"SHRUBWATCH" MONITORING
BOW VALLEY, BANFF NATIONAL PARK
BASELINE ANALYSIS FOR THE PERIOD 1990 TO 2006

March, 2011 (minor revisions on 2016/08/12)

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Citation:
White, Clifford A., A. Buckingham, and M. Hebblewhite. 2011 (revisions 2016). "Shrubwatch" Monitoring, Bow Valley Banff National Park: Baseline for Period 1990-2006. CW & Associates. Technical Report to Parks Canada, Banff, Alberta. 56p.

1. INTRODUCTION

The long-term ecosystem states and processes of eastern slope, Rocky Mountain ecosystems have been altered by numerous effects tied to European settlement. Main effects include the end of subsistence hunting, gathering and burning by First Nations, the extirpation of plains bison (*Bison bison*), increases in ungulate populations such as elk due to predator control, displacement of predators due to high human use, effects of highways on wildlife populations, and fire suppression. In Canada's national parks, recent legislative changes (Government of Canada 2000) require that:

Maintenance or restoration of ecological integrity, through the protection of natural resources and natural processes, shall be the first priority of the Minister when considering all aspects of the management of parks.

Ecological integrity" means, with respect to a park, a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes.

Based upon a synthesis of knowledge and stakeholder direction from the Banff Bow Valley Study (1996), the Banff National Park Management Plan (BNP, 1997, updated 2004/2008, p. 19) recognized that for park vegetation, there was "decline in biodiversity in some areas, specifically aspen, open conifer, and young pine stands", and specified a goal "to maintain, and where feasible, restore native vegetation communities to reflect long-term ecosystem states and processes." Moreover, the 1997 plan (p. 21) acknowledged that altered predator/prey relationships might be cause of vegetation decline, and required the park "to maintain viable populations of wary species such as grizzly bear, wolf, wolverine and cougar", "to restore long-term patterns of behaviour, distribution, and abundance of ungulates," and to "restore predator/prey relationships". Accordingly, in consultation with stakeholders and scientists, Parks Canada began an aggressive program of ecological restoration in the Banff Bow Valley (BBV) that included mitigation of highway effects, restoration of wildlife movement corridors around the Town of Banff, and prescribed burning (White et al. 2007). In combination with the recolonization of wolves to the BBV (Hebblewhite et al. 2002, 2005), these actions appear to have resulted in major ecosystem changes.

The research described here evaluates outcomes of the restoration program on woody plant height and cover, and generally relates this to predator and elk distribution patterns in the Banff Bow Valley (BBV) for the years 1990, 1998, and 2006. The focus is on developing and evaluating a browsing intensity monitoring and mapping system that can be applied over broad areas, and extrapolated back in time (by aging woody plant stems) to obtain baseline information. Further, the shrub monitoring system should be simple enough for use by volunteers and other stakeholders participating in Parks Canada's "Shrubwatch" citizen scientist program. Future work will provide more spatially-specific analyses tied to fine scale models of human, wolves, and elk use, and the potential productivity of woody plants.

2. BACKGROUND

Factors influencing browsing patterns in the Rocky Mountains can be conceptualized through a 4-level trophic model (Figure 2.0.1), greatly simplified here to focus on key species and processes for the Banff Bow Valley. “Bottom up” processes such as fire, site conditions and weather/climate influence the distribution and productivity key woody plant species trembling aspen and willow. These species in turn provide food and are influenced by herbivory by elk (and other species such as bighorn sheep and deer). Similarly, these herbivores provide prey for predators such wolves, cougars, grizzly bears black bears. At the top trophic level humans can influence all other trophic levels through top-down effects on demographics, behaviour or fire use or suppression.

