 7).

Graminoid biomass and graminoid cover were strongly and positively correlated (Figure 9). Differences in cover explained 47% of the variance in biomass. Most plots had <40% graminoid cover. Forb cover was also positively, but less strongly correlated with forb biomass, with differences in forb canopy cover explaining 8% of the biomass variance (P = 0.015, n = 67). Shrub biomass was not correlated with shrub cover (P = 0.161, n = 67). No significant difference occurred between exclosure and plot biomass (Wilcoxon rank sum tests, P >0.05) in any of the 12 vegetation types.

A weak negative correlation occurred between peak forage biomass and plot age (Figure 10). Peak biomass was not correlated with *Picea glauca* (P = 0.074, n = 16), *Populus tremuloides* (P = 0.948, n = 19), or *Pinus contorta* (P = 0.736, n = 8) stand age.

Forage Quality

Sixty biomass samples were analyzed for nutrient content: 16 graminoid; 21 forb; and 23 shrub samples. Table 8 summarizes the crude protein, and neutral (NDF) and acid detergent fibre (ADF) contents by vegetation types. Graminoid crude protein differed among vegetation types, but was not differentiated with Scheffé rank tests (Table 8).

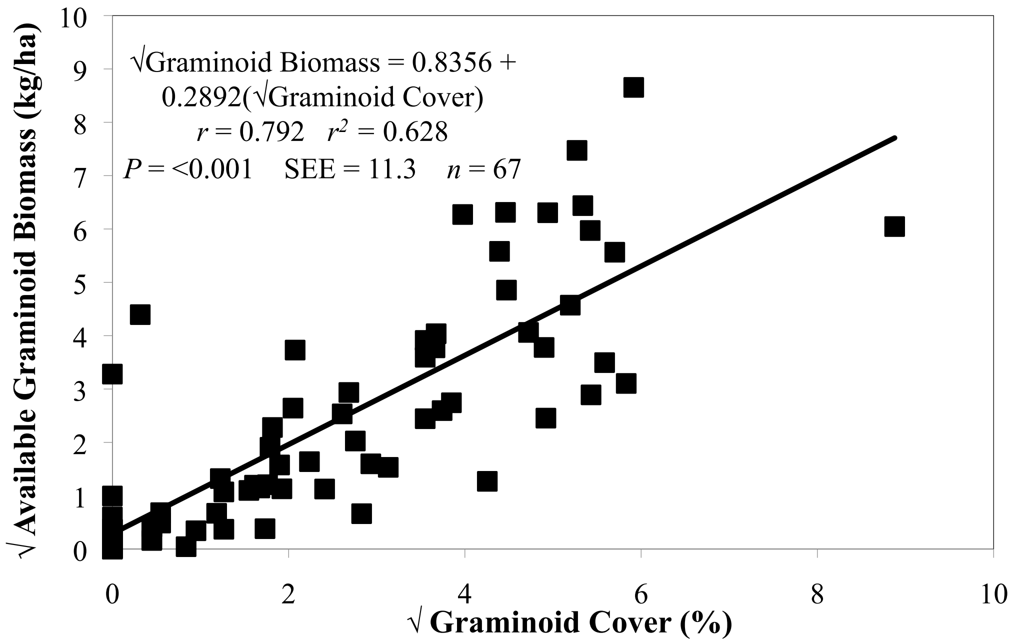


Figure 9. Scatter diagram of graminoid cover and available graminoid biomass within the Takhini Valley study area.

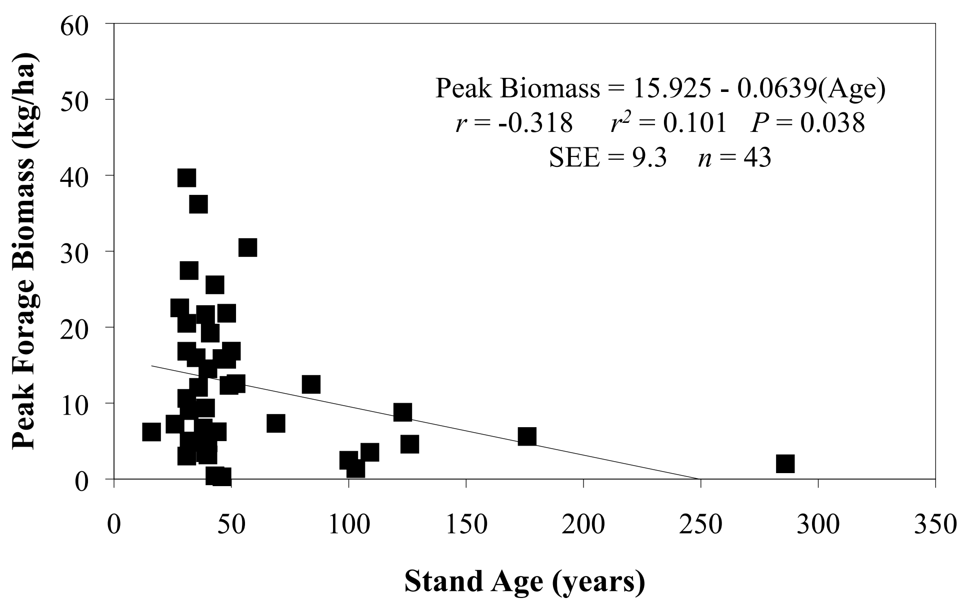


Figure 10. Relationship between stand age and available forage for treed plots within the Takhini Valley study area.

Table 8. Average protein, acid detergent fibre (ADF) and neutral detergent fibre (NDF) percent content values for fall peak biomass samples by vegetation type within the Takhini Valley study area. Values compared using Kruskal Wallis tests and differences identified using Scheffé rank tests.

	Vegetation Type								
Variables (%)	*Populus tremuloides**	*Populus tremuloides/ Shepherdia canadensis-Rosa acicularis*	*Calamagrostis purpurascens*	*Pinus contorta// Calamagrostis purpurascens–Linnaea borealis*	*Bromus inermis–Rosa acicularis–Achillea millefolium*	*Picea glauca*[†]	*Picea glauca// Hylocomium splendens*	*Nontreed*[‡]	*P*
	Mean value[standard deviation]								
Graminoids									
Crude Protein	6.28[0.34]a[§]	6.29[0.15]a	6.04[0.18]a	6.47[0.80]a	5.32[0.08]a	-	-	5.35[0.12]a	0.041
ADF	38.11[1.31]a	36.78[0.35]a	36.52[0.24]a	35.11[0.66]a	32.93[0.71]a	-	-	37.82[1.88]a	0.077
NDF	55.12[3.62]a	54.74[2.27]a	55.6[1.32]a	53.49[1.42]a	50.59[1.03]a	-	-	58.07[0.55]a	0.137
Number of samples	2	2	3	3	3			3	
Forbs									
Crude Protein	7.15[0.71]a	6.77[0.71]a	6.90[0.84]a	10.97[0.81]a	8.88[0.44]a	8.87[0.59]a	8.41[1.22]a	6.57[0.44]a	0.181
ADF	18.88[1.21]ab	19.22[0.60]b	20.94[1.03]ab	19.22[1.12]ab	23.27[2.20]ab	14.75[2.06]a	13.89[1.39]ab	25.33[1.15]ab	0.034
NDF	23.22[0.91]ab	21.96[0.71]b	26.20[1.56]ab	24.02[2.12]ab	27.91[2.76]ab	18.51[1.48]a	18.09[0.25]ab	31.50[2.39]ab	0.015
Number of samples	3	3	3	1	3	3	2	3	
Shrubs									
Crude Protein	7.16[0.56]a	8.13[0.46]a	9.17[1.01]a	8.59[1.80]a	11.69[5.63]a	8.38[0.53]a	8.24[0.35]a	9.01[1.09]a	0.353
ADF	15.64[1.55]a	15.77[1.77]a	14.16[0.97]a	16.25[1.07]a	17.40[3.86]a	18.17[1.77]a	20.87[4.12]a	14.92[1.25]a	0.656
NDF	17.73[0.63]a	16.95[1.59]a	16.07[0.35]a	18.53[1.52]a	21.93[4.24]a	21.45[2.61]a	24.81[4.12]a	17.82[0.74]a	0.214
Number of samples	2	3	3	3	3	3	3	3	

* Includes *Populus tremuloides//Arctostaphylos uva-ursi, Populus tremuloides/Shepherdia canadensis–Rosa acicularis*, and *Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi*.

[†] Includes *Picea glauca/Salix glauca/Shepherdia canadensis* and *Picea glauca//Arctostaphylos uva-ursi–Linnaea borealis*.

[‡] Includes *Carex supina* and *Calamagrostis purpurascens* vegetation types.

[§] Letters denote the result of Scheffé rank test at the α 0.05 level, different letters by variable indicate which vegetation types differ significantly from each other.

[‖] Insufficient graminoid biomass for analysis (Table 3).

There were significant differences in forb fibre content between the *Populus tremuloides*/*Shepherdia canadensis–Rosa acicularis* type and the *Picea glauca* type (Table 8), but not between the other treed vegetation types. There were no significant differences in graminoid ADF and NDF; forb crude protein; and shrub ADF, NDF, and crude protein content among vegetation types (Table 8). Graminoids had less crude protein content and more ADF and NDF content than the other growth-forms (Table 9). Forbs and shrubs did not differ significantly in crude protein, ADF, or NDF content (Table 9).

Crude protein content of *Bromus inermis, Calamagrostis purpurascens, Salix glauca, Carex supina,* and *Populus tremuloides* appeared to decrease overall from May to August (Figure 11), whereas ADF and NDF content showed no trends over time (Figure 12 and 13).

Table 9. Average crude protein, acid detergent fibre (ADF) and neutral detergent fibre (NDF) values of forb, graminoid and shrub samples collected at the end of the 2008 growing season among all vegetation types within the Takhini Valley study area. Values compared using Kruskal-Wallis tests and differences identified using Scheffé rank tests.

	Growth-form			
Variables	**Graminoid**	**Forb**	**Shrub**	***P***
	Mean value[standard deviation]			
Crude Protein (%)	5.96[0.5]a*	8.07[1.5]b	8.80[1.3]b	0.001
Acid Detergent Fibre (%)	36.21[1.9]b	19.44[3.9]a	16.65[2.1]a	0.001
Neutral Detergent Fibre (%)	54.60[2.5]b	23.87[4.5]a	19.41[3.0]a	0.001
Number of Samples	16	21	23	

* Letters denote the result of Scheffé rank test at the α 0.05 level, different letters by variable indicate which growth-forms differ significantly from each other.

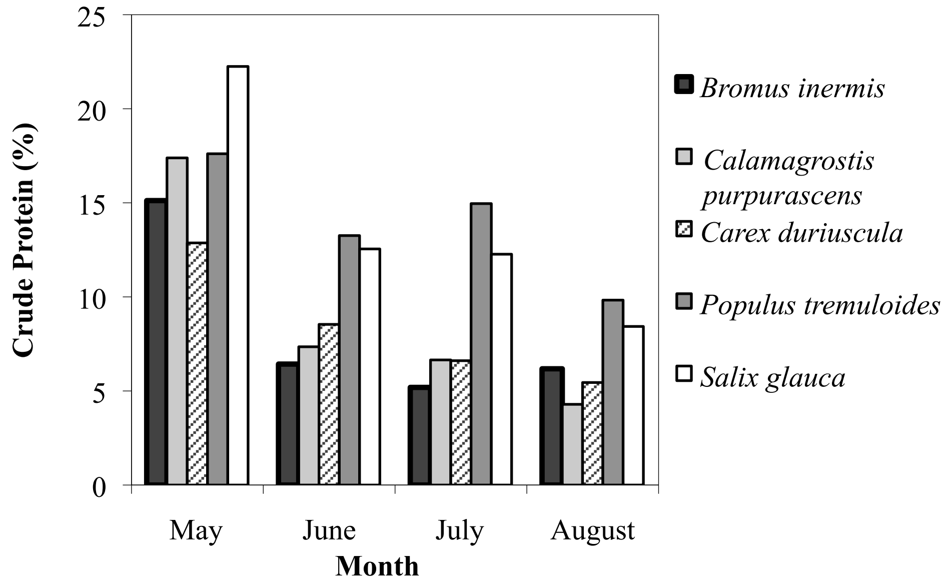


Figure 11. Percent crude protein content of five preferred elk forage species, collected monthly (May–August 2008) within the Takhini Valley study area.

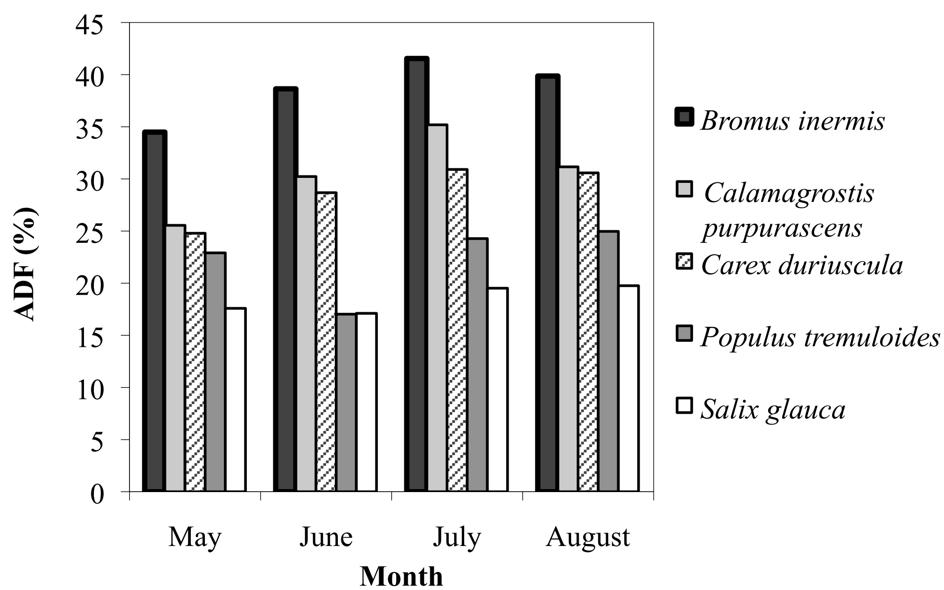


Figure 12. Percent acid detergent fibre (ADF) content of five preferred elk forage species, collected monthly (May–August 2008) within the Takhini Valley study area.

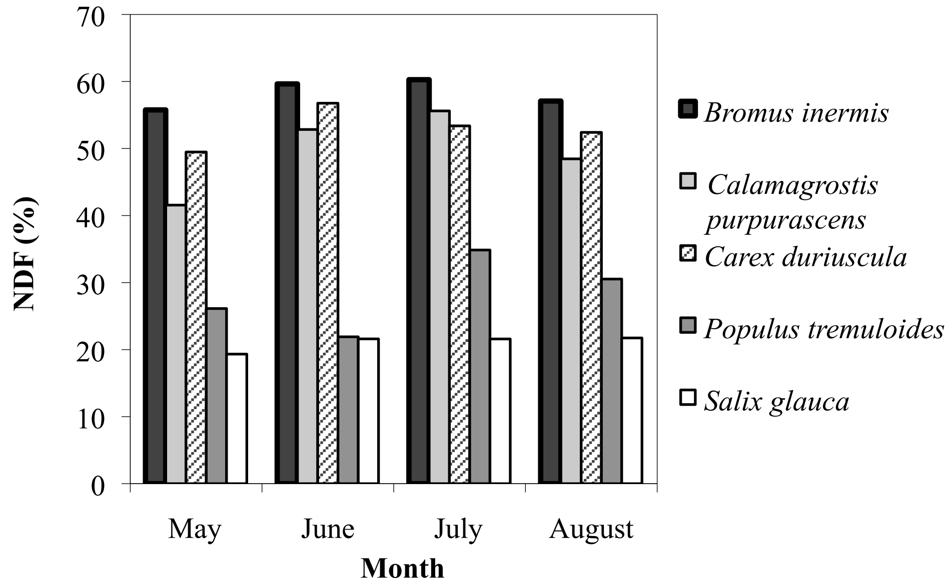


Figure 13. Percent neutral detergent fibre (NDF) content of five preferred elk forage species, collected monthly (May–August 2008) within the Takhini Valley study area.

Forage index values

Based on previous studies, forage index values >2 were considered to represent good foraging areas, but none occurred in the study area. Summer forage index values ranged from 0.75 in the commonly occurring *Populus tremuloides//Arctostaphylos uva-ursi* to 1.97 in the *Calamagrostis pupurascens* type (Table 10, Figure 14). Fall forage index values ranged from 0.79 in the *Picea glauca//Hylocomium splendens* vegetation type to 1.78 in the *Populus tremuloides/Shepherdia canadensis–Rosa acicularis* type (Table 10, Figure 15). This was the season with the largest areal extent of vegetation types with a forage value in the 1.6–2.0 class (Table 11). Winter forage index values were the least in the *Picea glauca//Hylocomium splendens* vegetation type and greatest in the *Bromus inermis–Rosa acicularis–Achillea millefolium* type, which had the smallest area among vegetation types (Table 10, Figure 16). The former contributed to the large area of winter forage within the 1.0–1.3 FIc value class (Table 11). Forage index values for spring ranged from 0.6 in the *Picea glauca//Arctostaphylos uva-ursi–Linnaea borealis* vegetation type to 2 in the *Calamagrostis purpurascens* type (Table 10, and Figure 17). Spring had the lowest overall FIc values based on the area within each class (Table 11).

Table 10. Seasonal forage index values (FIc) by vegetation type within the Takhini valley study area, based on species cover and elk forage preference values were calculated on a scale of 3. Values <1 were poor, 1–2 were fair, and >2 were good. Vegetation types are presented in order of decreasing area.

	Forage index value (FIc)			
Vegetation type	**Winter**	**Spring**	**Summer**	**Fall**
	Mean value[Standard deviation]			
Populus tremuloides//Arctostaphylos uva-ursi	1.76[0.44]	1.26[0.18]	0.75[0.24]	1.67[0.17]
Populus tremuloides/Shepherdia canadensis–Rosa acicularis	1.53[0.65]	1.23[0.39]	1.60[0.37]	1.78[0.35]
Picea glauca/ Salix glauca/Shepherdia canadensis	1.12[0.97]	1.31[0.36]	1.29[0.52]	1.64[0.32]
Picea glauca//Hylocomium splendens	0.67[0.98]	0.60[0.52]	0.76[0.74]	0.79[0.56]
Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi	1.44[0.83]	1.33[0.30]	1.33[0.45]	1.80[0.33]
Carex duriuscula–Artemisia frigida	1.96[0.05]	1.44[0.19]	1.50[0.32]	1.36[0.20]
Picea glauca//Arctostaphylos uva-ursi–Linnaea borealis	1.63[0.74]	0.81[0.20]	0.72[0.25]	1.07[0.42]
Calamagrostis purpurascens	1.97[0.25]	2.00[0.29]	1.97[0.36]	1.49[0.20]
Pinus contorta//Calamagrostis purpurascens –Linnaea borealis	1.78[0.60]	0.94[0.74]	1.15[0.72]	1.07[0.57]
Rosa acicularis–Fragaria virginiana	1.40[0.45]	1.53[0.29]	1.56[0.36]	1.47[0.34]
Carex supina	1.76[0.34]	1.22[0.49]	1.69[0.38]	1.29[0.41]
Bromus inermis–Rosa acicularis–Achillea Millefolium	1.99[0.23]	1.63[0.37]	1.72[0.39]	1.67[0.36]

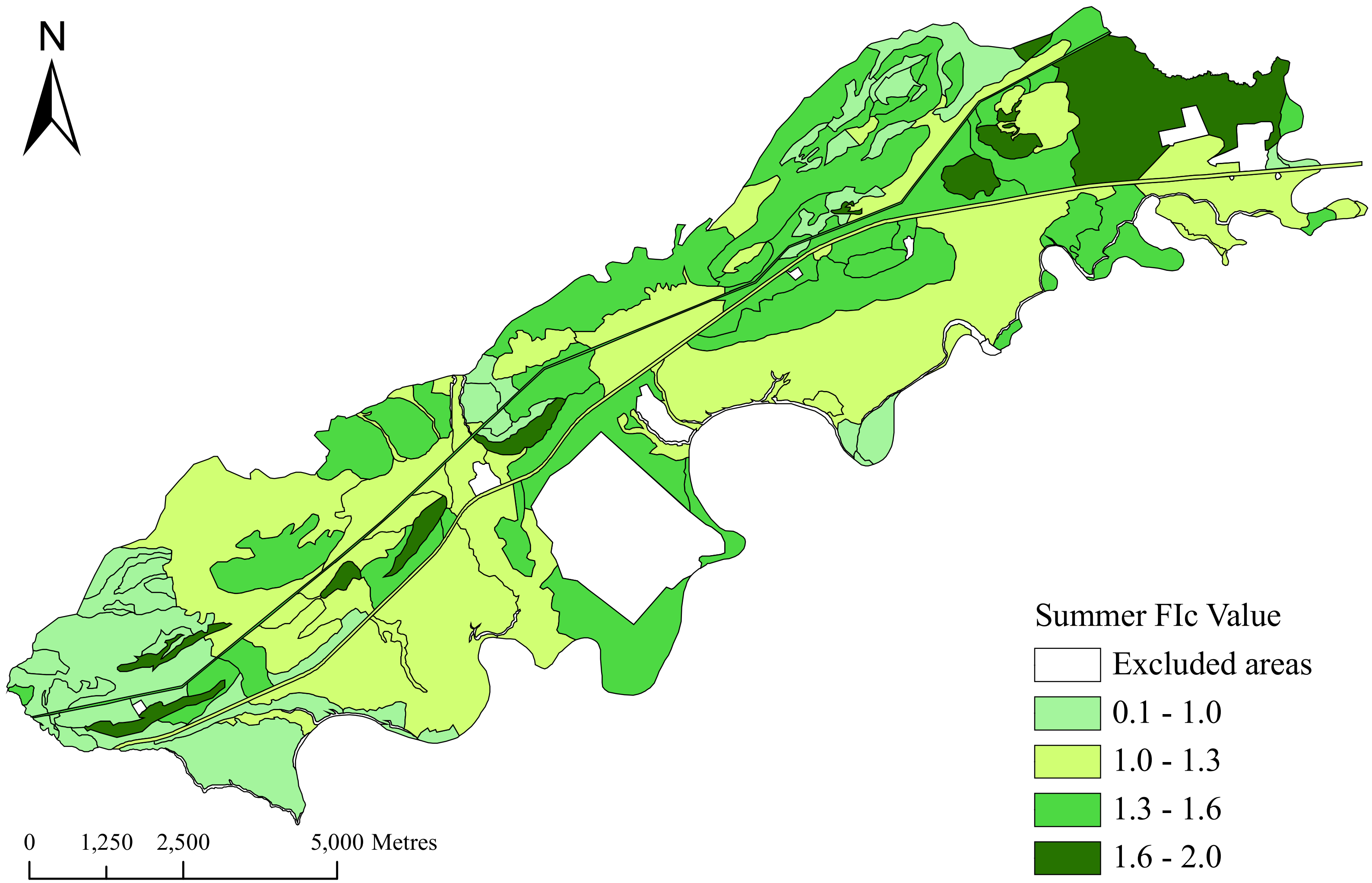


Figure 14. Summer forage index values by vegetation type within the Takhini Valley study area. Farmland and disturbance areas were excluded from calculations. Maximum possible FIc value is three.