One of the more serious cumulative ecosystem effects of recent regional-level landscape change in the Rocky Mountains is intense herbivory on woody plants, particularly in national parks where elk are not hunted, and where predation has been decreased by past carnivore control programs, current high human use, and removal of First Nations (White et al. 1998, Kay et al. 2000). In the Canadian Rockies numerous species of woody plants could be affected by browsing include trembling aspen, willow spp., and red-osier dogwood (White et al. 1998). High browsing rates may occur directly because a herbivore generalist, elk, dominates the ecosystem as opposed to grazing specialists such as bighorn sheep or browsing specialists such as moose and deer species (Flook 1964). Indirect factors causing high browsing rates a decline in fire frequency which causes an increase in the forest canopy which in turn suppresses browse plant productivity (White et al. 2003), or the effect of high elk numbers removing willows, and in turn beaver activity, which further reduces shrub habitat (Flook 1964, Nietveldt 1998, Hebblewhite et al. 2005).

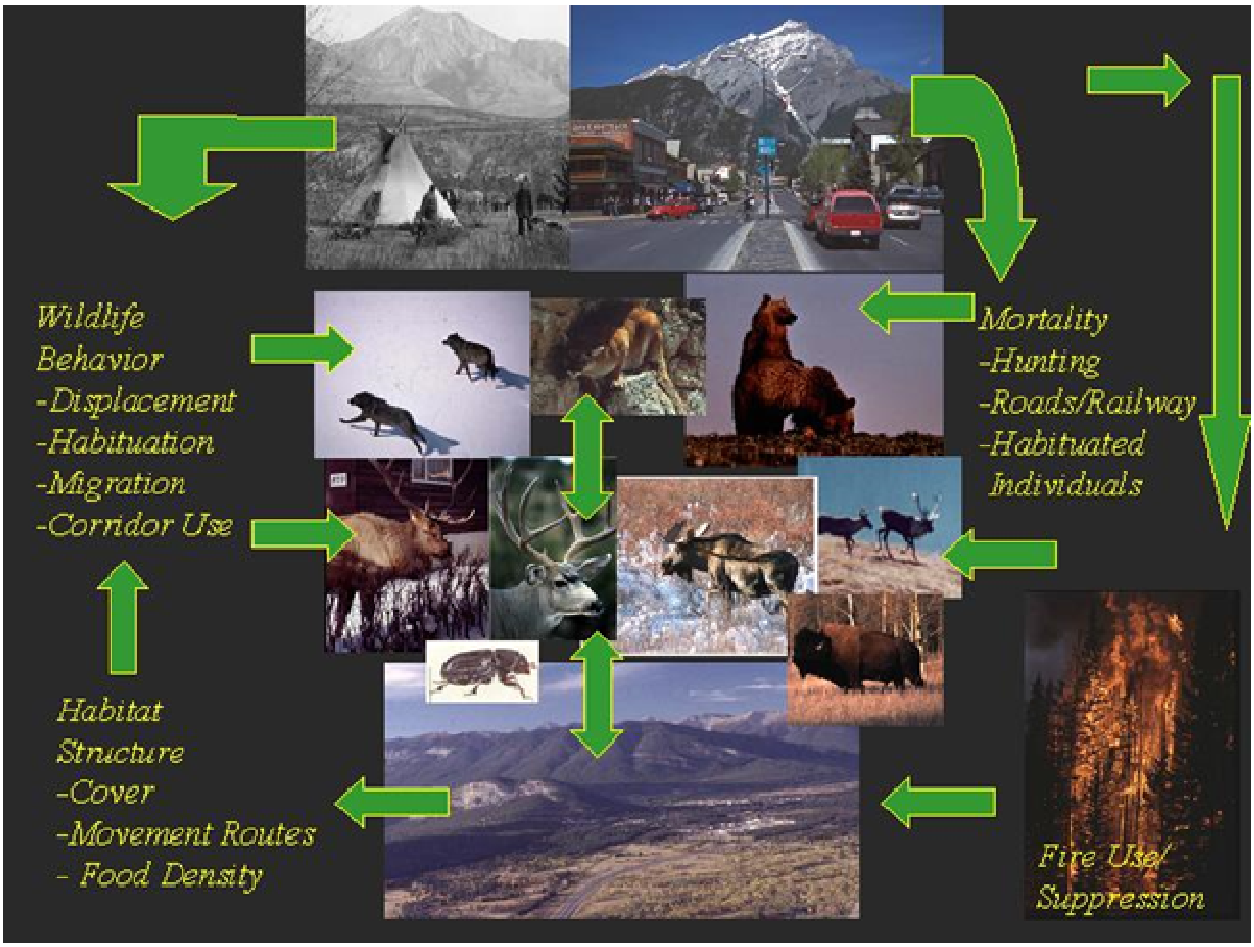

Figure 2.0.1. A simplified pictorial trophic model showing how humans, past and present (top tier) influence vegetation and habitat conditions (bottom tier) through fire use and suppression, direct wildlife mortality effects (hunting, roads/railroads etc.), and altered wildlife behaviour patterns (displacement, habituation, corridor use etc.).

2.1 History of Elk in the Banff Bow Valley

Archaeological and detailed explorer journal analyses indicate that elk were relatively rare (<10% of total ungulates observed) in the eastern slopes during the prehistoric and historic periods (Kay et al. 1999, 2000). Intense human exploitation during the late 1800s extirpated elk from Banff. In 1918 and 1920, park managers released a total of 235 elk into the Bow Valley (Lloyd 1927). Population simulation modelling (White 2001) indicates that the population likely increased rapidly due to few predators (Holroyd and Van Tighem 1983) to over 4000 elk by 1940. In addition, elk dispersed widely out of the Bow Valley into adjacent watersheds (Morgantini and Hudson 1988).