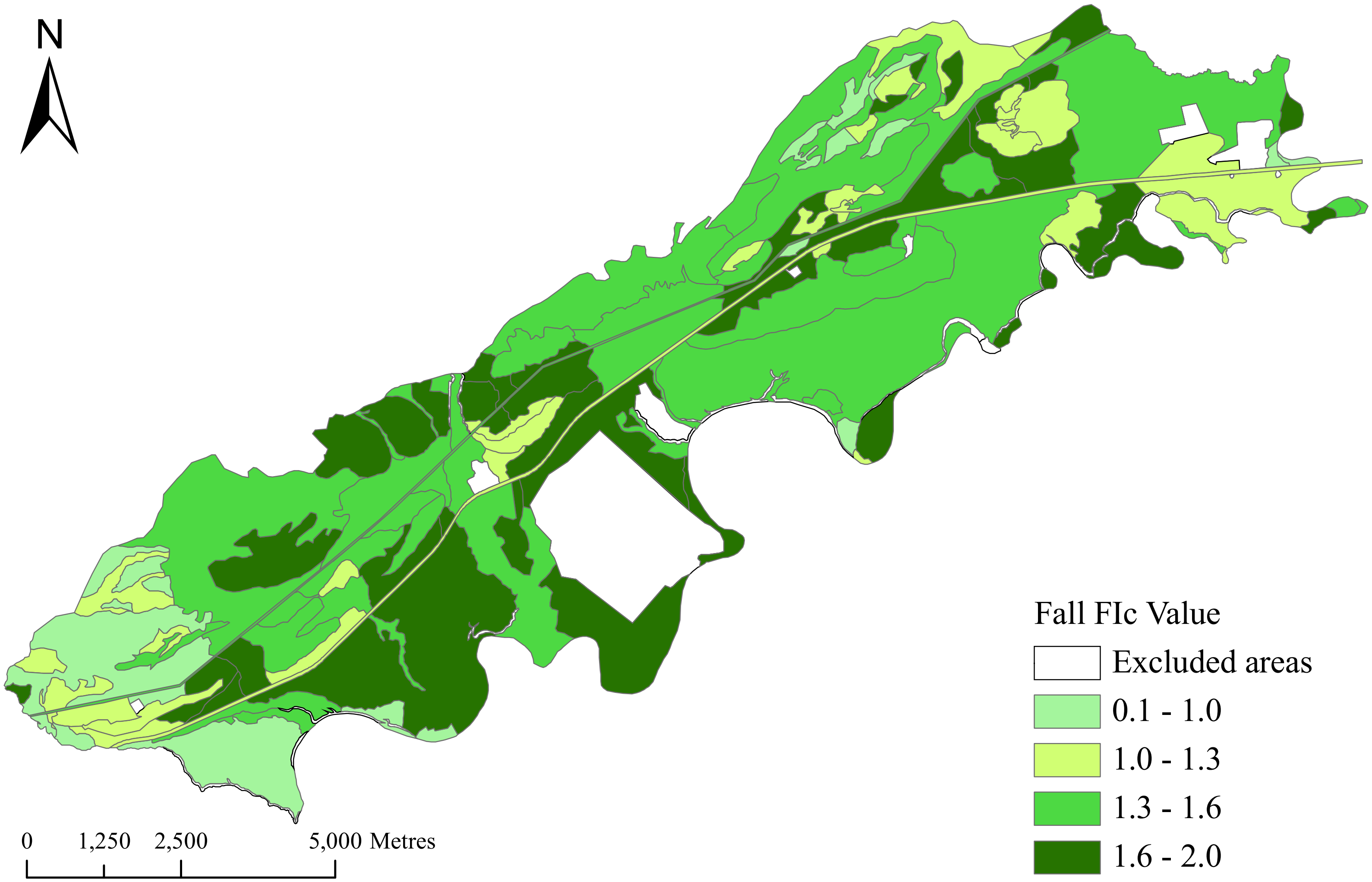


Figure 15. Fall forage index values by vegetation type within the Takhini Valley study area. Farmland and disturbance areas were excluded from calculations. Maximum possible FIc value is three.

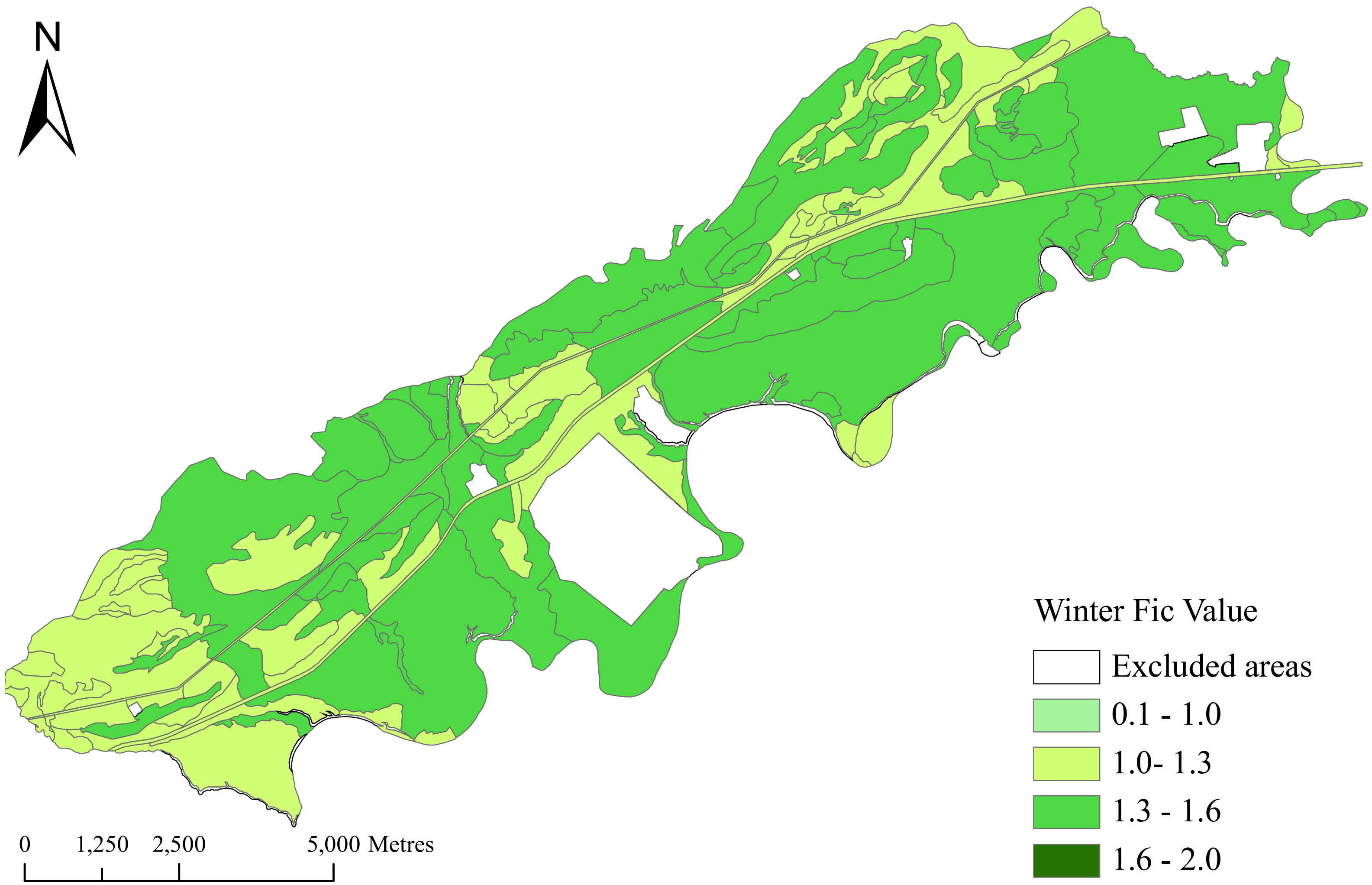


Figure 16. Winter forage index values by vegetation type within the Takhini Valley study area. Farmland and disturbance areas were excluded from calculations. Maximum possible FIc value is three.

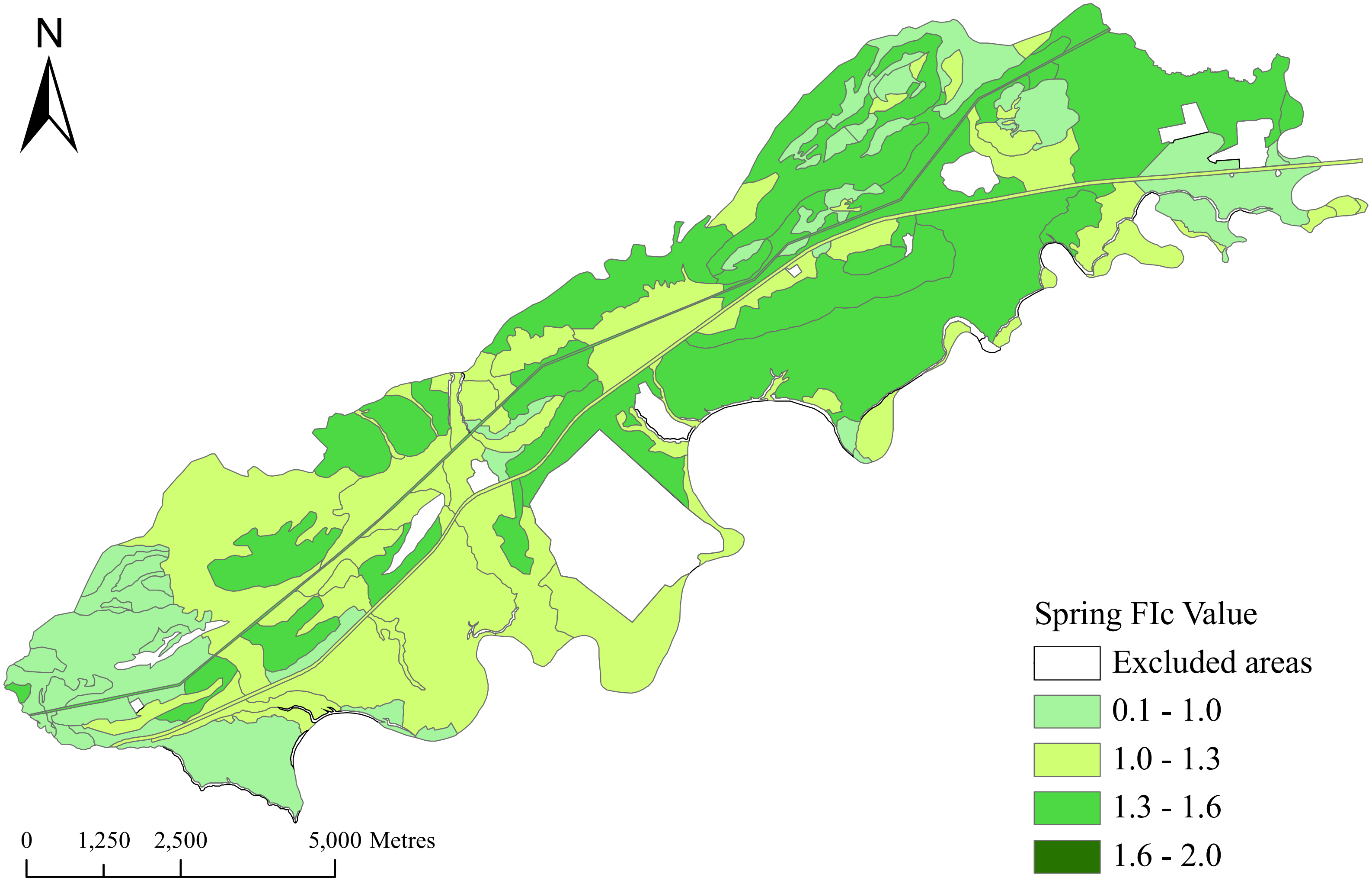


Figure 17. Spring forage index values by vegetation type within the Takhini Valley study area. Farmland and disturbance areas were excluded from calculations. Maximum possible FIc value is three.

Table 11. Areal extent (ha) of forage index values by class and season.

FIc value classes	Winter	Spring	Summer	Fall
		Hectares		
0–1.0	0	2325	2819	779
1.0–1.3	4619	2780	1021	1813
1.3–1.6	1370	3137	2510	1499
1.6–2.0	2794	541	2433	4692

Habitat selection

Radio-collared elk were not restricted in their movements in the study area, or within the greater Takhini Valley. Data from the 12 radio-collared elk indicated that elk were within the study area 83% of the time during fall, 31% during winter, 95% during spring, and 86% during summer.

During the summer, within 250-m of each point location, *Populus tremuloides//Arctostaphylos uva-ursi* vegetation was present more (P <0.05) than its proportionate availability (Table 12). This was the only vegetation type among seasons that occurred more than would be expected. In contrast, most vegetation types were present less than expected during winter. Winter was also the season with the fewest telemetry locations due to lower sampling intensity, but the majority of the radio-collared elk were in a single herd. The low number of locations was also partially due to the movement of elk to the east of the study area along the highway right-of-way and in agricultural fields.

Within the 250-m buffer, six vegetation types were present less than expected during the winter, including all of the conifer forest types (Table 12). Elk locations in the

Table 12. Observed habitat selection of elk within the Takhini Valley study area based on Bonferonni simultaneous confidence intervals by vegetation type, at a 250-m buffer distance from elk telemetry locations. Usage <1.0 because eroding slopes, disturbed areas and water were excluded from the table.

Vegetation Type	Expected usage (P_i)	Actual usage (P_o)	Bonferroni intervals Lower		Upper	Selection*	Actual usage (P_o)	Bonferroni intervals Lower		Upper	Selection
			Winter					**Spring**			
Pinus contorta//Calamagrostis purpurascens–Linnaea borealis	0.0413	0.000	0.000	$\leq P_1 \geq$	0.000	---	0.086	-0.022	$\leq P_1 \geq$	0.194	
Picea glauca/Salix glauca/ Shepherdia canadensis	0.1207	0.007	-0.028	$\leq P_2 \geq$	0.042	---	0.089	-0.021	$\leq P_2 \geq$	0.198	
Picea glauca//Arctostaphylos uva-ursi–Linnaea borealis	0.0657	0.003	-0.019	$\leq P_3 \geq$	0.024	---	0.068	-0.029	$\leq P_3 \geq$	0.165	
Picea glauca//Hylocomium splendens	0.0816	0.000	0.000	$\leq P_4 \geq$	0.000	---	0.009	-0.028	$\leq P_4 \geq$	0.047	---
Populus tremuloides//Arctostaphylos uva-ursi	0.0931	0.011	-0.032	$\leq P_5 \geq$	0.054	---	0.030	-0.036	$\leq P_5 \geq$	0.095	
Populus tremuloides/Shepherdia canadensis–Rosa acicularis	0.1703	0.067	-0.036	$\leq P_6 \geq$	0.171		0.093	-0.019	$\leq P_6 \geq$	0.205	
Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi	0.1507	0.085	-0.030	$\leq P_7 \geq$	0.201		0.209	0.052	$\leq P_7 \geq$	0.365	
Carex duriuscula–Artemisia frigida	0.0743	0.029	-0.040	$\leq P_8 \geq$	0.099		0.024	-0.035	$\leq P_8 \geq$	0.083	
Carex supina	0.0279	0.008	-0.029	$\leq P_9 \geq$	0.046		0.040	-0.035	$\leq P_9 \geq$	0.116	
Calamagrostis purpurascens	0.0448	0.021	-0.038	$\leq P_{10} \geq$	0.081		0.161	0.019	$\leq P_{10} \geq$	0.302	
Rosa acicularis–Fragaria virginiana	0.0379	0.005	-0.025	$\leq P_{11} \geq$	0.036	—	0.017	-0.033	$\leq P_{11} \geq$	0.068	
Bromus inermis–Rosa acicularis–Achillea millefolium	0.0080	0.004	-0.023	$\leq P_{12} \geq$	0.032		0.042	-0.035	$\leq P_{12} \geq$	0.118	
			Summer					**Fall**			
Pinus contorta//Calamagrostis purpurascens–Linnaea borealis	0.041	0.013	-0.016	$\leq P_1 \geq$	0.041		0.022	-0.032	$\leq P_1 \geq$	0.075	
Picea glauca/Salix glauca/ Shepherdia canadensis	0.121	0.120	0.053	$\leq P_2 \geq$	0.203		0.038	-0.032	$\leq P_2 \geq$	0.109	-
Picea glauca//Arctostaphylos uva-ursi–Linnaea borealis	0.066	0.037	-0.014	$\leq P_3 \geq$	0.086		0.044	-0.031	$\leq P_3 \geq$	0.119	
Picea glauca//Hylocomium splendens	0.082	0.004	-0.015	$\leq P_4 \geq$	0.019	---	0.093	-0.013	$\leq P_4 \geq$	0.200	
Populus tremuloides//Arctostaphylos uva-ursi	0.093	0.198	0.090	$\leq P_5 \geq$	0.299	+	0.129	0.006	$\leq P_5 \geq$	0.252	
Populus tremuloides/Shepherdia canadensis–Rosa acicularis	0.170	0.208	0.105	$\leq P_6 \geq$	0.311		0.186	0.044	$\leq P_6 \geq$	0.329	
Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi	0.151	0.187	0.086	$\leq P_7 \geq$	0.286		0.126	0.004	$\leq P_7 \geq$	0.247	
Carex duriuscula–Artemisia frigida	0.074	0.043	-0.008	$\leq P_8 \geq$	0.095		0.075	-0.022	$\leq P_8 \geq$	0.171	
Carex supina	0.028	0.039	-0.013	$\leq P_9 \geq$	0.089		0.147	0.017	$\leq P_9 \geq$	0.276	
Calamagrostis purpurascens	0.045	0.013	-0.016	$\leq P_{10} \geq$	0.041	-	0.057	-0.028	$\leq P_{10} \geq$	0.142	
Rosa acicularis–Fragaria virginiana	0.038	0.062	0.002	$\leq P_{11} \geq$	0.123		0.055	-0.028	$\leq P_{11} \geq$	0.139	
Bromus inermis–Rosa acicularis–Achillea millefolium	0.008	0.007	-0.014	$\leq P_{12} \geq$	0.029		0.012	-0.028	$\leq P_{12} \geq$	0.053	

* "+" Use greater than expected ($P \leq 0.05$), "-" use less than expected ($P \leq 0.05$), "—" use less than expected ($P \leq 0.01$), "---" use less than expected ($P \leq 0.005$).

spring were less likely to be in the *Picea glauca//Hylocomium splendens* vegetation and on eroding slopes than their proportionate availability would suggest. *Picea glauca//Hylocomium splendens* and *Calamagrostis purpurascens* vegetation types were present less than would be expected during summer. *Picea glauca/Salix glauca/Shepherdia canadensis* was the only type that occurred less than its availability during the fall.

At the 500-m buffer distance, there were fewer differences between observed and expected occurrence of the vegetation types. During the winter, two vegetation types were present less than their availability, one third as many as at the 250-m buffer distance, the two evergreen types with the least biomass: *Pinus contorta//Calamagrostis purpurascens–Linnaea borealis* and *Picea glauca//Hylocomium splendens* (Table 13). Spring and fall habitat occurrences were similar for both buffer sizes, whereas summer occurrences included less of the *Picea glauca//Hylocomium splendens* vegetation type.

Pellet Groups

Carex duriuscula–Artemisia frigida, a south facing vegetation type had the most ($0.24/m^2$) elk pellet groups (D1 – Figure 18). *Rosa acicularis–Fragaria virginiana* had the fewest pellet groups of the nontreed types ($0.02/m^2$), the same amount as *Pinus contorta//Calamagrostis purpurascens-Linnaea borealis*, which had the greatest density of pellet groups of the treed types. The *Picea glauca//Hylocomium splendens*, *Populus tremuloides/Shepherdia canadensis-Rosa acicularis*, and *Populus tremuloides/Rosa*

Table 13. Observed habitat selection of elk within the Takhini Valley study area based on Bonferroni simultaneous confidence intervals by vegetation type, at a 500-m buffer distance from elk telemetry locations. Usage <1.0 because eroding slopes, disturbed areas and water were excluded from the table.

Vegetation Type	Expected usage (P_i)	Actual usage(P_o)	Bonferroni intervals Lower		Upper	Selection*	Actual usage (P_o)	Bonferroni intervals Lower		Upper	Selection
			Winter					**Spring**			
Pinus contorta//Calamagrostis purpurascens–Linnaea borealis	0.0413	0.002	-0.018	$\leq P_1 \geq$	0.022	---	0.068	-0.029	$\leq P_1 \geq$	0.164	
Picea glauca/Salix glauca/ Shepherdia canadensis	0.1207	0.068	-0.036	$\leq P_2 \geq$	0.171		0.121	-0.005	$\leq P_2 \geq$	0.246	
Picea glauca//Arctostaphylos uva-ursi–Linnaea borealis	0.0657	0.021	-0.038	$\leq P_3 \geq$	0.080		0.062	-0.031	$\leq P_3 \geq$	0.155	
Picea glauca//Hylocomium splendens	0.0816	0.000	0.000	$\leq P_4 \geq$	0.000	---	0.016	-0.032	$\leq P_4 \geq$	0.063	—
Populus tremuloides//Arctostaphylos uva-ursi	0.0931	0.060	-0.038	$\leq P_5 \geq$	0.158		0.053	-0.033	$\leq P_5 \geq$	0.138	
Populus tremuloides/Shepherdia canadensis–Rosa acicularis	0.1703	0.267	0.084	$\leq P_6 \geq$	0.450		0.113	-0.009	$\leq P_6 \geq$	0.234	
Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi	0.1507	0.273	0.089	$\leq P_7 \geq$	0.457		0.205	0.049	$\leq P_7 \geq$	0.360	
Carex duriuscula–Artemisia frigida	0.0743	0.120	-0.014	$\leq P_8 \geq$	0.255		0.033	-0.036	$\leq P_8 \geq$	0.101	
Carex supina	0.0279	0.031	-0.041	$\leq P_9 \geq$	0.102		0.046	-0.035	$\leq P_9 \geq$	0.126	
Calamagrostis purpurascens	0.0448	0.076	-0.034	$\leq P_{10} \geq$	0.185		0.122	-0.004	$\leq P_{10} \geq$	0.248	
Rosa acicularis–Fragaria virginiana	0.0379	0.029	-0.040	$\leq P_{11} \geq$	0.098		0.028	-0.036	$\leq P_{11} \geq$	0.092	
Bromus inermis–Rosa acicularis–Achillea millefolium	0.0080	0.010	-0.031	$\leq P_{12} \geq$	0.051		0.027	-0.035	$\leq P_{12} \geq$	0.089	
			Summer					**Fall**			
Pinus contorta//Calamagrostis purpurascens–Linnaea borealis	0.041	0.015	-0.016	$\leq P_1 \geq$	0.045		0.031	-0.033	$\leq P_1 \geq$	0.094	
Picea glauca/Salix glauca/ Shepherdia canadensis	0.121	0.142	0.053	$\leq P_2 \geq$	0.231		0.045	-0.031	$\leq P_2 \geq$	0.122	
Picea glauca//Arctostaphylos uva-ursi–Linnaea borealis	0.066	0.029	-0.014	$\leq P_3 \geq$	0.071		0.042	-0.032	$\leq P_3 \geq$	0.116	
Picea glauca//Hylocomium splendens	0.082	0.008	-0.015	$\leq P_4 \geq$	0.030	---	0.079	-0.020	$\leq P_4 \geq$	0.178	
Populus tremuloides//Arctostaphylos uva-ursi	0.093	0.189	0.090	$\leq P_5 \geq$	0.289		0.128	0.005	$\leq P_5 \geq$	0.250	
Populus tremuloides/Shepherdia canadensis–Rosa acicularis	0.170	0.208	0.105	$\leq P_6 \geq$	0.312		0.216	0.066	$\leq P_6 \geq$	0.367	
Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi	0.151	0.184	0.086	$\leq P_7 \geq$	0.283		0.129	0.006	$\leq P_7 \geq$	0.252	
Carex duriuscula–Artemisia frigida	0.074	0.045	-0.008	$\leq P_8 \geq$	0.098		0.080	-0.019	$\leq P_8 \geq$	0.180	
Carex supina	0.028	0.032	-0.013	$\leq P_9 \geq$	0.076		0.093	-0.014	$\leq P_9 \geq$	0.199	
Calamagrostis purpurascens	0.045	0.015	-0.016	$\leq P_{10} \geq$	0.046		0.067	-0.025	$\leq P_{10} \geq$	0.158	
Rosa acicularis–Fragaria virginiana	0.038	0.064	0.002	$\leq P_{11} \geq$	0.126		0.064	-0.026	$\leq P_{11} \geq$	0.153	
Bromus inermis–Rosa acicularis–Achillea millefolium	0.008	0.006	-0.014	$\leq P_{12} \geq$	0.027		0.009	-0.026	$\leq P_{12} \geq$	0.045	

* Use greater than expected ($P \leq 0.05$), "-" use less than expected ($P \leq 0.05$), "—" use less than expected ($P \leq 0.01$), "---" use less than expected ($P \leq 0.005$).

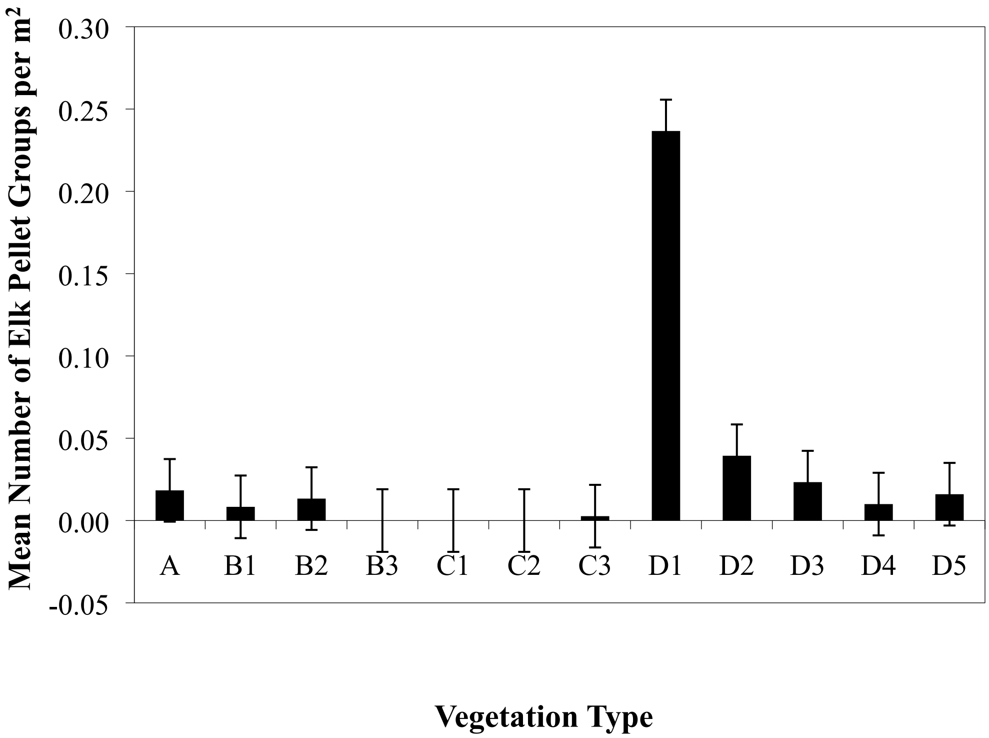


Figure 18. Mean number of elk pellet groups in biomass sampling plots by vegetation types within the Takhini Valley study area. Vertical lines represent mean standard error. A – *Pinus contorta//Calamagrostis purpurascens–Linnaea borealis*; B1 – *Picea glauca/Salix glauca/Shepherdia canadensis*; B2 – *Picea glauca//Arctostaphylos uva-ursi–Linnaea borealis*; B3 – *Picea glauca//Hylocomium splendens*; C1 – *Populus tremuloides//Arctostaphylos uva-ursi*; C2 – *Populus tremuloides/Shepherdia canadensis–Rosa acicularis*; and C3 – *Populus tremuloides/Rosa acicularis–Arctostaphylos uva-ursi*; D1 – *Carex duriuscula–Artemisia frigida*; D2 – *Carex supina*; D3 – C*alamagrostis purpurascens*; D4 – *Rosa acicularis–Fragaria virginiana*; and D5 – *Bromus inermis–Rosa acicularis–Achillea millefolium* vegetation types.

acicularis/Arctostaphylos uva-ursi vegetation types had no pellet groups on any of the sampling transects. Number of elk pellet groups was negatively correlated with tree densities (Figure 19). There was no correlation between number of elk pellets groups per plot and peak biomass availability (P = 0.470), or average FIc values (P = 0.684).

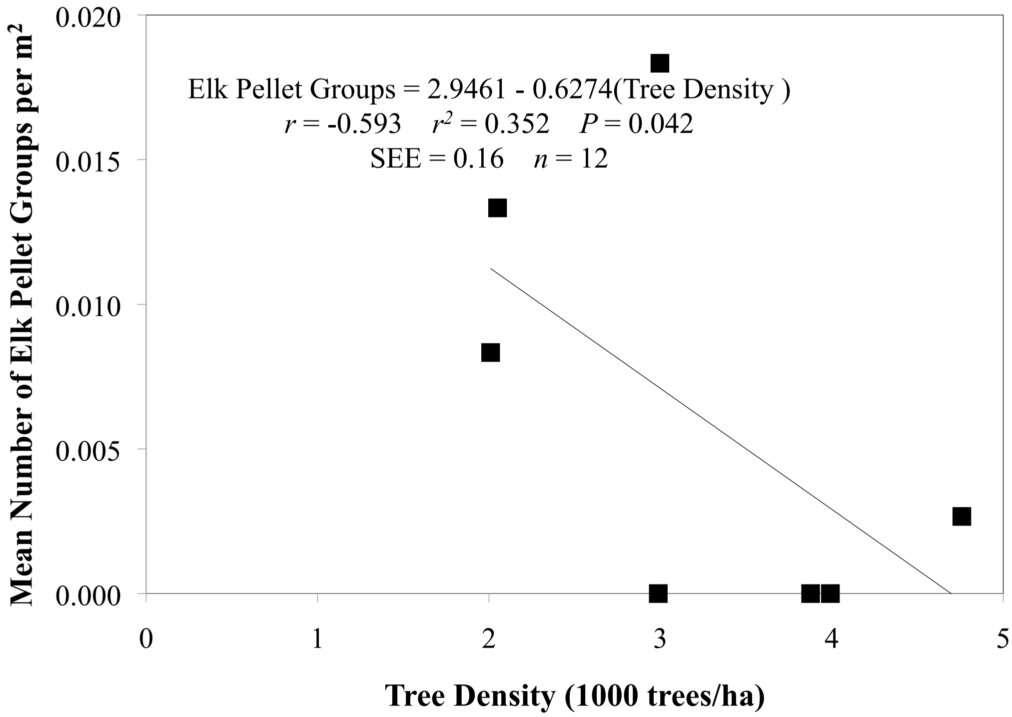


Figure 19. Mean number of elk pellet groups within the treed plots compared to the average tree densities, within the Takhini Valley study area.

Carrying capacity

Potential carrying capacity for the study area was estimated by season based on a series of cumulative assumptions (Table 14). Peak forage biomass was divided proportionately among seasons based on number of days per season, whereas leaf litterfall was only included in the fall biomass. The first scenario assumed that elk

Table 14. Potential carrying capacity of the Takhini Valley study area based on forage availability‡.

Scenario 1 : Maximum carrying capacity

Assumptions

1. 2,072 tonnes of forage are available annually for elk consumption, excluding leaf litterfall.
2. Healthy elk consume 3% of their body mass in forage daily (Baker et al. 1998; Gedis and Hudson 2000; Kuzyk et al. 2006).
3. Elk weigh 243 kg (Florkiewicz 1994).
4. All elk, horses and mule deer remain within the study area and use all vegetation types equally.

Number of elk, without horses and deer	**Full Year**	**762**

Scenario 2 : Seasonally weighted carrying capacity

Assumptions

5. Deciduous trees produced 3,454 tonnes of leaf litterfall biomass per year.
6. Seasons of unequal length occur.
7. Seasonal forage availability was a proportion of peak biomass.
8. Fall forage availability is the total of peak biomass and leaf litterfall biomass.
9. A total of 15 horses and 30 mule deer are part of the study area environment (T. Jung, Yukon Department of Environment, 2009, pers. comm.)
10. Mule deer (88 kg – Kuzyk and Hudson 2007; Yukon Department of Environment, unpublished data, 2008), and horses (450 kg – Marlow et al. 1992) require 3% of their body mass in forage per day (Kuzyk and Hudson 2007).
11. All elk, horses, and deer remain within the study area and equally use all vegetation types in proportion to the abundance of forage.

	Winter	Spring	Summer	Fall
Number of elk, without horses and deer	**762**	**762**	**762**	**8,545**
Number of elk, with horses and deer	**723**	**723**	**723**	**8,531**

Scenario 3 : Adjustment for winter diet composition

Assumption

12. In winter, browse forms an average of 29% of an elk's diet (Christianson and Creel 2007).

	Winter*			**Spring**	**Summer**	**Fall**
	19%†	29%	39%			
Number of elk, without horses and deer	941	**1,072**	1,249	**762**	**762**	**8,545**
Number of elk, with horses and deer	893	**1,017**	1,185	**723**	**723**	**8,501**

Scenario 4 : Adjustment for diet similarities between mule deer and elk diets

Assumption

13. Mule deer forage intake was weighted by similarity to elk diets. Mule deer diet composition was not known, therefore forage intake was reduced by 72% (Hansen and Clark 1977; Bartmann et al. 1992).

	Winter			**Spring**	**Summer**	**Fall**
	19%	29%	39%			
Number of elk, without horses and deer	941	**1,072**	1,249	**762**	**762**	**8,545**
Number of elk, with horses and deer	904	**1,030**	1,200	**730**	**726**	**8,515**

Table 14. Concluded.

Scenario 5 : Adjustment for seasonal forage availability

Assumptions

14. Forbs were excluded from fall forage use as they are inaccessible or physically disintegrated.
15. Forbs and shrub leaves were excluded from winter forage use as they are inaccessible or physically disintegrated.

	Winter			Spring	Summer	Fall
	19%	29%	39%			
Number of elk, without horses and deer	710	**809**	942	**657**	**566**	**8,249**
Number of elk, with horses and deer	693	**790**	919	**627**	**536**	**8,219**

Scenario 6 : Adjustment for forage preference

Assumption

16. Forage biomass by season was weighted by relative forage index values (Table 10).

	Winter			Spring	Summer	Fall
	19%	29%	39%			
Number of elk, without horses and deer	269	**306**	356	**657**	**566**	**8,114**
Number of elk, with horses and deer	233	**266**	309	**267**	**536**	**8,084**

Scenario 7 : Application of ecologically sustainable safe-use factors

Assumption

17. Ecologically sustainable safe-use factors were applied, 25% of seasonal forage biomass for treed and 50% for nontreed vegetation types (Alberta Sustainable Resource Development 2004).

	Winter			Spring	Summer	Fall
	19%	29%	39%			
Number of elk, without horses and deer	109	**124**	144	**225**	**195**	**2,058**
Number of elk, with horses and deer	72	**82**	96	**192**	**165**	**2,029**

Scenario 8 : Alaska Highway right-of-way biomass excluded

Assumption

18. Forage biomass within the Alaska Highway right-of-way was excluded.

	Winter			Spring	Summer	Fall
	19%	29%	39%			
Number of elk, without horses or deer	100	**114**	132	**216**	**187**	**2,051**
Number of elk, with horses or deer	63	**72**	83	**188**	**165**	**2,022**

* Browse was not included in biomass collection, so elk winter forage requirements were reduced by 29% (Christianson and Creel 2007).

† The actual composition of the elk diet is unknown, so the average from the literature and 10% on either side are presented.

‡See Appendix IV for detailed carrying capacity calculations

consumed all available forage and resulted in a carrying capacity estimate of 762 elk (Table 14). Leaf litterfall was included in the fall biomass in Scenario 2, and a second carrying capacity estimate was added to this and all subsequent scenarios – an estimate that incorporated the mule deer and horse populations that share the elk range. In Scenario 2, fall carrying capacity was 11 times greater than that of the other seasons due to the availability of consumable leaf litter. The inclusion of horses and mule deer reduced the carrying capacity of the other seasons by 5%. Winter carrying capacity increased in Scenario 3, because it was assumed that elk consume more browse during this time than in other seasons. Three browse use levels were presented, an average of 29% (Christianson and Creel 2007) and a buffer (±10%). Under Scenario 4, mule deer forage requirements were weighted according to diet similarities with elk, reducing their forage intake, and increasing the number of elk that could be supported in the study area to 1,030. Scenario 5 assumed the removal of forbs from fall and winter biomass availability, which reduced winter carrying capacity to 21% of Scenario 4. In Scenario 6, biomass was weighted for forage preference and quality as represented by the seasonal forage index values (Table 10), this further decreased the winter carrying capacity by approximately 60%. The inclusion of ecologically sustainable safe-use factors (Scenario 7) further decreased seasonal carrying capacities by more than half (Table 14).

The exclusion of forage within the Alaska Highway right-of-way decreased the carrying capacity by approximately 12% during winter, and <2% during spring and summer. Fall carrying capacity was reduced by <1%. Excluding consideration of reduced roadside vegetation, winter carrying capacity in the study area was estimated to be 72 and 144 elk with and without mule deer and horses, respectively. The carrying capacity of Scenario 7 represented 9–19% of Scenario 1. The range of values in Scenario 7, excluding the fall season, suggests the overall study area has a minimum carrying capacity of 0.8 – 1.5 elk/km^2 based on the applied assumptions.

A sensitivity analysis of Scenario 7 showed how the winter carrying capacity for elk changed when the population sizes of horses or mule deer were varied (Table 15). Elk carrying capacity within the study area was not very sensitive to changes in the number of mule deer, but was very sensitive to the potential number of horses. At half of the current horse numbers, carrying capacity would increase by ~20 elk.

Table 15. Sensitivity of Scenario 7 winter carrying capacity estimates to changes in horse and mule deer population sizes.

		Horse Population				
		0	**7**	**15**	**22**	**30**
Mule Deer Population	**0**	124	106	85	67	46
	15	123	105	84	65	44
	30	121	103	82*	64	43
	45	120	102	81	62	41
	60	119	100	79	61	40

* Indicates winter elk carrying capacity based on Scenario 7, and mule deer and horse populations provided by Yukon Department of Environment.

DISCUSSION

An estimated 190 large mammalian herbivores occurred within the 95 km^2 Takhini Valley study area in 2008, of which 144 were elk. The post-1989 growth rate is believed to have been ~1% per year until 2004, after which it increased substantially to ~20% per year (Florkiewicz et al. 2007). The more recent growth rate is comparable to herds in Yellowstone National Park (Eberhardt 1987; Eberhardt et al. 1996), where forage supply is more abundant and greater population growth does not pose as much concern of range over-use. It is unlikely, given the use of the same range since 1989, that elk population growth was limited by forage availability in the past, but forage availability may become limiting due to the rapidly increasing population size. Alternately, if the density of elk increases beyond that which can be supported by the study area, elk may increase their range.

Forage Supply

Forage availability in both treed and nontreed vegetation types (Table 7) was below previously published thresholds for efficient foraging by elk. Wickstrom et al. (1984) demonstrated that bite rate increased and bite size decreased when forage availability was <1,500 kg/ha. Below this abundance level, elk were unable to increase their intake with greater bite rates. In contrast, a threshold value of 900 kg/ha of forage was determined by Hudson and Nietfeld (1985) in the Ministik Field Station, Alberta, and 600–800 kg/ha in the shrub-steppe vegetation of Washington (McCorquodale 1991). Differences in foraging efficiency are likely due to the accessibility and quality of forage available in the different locations. Within the study area, only *Bromus inermis–Rosa acicularis–Achillea millefolium* vegetation, found along the highway verge, produced more forage (not including leaf litter) than the minimum threshold reported by McCorquodale (1991). By comparison, elk range in Banff National Park in contrast had forage biomass availability greater than 600 kg/ha in five of seven vegetation types (Sachro et al. 2005). Grass, forb, and shrub foliage biomass was less in *Populus tremuloides* stands than in Elk Island National Park, Alberta (Bork et al. 1997b). Forage availability below the efficiency threshold does not indicate that the range is not useable by elk, but suggests that elk would spend more time and expend more energy to obtain forage than on higher quality ranges.

Browse availability was not measured, but is an important consideration with respect to elk diets (Findholt et al. 2004), and was likely high due to the successional stage of the *Populus tremuloides* stands. Winter browse consumption is important because forbs, and tree and shrub leaves are unavailable for foraging, reducing the total forage supply (Visscher et al. 2006), and availability varies with snow depth (Kufeld 1973). The sampling methods did not directly account for shrub and tree twigs that were available for consumption. Therefore, assumptions were made about elk winter diets and the amount of browse biomass consumed based on previous studies (Trout and Leege 1971; Morgantini and Hudson 1989; Christianson and Creel 2007). Browse consumption by elk in the Takhini Valley was not constant between 1988 and 1989 (Florkiewicz 1994), but was similar to the average winter browse consumption of 29% reported by Christianson and Creel (2007). Because of the variation in browse consumption, it was assumed that browse was abundant and so carrying capacities were calculated for a range of values. Should elk populations become limited by factors other than available forage, it is not known if they would increase their browse intake to sustain their body condition and increase overwinter survival.

Forage abundance at the end of the growing season differed among vegetation types within the study area, but forage quality based on protein content did not significantly vary (Table 8). Crude protein content of forage in the Takhini Valley was below that of shrubs and graminoids in western Alberta (Morgantini and Hudson 1989), but higher than forbs in Rocky Mountain National Park in Colorado (Hobbs et al. 1981) and in Montana (van Dyke and Darragh 2007). *Calamagrostis purpurascens* had higher crude protein levels than either *Calamagrostis canadensis* (3.6%) or *Elymus innovatus* (6.0%) (Strong et al. 2005), both common forage species in the western boreal forest in Alberta. Crude protein from the Takhini Valley samples were assessed near the lowest levels of their yearly cycle, which typically occurs just before first snowfall (Morgantini and Hudson 1989). All assessed forage species and vegetation types had forage with a 5–12% crude protein content at the end of the growing season, which exceeded the minimum necessary content of 5% (Hobbs et al. 1981). Sufficient crude protein indicated that elk in the Takhini Valley were probably not limited by forage quality during the winter.

Acid detergent fibre (ADF) includes cellulose and lignin components of the forage. As percent ADF increases, elk are able to digest less of the forage. Neutral detergent fibre (NDF) includes ADF and all of the other fibre in the forage. Both ADF and NDF in the preferred forages were similar to the values measured in 1989 (Florkiewicz 1994). Percent ADF in the Takhini Valley was lower than forage on elk range in northern Colorado (Hobbs et al. 1981), and ungulate range in Oregon (Canon et al. 1987), indicating more digestible forage. Percent ADF in all three tested graminoid species was lower than in *Calamagrostis canadensis* and *Elymus innovatus* in early fall at Fox Lake, Alberta (Strong et al. 2005). Graminoids had the highest levels of NDF and most digestible fibres, whereas the *Salix* and *Populus tremuloides* leaves had the lowest percent NDF and the least digestible fibres (Figures 12 and 13), which indicates that vegetation types high in graminoid cover should be preferred over those such as the *Picea glauca* vegetation types.

Habitat Selection

Elk require various habitats for different purposes, i.e., foraging, thermal and hiding cover, and resting (Anderson et al. 2005), and needs change according to season. Marcum and Scott (1985) reported that in a northern Montana elk range, with similar daily summer temperatures as Whitehorse, were often correlated with selection by elk of dense forest habitats. Dense forest habitats provide thermal and hiding cover, which are important during the summer calving season, but only provide limited forage (Collins and Urness 1983). The densest of the treed vegetation types in the study area, *Populus tremuloides//Arctostaphylos uva-ursi*, was selected during summer and was the only vegetation type significantly selected among seasons (Table 9). Previous radio telemetry results also showed a similar pattern of use during the summer (Florkiewicz 1994).

Populus tremuloides forest also provided greater forage availability compared with other treed vegetation types in the study area. If elk were using the densely treed vegetation types for thermal or hiding cover, it was beneficial to select the *Populus tremuloides* forests over the coniferous forest types because they provided greater amounts of forage.

Winter habitat selection is influenced by the amount of forage present and snow cover (Poole and Mowat 2005; White et al. 2009). The magnitude of the effect of snow on energy expenditure by elk is dependent on depth and density (Parker et al. 1984). Dietary composition changes occur at 20 cm of snow depth, when browse consumption increases, because graminoids are more inaccessible (Gates and Hudson 1983). Elk change their foraging patterns and selection when snow depth exceeds 46–50 cm (Parker et al. 1984; Poole and Mowat 2005). Snow depths at the end of the month (1971–2000) in the Whitehorse area were between 15–32 cm from November to March (Meteorological Service of Canada 2009). Although no specific data were available for the Takhini Valley, it is thought to receive less precipitation than Whitehorse (Sproule 1996). This amount of snowfall accumulation should not be sufficient to greatly alter elk habitat selection patterns during the majority of the winter.

Across their range in North America, elk select southfacing slopes in the winter (Stephenson et al. 1985; Schaefer et al. 1996). South aspects are typically windblown areas where snow cover is less than that on level ground or north aspects. Closed canopy forests (e.g., *Picea glauca//Hylocomium splendens*) also typically have less snow accumulation than level, open grassy areas, and are also selected by elk during the winter (Visscher et al. 2006). Florkiewicz (1994) found that the Takhini Valley elk population selected southfacing slopes during winter and early spring, and avoided coniferous vegetation types. *Pinus contorta//Calamagrostis purpurascens–Linnaea borealis* and *Picea glauca//Hylocomium splendens* vegetation types produced the least forage (Table 7), had low winter forage index values (Table 10), and were among the least used during winter. Elk select forage based on minimizing energy costs (Fortin et al. 2005) and appear to avoid vegetation types with little biomass or fewer preferred species. Typically, elk have larger home ranges in winter than summer in order to increase forage availability (Anderson et al. 2005), as is the case in the study area. The 31% of elk telemetry locations that occurred in the study area appeared to be concentrated on southfacing slopes in the centre of their home range. The vegetation types on the south slopes produce more graminoid biomass than the coniferous forests and are among the most productive habitats within the study area.

Fecal pellet counts as an indicator of habitat use are not as reliable as radio telemetry data (Collins et al. 1978; Prugh and Krebs 2004). Though there are drawbacks to the technique (Collins et al. 1978; Edge and Marcum 1989), pellet group counts are a simple and often applied estimate of habitat use (Prugh and Krebs 2004; Forester et al. 2007; White et al. 2009). Elk pellet group densities were greatest on southfacing slopes where *Carex duriuscula–Artemisia frigida* and *Carex supina* vegetation occurred (Figure 14). Pellet group counts supported the telemetry and fecal analysis results of Florkiewicz (1994), who identified forage species on southfacing slopes as very important to elk diets. Considering only pellet counts, it would appear that elk do not use some treed vegetation types (*Populus tremuloides/Shepherdia canadensis–Rosa acicularis*, *Populus* *tremuloides/Rosa acicularis–Arctostaphylos uva-ursi*, and *Picea glauca//Hylocomium splendens*) and are almost exclusively using southfacing nontreed vegetation types, but telemetry data show that elk used *Populus tremuloides* types 30–60% of the time, depending on the season (Table 12 and 13).

Discrepancies between the two habitat selection indicators are possibly due to differences in elk activity. Telemetry locations were only recorded during the middle of the day, whereas fecal pellets are mainly deposited during traveling and foraging (Collins et al. 1978). These latter activities occur primarily at dusk and dawn (Witmer and deCalesta 1983), following daily and seasonal activity patterns (Green and Bear 1990). Florkiewicz (1994) recorded activity patterns of the Takhini Valley elk and these patterns did not change between seasons. Telemetry and fecal pellet habitat selection results may represent two different activities – resting and foraging, respectively. Alternately, the difference in fecal pellet counts among vegetation types may be related to differences in decomposition rates. Kukka and Jung (Yukon Environment, unpublished data) found that elk pellets in *Populus tremuloides* and *Picea glauca* dominated stands disappeared more quickly than in nontreed areas in the Takhini Valley.

Roadside Vegetation

The use by elk, often in large groups, of highway right-of-way vegetation, which passes through the centre of the elk range, has been a concern to local residents (Yukon Elk Management Planning Team 2008). Along the 20 km of the Alaska Highway within the study area, there were 27 elk-vehicle collisions between 2001 and 2008 (Yukon

Department of Environment, 2008, unpublished data). Elk-vehicle collisions are often fatal to elk, and can cause serious damage to vehicles and injuries to passengers. Elk use of roadsides at dusk and dawn, peak foraging times (Witmer and deCalesta 1983), may increase the probability of collisions due to poor visibility, as was found in moose-vehicle collisions in Newfoundland (Joyce and Mahoney 2001).

Elk are known to prefer roadside vegetation for foraging and resting (Collins et al. 1978; Beck et al. 2006). Roadside vegetation is attractive due to its quality and quantity (Finder et al. 1999). Other incentives include plants that sprout earlier in the spring (Puglisi et al. 1974; Feldhamer et al. 1986); and the vegetation remains in an early successional stage, because shrubs and trees are cut to maintain visibility along the road (Rea 2003). This allows more graminoids to grow, which are important forage (Hobbs et al. 1981; Christianson and Creel 2007). Agronomic species are often planted along the right-of-way (Rea 2003) to maintain roadside stability (Larson et al. 2001). *Bromus inermis*, one such species, was seeded along the Alaska Highway and was the principal component of *Bromus inermis–Rosa acicularis–Achillea millefolium* type (Table 4), which was the only vegetation that had greater forage abundance than the foraging efficiency threshold for elk (McCorquodale 1991). Roadsides are likely an important foraging habitat for elk because they provide the most forage for the least energy expenditure. In addition, use of roadsides by ungulates may be a predator-avoidance strategy (Berger 2007).

Carrying Capacity

Two concepts are relevant with respect to determining elk carrying capacity in the Takhini Valley. Wildlife managers, similar to agricultural producers, may be concerned with maintaining an animal population within the limits of the forage supply. In contrast, the concept used in calculating carrying capacity in this study was that of sustaining ecological structure and function of vegetation (Pyke et al. 1977). In this concept, the forage consumed by herbivores, or offtake, is limited by managing stocking rate to ensure range health through the application of safe-use factors. Safe use factors, though taken from Alberta rangelands, may be reasonably applied to the study area due to similarities between vegetation composition in both treed and nontreed areas (Adams et al. 2003). However, the Alberta safe-use factors were developed for cattle on Alberta rangelands and their applicability to cervids on Yukon rangelands may result in overly conservative carrying capacities, specifically for the treed vegetation types. Elk carrying capacity in the study area was lower than in other ranges in western North America. Winter carrying capacities were estimated to be 10 elk/km^2 in Alberta's Bow Valley (Hebblewhite et al. 2002) and in Rocky Mountain National Park (Lubow et al. 2002). Both of these carrying capacities are lower than the carrying capacity estimated for elk winter range in Montana, 13.7 elk/km^2 (Creel and Winnie 2005). The trend towards lower carrying capacities in northern elk ranges may be partially due to the trend of decreasing understory vegetation cover, and presumably forage, in the boreal forest with increasing latitude (Mitchell and Smoliak 1971; Crête and Manseau 1996; Strong and Redburn 2009).

Eight carrying capacity estimates were developed, ranging from a liberal (100% forage consumption Scenario 1) to highly conservative scenarios (various constraints applied, Scenario 8). Because Scenarios 1–6 did not include an assumption of safe-use, and Scenario 8 represents a special case, only Scenario 7 will be discussed, with focus on the winter carrying capacity, as it is the season with the most limited forage availability. Based on Scenario 7, winter carrying capacity in the study area was estimated to be 0.76-1.01 elk/km^2 (72–96 animals) and 1.15–1.52 elk/km^2 (109–144 animals) with and without the inclusion of horses and mule deer, respectively. In comparison, Florkiewicz (1994) estimated the winter carrying capacity to be ~7.3 elk/km^2, or 690 elk for the study area, in 1989 when 50 elk resided in the area. The key differences between the two estimates were:

i) End of season forage biomass collected from enclosures in the previous study was allocated only to winter (late October to early April), and did not take into account spring, summer, or fall forage needs;

ii) A safe-use factor of 50% was applied across all vegetation types by Florkiewicz (1994), rather than a safe-use factor of 50% for nontreed and 25% for treed vegetation types;

iii) The elk daily forage intake used by Florkiewicz (1994) was lower, 3–5 kg/day (1–2% of body mass) compared to 7.3 kg/day, or 3% of body mass (Kuzyk et al. 2007); and

iv) Horses and mule deer, which share the same range and similar forage requirements with elk, were not considered in the 1989 calculation of carrying capacity.

The first consideration explained most of the difference between winter carrying capacity estimates. Making all end of growing-season forage available during winter did not account for consumption during the fall (September and early October), or offtake that would have occurred during the spring and summer (Workman and MacPherson 1973; Teague et al. 2001; Alberta Sustainable Resource Development 2004; Redburn et al. 2008; Strong and Gates 2009). Spreading available forage biomass proportionally across all seasons was a more conservative approach that assumed that end of growing-season biomass represented the total available amount among all seasons, when there was no significant difference between exclosures and biomass sampling plots. The 1989 carrying capacity estimate would have been reduced by more than half (3.9 elk/km^2) had total end of season forage biomass been allocated among all seasons.

If a safe-use factor of 25% had been applied to treed vegetation types, which represented ~90% (Florkiewicz 1994) in 1989, the resulting forage biomass estimate would have been reduced by 59%. This factor is important because treed vegetation types covered 80% of the study area in 2008 (Table 2), or ~900 ha less than in the 1989 study. Differences in cover percentages were likely due to more precise mapping of the area in 2008. Further contributing to the difference in carrying capacity were 30–60% lower elk forage intake rates (Point iii), which would have increased the number of elk capable of being supported within the study area. Finally, mule deer and horse diets were not included in the 1989 carrying capacity assumptions, and though their diets are not identical to those of elk, they all forage from the same finite supply. Forage eaten by these other species should be removed from the amount available to elk. When these differences in calculation were taken into consideration, the 1989 carrying capacity would be between 0.6 and 1.0 elk/km^2.

The current carrying capacity model was based on many assumptions with varying degrees of uncertainty that affect the sensitivity of the calculations. Sensitivity of a model considers whether changing an uncertain variable has a large or small effect on the overall result (Lilburne and Tarantola 2009). The number of horses and mule deer within the study area was speculative, and greatly impacted the outcomes of the model. The carrying capacity model was less sensitive to the number of mule deer than to the number of horses (Table 15), because horses consume more forage than either elk or mule deer, and share a diet similar to elk (Olsen and Hansen 1977). Many species were not assigned a forage rating based on the literature, but may be consumed by elk in the study area. This likely provided an underestimate in the forage index values. Browse consumption was also an important assumption, with a high degree of uncertainty. Browse (shrub and tree twigs) was a potentially important component of elk, deer, and horse winter diets, but was not measured. The carrying capacity model was very sensitive to the percentage of browse incorporated into the elk winter diet, a more specific diet analysis, through compositional analysis of fecal pellets would further refine the carrying capacity.

Mean temperature was 13° vs. 11°C and total precipitation was 84 vs. 154 mm during the 1989 and 2008 May to August study periods, respectively (Meteorological Service of Canada 2009). It is unlikely that differences in temperature significantly decreased the forage biomass production and the carrying capacity of the study area between 1989 and 2008. Differences in precipitation probably resulted in greater forage production in 2008. But not substantially beyond normal based on the 30-year summer precipitation average of 126 mm (Meteorological Service of Canada 2009).

Changes in vegetation occur over time, and differences between cover types in 1989 and 2008 may be due to natural vegetation development. *Populus tremuloides* stands have regenerated slowly since the 1958 fire (Hogg and Wein 2005), and it has been suggested that browsing by elk may be one of the causes (Yukon Elk Management Planning Team 2008). It was only after 2004 that the population was believed to be >100 elk (Florkiewicz et al. 2007). The 1989 population density of 0.6 elk/km^2, and the current density of 0.8 elk/km^2 (i.e., 144 elk/(95 km^2/0.56)), were both below levels that affect *Populus tremuloides* recruitment and growth on other ranges. Elk densities of ~9 elk/km^2 in Yellowstone National Park (Halofsky and Ripple 2008) and 4 elk/km^2 in Rocky Mountain National Park (White et al. 1998) began to affect the growth of *Populus tremuloides*. It is unlikely that the low elk densities in the past <0.6 elk/km^2 until 2004 had important effects on *Populus tremuloides*. The slow rate of regeneration since the fire is more likely a result of the moisture-limited environment (Hogg and Wein 2005), and the solonetzic type soils in the large *Populus tremuloides*–nontreed interspersed areas, rather than intensive browsing by elk.

Although the carrying capacity was lower in the Takhini Valley study area than in more southern ranges (Elk Island National Park – Bork et al. 1997b, Nevada – Beck et al. 2006, and western Alberta – Morgantini and Hudson 1989), it is likely greater than in surrounding areas. Differences among the carrying capacities are likely similar to those encountered when comparing this carrying capacity to that of the previous study from 1989; daily forage intake, competition with other foragers, and safe-use factor inclusion, as well as the cold, semi-arid climate of the study area. The Takhini Valley study area has a mixture of vegetation types that are not typical to the surrounding areas, including the highly productive *Rosa acicularis–Fragaria virginiana* and *Calamagrostis pupurascens* vegetation types. The *Populus tremuloides*-dominated vegetation types within the study area produced much more forage than the common coniferous types (Table 7), and do not form a large part of forest cover in southwestern Yukon (Orloci and Stanek 1979). Conversion of the study area to *Populus tremuloides* after the 1958 burn likely increased forage availability, supplementing the vegetation available on the dry southern slopes and increasing the overall carrying capacity of the study area. These vegetation types were important to elk, but only 31% of elk telemetry locations are within the study area during the winter and 86% during the summer, indicating that elk were foraging outside of the study area to sustain their current population size.

Conclusions

The current elk population (144+ animals) appears to exceed the winter ecologically-based forage carrying capacity of the study area, 72 to 144 elk (Scenario 7). The study area, however, did not include the entire range of the herd, and the number that the entire current range would support is unknown, but is greater than that of the study area alone. If the winter forage carrying capacity for the local range (~170 km^2) and the study area (0.76–1.52 elk/km^2) are the same, it would appear that elk are within the local range's carrying capacity of 129–258 animals. The same limitation does not apply to other seasons and indicate a minimum carrying capacity is ~295 for the range (i.e., 165 elk/0.56). This value would vary based upon estimates of lesser or greater winter browse intake, with different horse and mule deer population sizes. It is critical to include actual elk, horse, and mule deer diet composition, range size and overlap, and a measure of the amount of browse available in the study area to determine a more accurate carrying capacity estimate for the study area. Moreover, the application of safe-use factors developed for Alberta rangelands, as well as potentially high forage consumption value of 3% of body weight/day may have resulted in a conservative estimate of carrying capacity.

MANAGEMENT OPTIONS AND FUTURE RESEARCH NEEDS

Management Options

More information is needed to more accurately determine an ecologically sustainable stocking level for the study area, but some management options are presented below for consideration. If the management objective is to maintain the elk population in the Takhini Valley study area at an ecologically sustainable level, the following suggestions might lead to the desired results.

If graminoids are the main component of elk diets, range management practices could be implemented to increase production within the elk range. These practices should compensate for decreases in forage availability due to successional changes over time. The oldest stands in the study area were those of the *Picea glauca//Hylocomium splendens* type (779 ha), which produced the least amount of forage among the recognized vegetation types. All of the *Picea glauca* vegetation types produced less graminoid biomass than *Populus tremuloides* types (Table 7), and it is likely that in time many of the *Populus tremuloides* stands will converted to *Picea glauca* and result in reduced forage availability, especially graminoids. Preventing the conversion of *Populus tremuloides* to *Picea glauca* stands would likely maintain the forage supply.

The best sites for improving forage production are the large mixed *Populus tremuloides* and nontreed vegetation areas, especially those to the south of the Alaska Highway (~1000 ha), and the *Populus tremuloides* stands (~ 200 ha) on south aspects. This former vegetation type is important spring and summer habitat, and the associated nontreed areas produce the greatest amounts of forage; and the latter is important during the winter when south slopes have less snow cover.

Prescribed burning could be used to reduce tree cover and increase graminoid, forb, and shrub production (Bork et al. 1997a), partially by increasing the amount of light that reaches the herb stratum. Light availability is an important resource in the boreal forest, and increasing light increases species richness and abundance in the stand understory (Hart and Chen 2008). Burning during spring is the best time to reduce *Populus tremuloides* regrowth by suckering (Haeussler et al. 2007), but can have a short-term negative effect on forage abundance (Quinlan et al. 2003). High intensity foraging of *Populus tremuloides* suckers in burned areas might also reduce their regrowth (Edenius and Ericsson 2007). If prescribed burning is not an option, selective cutting of *Populus tremuloides* stands in these areas would have a similar effect. Herbicide use is also an option to reduce tree cover (Mastro et al. 2008), but likely a controversial method (Rea 2003). Removing *Populus tremuloides* trees from the suggested areas may encourage the more permanent spread of nontreed vegetation types which would in turn increase forage availability. Improving light conditions in a stand through thinning may also improve forage growth (Maundrel and Hawkins 2004). It is important that the stands be selected with access to cover in mind. Elk prefer foraging in areas close to cover (Collins and Urness 1983) and as such, not all of the *Populus tremuloides* stands should be removed. Due to the slow *Populus tremuloides* regeneration rate, management interventions will not need to be frequent, and the timing of when they should begin in order to optimize forage production is not known.

An alternative for maintaining elk carrying capacity at current levels, if successional changes reduce the forage supply, is to feed elk during the winter when forage is less accessible (Mastro et al. 2008). Winter-feeding would require more intensive management, and probably at a greater cost than other habitat improvement options. There are also drawbacks including possible introduction of non-native plant species, increased rates of disease, changes in habitat use, increased population size, and behavioural changes (Smith 2001).

If reducing the number of elk-vehicle collisions along the Alaska Highway is an objective, attention should focus on reducing the amount of time elk spend in the right-of-way. Modification of roadside vegetation should be considered instead of building fences or other such structures that could impede movement of elk from the important winter feeding sites on the south slopes to the north of the highway and the open areas to the south.

Removal of vegetation within 20–30 m of roads has been found to decrease ungulate-vehicle collisions (Jaren et al. 1991). If roadside vegetation were to be removed from along the Alaska Highway (Scenario 8, Table 14), the carrying capacity for the study area would decrease from 82 to 72 animals, when horses and mule deer were included in the estimate. Eliminating roadside forage would reduce the amount of time elk spend along the Alaska Highway. This is a technique that has proved effective (Jaren et al. 1991), but may not be possible in all areas because vegetation is often needed for roadside stability (Larson et al. 2001). Another drawback of this method is that it would likely require repeated use of herbicides to kill all vegetation. This would probably be unpopular with landowners and the community. Also, if browse forms a larger part of the elk diet than assumed in this study, the impact of removing roadside vegetation from the food supply would be less because roadsides are mainly composed of graminoids. Though they are important for elk foraging areas, the removal of roadside vegetation would not largely impact the carrying capacity of the study area because they form a small percentage of the total area (Table 2).

An alternative would be to reduce roadside vegetation. Trees and shrubs provide cover and forage for elk, and impede the vision of drivers, increasing the probability of collisions (Puglisi et al. 1974). Most of the vegetation along the Alaska Highway is <1 m tall, and the continued removal of any trees or shrubs within 30 m of the road would increase sightlines and reduce the possibility of collisions (Jaren et al. 1991). Removal of browse and preferred forage species would likely also reduce the amount of time elk spend along the highway (Rea 2003). Cutting or mowing the shrub vegetation at the correct time, late in the growing season, reduces the possibility that removing unwanted vegetation in one year increases the amount of unwanted vegetation in following years (Rea et al. 2007). More frequent mowing would minimize the amount of available forage, but at a greater financial cost.

In addition to removing preferred vegetation within the right-of-way, unpalatable species for elk could be seeded (Mastro et al. 2008). A decision between introducing a species that is unpalatable to elk, and maintaining a natural species composition would have to be made. Few species are completely unpalatable to elk, and the species seeded would have to be resistant to competition from existing species. Although the currently seeded agronomic species, *Bromus inermis*, has not invaded the natural vegetation, another introduced species might. It would be important to monitor any species that is planted along the roadside, and to minimize invasion into native vegetation types.

Modifying roadside vegetation will not prevent elk from occurring along the Alaska Highway, because the road runs through the centre of their home range. Therefore, other approaches such as behavioural modification through hunting (Frair et al. 2008), or aversive conditioning (Kloppers et al. 2005) might make elk more wary of the road could be considered. Driver behaviour can be modified through education and greater awareness. Signs are present along the Alaska Highway at both ends, and in the middle of the elk range reminding drivers to be aware of elk. The number of signs could be increased and their message updated to catch driver's attention. Lowering speed limits might also reduce the number of elk-vehicle collisions (Sullivan and Messmer 2003).

Management Recommendation

It is recommended that the elk population be maintained at a population size that is within ecologically safe limits and that does not impair the ecological functioning of the vegetation communities. The study area did not encompass the entire range of the Takhini Valley elk population, and data gaps need to be filled before a carrying capacity estimate can be produced for the entire range. Range management through thinning of *Populus tremuloides* stands, and the minimization of *Picea glauca* invasion may be helpful in maintaining forage availability. Removal of palatable vegetation along the Alaska Highway may decrease the amount of time that elk spend along the roadside. The critical outcomes of this study were the need for further investigation of elk diets, particularly the proportion of browse in the elk diet and the competition for forage with horses. These two factors strongly affect the carrying capacity of the study area, and any management interventions should be taken only after their degree of uncertainty is reduced through further study.

Future Research

Reducing the number of assumptions and the amount of uncertainty which is present in all model, increases the model's usefulness and accuracy. Many of the assumptions made in the calculation of carrying capacity for the Takhini Valley study area could be improved with further research, and could then provide the ability to apply these results to the entire range of the elk population. Studies that could provide valuable insight into other aspects of the elk habitat use, diets, and competition with other animal species in the study area include:

- Determination of elk, horse, and mule deer seasonal diets in the study area and the immediately surrounding area.
- Determination of the actual use of the elk range, and forage offtake estimates for each of the three species.
- Determination of the amount and types of browse available to elk within the study area.

- Determination of the number of horses and mule deer that use the elk range.
- Evaluation of resource partitioning and competition for forage among elk, horses, and mule deer for the range.
- Monitoring elk distribution patterns along the Alaska Highway and changes in elk-vehicle collisions in relation to management interventions.

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APPENDIX I: Species Listing

Animals

Alces americanus L.
Canus latrans Say
Canus lupus L.
Cervus elaphus L.
Equus ferus caballus L.
Lepus americanus Erxleben
Odocoileus hemionus Rafinesque
Spermophilus parryii Richardson
Ursus arctos L.

Vascular plants, lichens, and mosses

Abietinella abietina (Hedw.) Fleisch.
Achillea millefolium L.
Achnatherum nelsonii ssp. *nelsonii* (Scribn.) Barkworth
Androsace spetentrionalis L.
Anemone multifida Poir.
Antennaria microphylla Rydb.
Antennaria rosea Greene
Aquilegia brevistyla Hook.
Arabis holboellii (Fern.) Rollins
Arabis drummondii Gray
Arabis hirsuta (L.) Scop.
Arctostaphylos rubra (Rehd. & Wilson) Fern.
Arctostaphylos uva-ursi (L.) Spreng.
Arnica cordifolia Hook.
Artemisia campestris L.
Artemisia frigida Wild.
Astragalus agrestis Dougl. ex G. Don
Astragalus alpinus L.
Astragalus bodinii Sheldon
Aulacomnium palustre (Hedw.) Schwaegr.
Brachythecium salebrosum (Web. & Mohr) Schimp. in B.S.G.
Bromus inermis Leyss.
Bromus pumpellianus Scribn.
Bryum caespiticium Hedw.
Calamagrostis purpurascens R.Br.
Carex concinna R. Br.
Carex rossii Boott
Carex duriuscula C.A. Mey.
Carex supina Willd. ex Wahlenb.
Carex tahoensis Smiley
Ceratodon purpureus (Hedw.) Brid.
Cetraria ericetorum Opiz
Cetraria islandica (L.) Ach.
Chamaerhodos erecta (L.) Bunge
Cladonia chlorophaea (Flörke ex Sommerf.) Spreng.
Cladonia coniocraea (Flörke) Spreng.
Cladonia ecmocyna Leighton
Cladonia fimbriata (L.) Fr.
Cladonia gracillis (L.) Willd.
Cladonia mitis Sandst.
Cladonia phyllophora Ehrh. ex Hoffm.
Cladonia pyxidata (L.) Hoffm.
Cladonia squamosa (Scop.) Hoffm.
Deschampsia caespitosa (L.) Beauv.
Dicranum acutifolium (Lindb. & Arnell) C. Jens. ex Weinm.
Dicranum brevifolium (Lindb.) Lindb.
Dicranum elongatum Schleich. ex Schwaegr.
Dicranum fuscescens Turn.
Elymus calderi Barkworth
Elymus trachycaulus (Link) Gould ex Shinners
Empetrum nigrum L.
Equisetum scirpoides Michx.
Erigeron compositus Pursh
Erysimum cheiranthoides L.
Eurybia sibirica (L.) Nesom
Festuca altaica Trin.
Festuca brachyphylla J.A. Schultes ex J.A. & J.H. Schultes
Festuca saximontana Rydb.
Flaviocetraria nivalis L.
Fragaria virginiana Duchesne
Galium circaezans var. *circaezans* Michx.
Gentianella propinqua (Richards.) J. Gillet
Geocaulon lividum (Richards.) Fern.
Geum aleppicum jacq.
Hedysarum alpinum L.
Helictotrichon hookeri (Scribn.) Henr.
Hordeum jubatum L.
Hylocomium splendens (Hedw.) Schimp. in B.S.G.

Appendix I. Concluded.

Chamerion angustifolium ssp. *angustifolium* (L.) Holub
Cladonia cornuta (L.) Hoffm.
Cladonia rangiferina(L.) Weber ex F.H. Wigg.
Cladonia amaurocraea (Flörke) Schaerer
Cladonia botrytes (K.G. Hagen) Willd.
Cladonia cariosa (Ach.) Spreng.
Cladonia cenotea (Ach.) Schaer.
Linnaea borealis L.
Linum lewisii Pursh
Lupinus arcticus S.Wats.
Mertensia paniculata var. *alaskana* (Britt.) L.O. Williams
Mertensia paniculata var. *paniculata* (Ait.) G. Don
Minuartia rubella (Wahlenb.) Hiern.
Moehringia lateriflora (L.) Fenzel
Orthilia secunda (L.) House
Oxytropis campestris (L.) DC.
Oxytropis deflexa var. *foliolosa* (Hook.) Barneby
Oxytropis borealis var. *viscida* (Nutt.) Welsh
Parmelia sulcata Taylor
Pedicularis labradorica Wirsing
Peltigera aphthosa (L.) Willd.
Peltigera canina (L.) Willd.
Peltigera malacea (Ach.) Funck
Peltigera ponojensis Gyeln.
Peltigera rufescens (Weiss) Humb.
Penstemon gormanii Greene
Penstemon procerus Dougl. ex Graham
Phascum cuspidatum Hedw.
Physconia muscigenia (Ach.) Poelt
Picea glauca (Moench) Voss
Pinus contorta Dougl. ex Loud.
Poa glauca Vahl
Poa palustris L.
Poa secunda J. Presl
Pohlia nutans (Hedw.) Lindb.
Polemonium pulcherrimum Hook.
Polytrichum juniperinum Hedw.
Populus balsamifera L.
Hypnum cupressiforme Hedw.
Hypnum procerrimum Mol.
Juncus balticus Willd.
Juniperus communis L.
Juniperus horizontalis Moench
Lappula squarrosa (Retz.) Dumort.
Leptobryum pyriforme (Hedw.) Wils.
Populus tremuloides Michx.
Potentilla bimundorum Soják
Potentilla hookeriana Lehm.
Potentilla pensylvanica L.
Ptilidium pulcherrimum (G. Web.) Hampe
Pyrola chlorantha Sw.
Rhytidium rugosum (Hedw.) Kindb.
Rosa acicularis Lindl.
Salix arbusculoides Anderss.
Salix bebbiana Sarg.
Salix glauca L.
Salix planifolia Pursh
Salix scouleriana Barratt ex Hook.
Saxifraga tricuspidata Rottb.
Scleropodium cespitans (C. Müll.) L. Koch
Sedum lanceolatum Torr.
Senecio lugens Richards.
Packera paupercula (Michx.) A.& D. Löve
Senecio strepthanfollius Greene
Shepherdia canadensis (L.) Nutt.
Solidago simplex Kunth
Stellaria longipes Goldie
Stereocaulon tomentosum Fr.
Taraxacum officinale G.H. Weber ex Wiggers
Tortula ruralis (Hedw.) Gaertn. et al.
Trisetum spicatum (L.) Richter
Vaccinium vitis-idaea L.
Viburnum edule (Michx.) Raf.
Xanthoparmelia chlorochroa (Tuck.)
Zigadenus elegans Pursh

APPENDIX II: Sampling Forms

PLOT __-____ Tentative Community Type _______________________

DATE ___/____ 2008 UTM 08V E __ __ __ __ __ __ N __ __ __ __ __ __ __

SPECIES	A	B	C	D	E	M	SPECIES	A	B	C	D	E	M
Trees >2.5 m tall (20 m x 30 m plot)													
Tall Shrubs 1-2.5m tall (2.5 x2.5 m plot)													
							Nonvascular Ground Plants (1 x1 m plot)						
Herbs <1 m tall (1 x1 m plot)													
							Total Tree						
							Total Tall Shrub						
							Total Shrub <1m						
							Total Forb						
							Total Graminoid						
							Total Moss						
							Total Lichen						

Appendix II. Concluded.

Humus Form Description			Profile Description				
Horizon	cm	Characteristics	Horizon	cm	Texture	Struct	Colour

Humus Form ____________/________ Soil________/________/_________

Depth to mottles **none faint** ____**distinct**____**prominent**____ **gleying**____

Depth to water table _____cm   Parent Material **F G L E Q W M**

Drainage Class ______Moisture Regime _______Nutrient Regime _______

Aspect _____*   Slope _______%   Topography _________________

Point Centered Quarter-Density

	0-m			**15-m**			**30-m**		
	Species	**Dist**	**Dia**	**Species**	**Dist**	**Dia**	**Species**	**Dist**	**Dia**
1									
2									
3									
4									
-									

Representative Trees

	Species	**Dist(m)**	**Top(%)**	**Bottom(%)**	**Sum**	**Height(m)**	**DBH(m)**	**Age**
1								
2								

Photos

	Photo	**Time**
1	Down Transect	
2	Plot 1	

APPENDIX III: Plot Data

See CD-ROM

APPENDIX IV: Table 14 Carrying Capacity Calculations

See CD-ROM