By 1940, biologists identified elk browsing effects on the winter ranges of both the BBV and Jasper National Park (Cowan 1947, Flook 1964). Park wardens culled at least 3900 elk from the Banff between 1943 and 1969 (Holroyd and Van Tighem 1983). Simulation modelling (White 2001) indicated these culls, in combination with railroad and highway mortality could have reduced elk numbers to <200 in the BBV by the latter 1960s. Elk culling ceased in Banff in 1969 when many western national park managers began to emphasize the use of food limitation and carnivore predation as potential means of regulating elk numbers (Cole 1971). With no culls, low predator numbers in the Bow Valley, and ongoing fencing of the Trans Canada Highway beginning in 1983 to minimize vehicle strikes (Woods 1991, Clevenger et al. 1998), elk numbers increased in the BBV to a maximum of nearly 1000 in 1991 (Figure 2.1.1). Wolves recolonized the valley in 1985 (Paquet et al. 1996), and by 2000 had, in eastern and western areas of the valley, reduced elk numbers by >80% from 1990 levels (Figures 2.1.1, Hebblewhite *et al*. 2002). In the central area near the town of Banff high human use prevented wolf predation, and elk numbers increased between 1990 and 1995, likely due to low predation rates, and possibly some dispersal in the central zone from areas east and west where predation risk was higher (McKenzie 1998).

After 1995, high densities elk near the town of Banff caused significant risks to public safety and high herbivory impacts. In response to these issues, Parks Canada (1999) implemented the Banff Elk Management Strategy with the objective of reducing human-elk incidents (aggressive reports, contact charges) by >75%, and reducing woody plant herbivory effects by maintaining the Bow Valley elk population at 100 to 300 with <100 elk in the area near Banff townsite. Key management actions included:

- Further reducing visitor use in several key wildlife corridors around the town in addition to the measures taken by the 1997 Park Management Plan (Parks Canada 1997) in order to increase carnivore use;
- Increasing use of low palatability native plant species in Banff townsite and golf course landscaping;
- Accelerating prescribed burning in areas away from the Town of Banff (White et al. 2003, 2004);
- In 2000, relocating 217 elk out of Banff National Park to the North Saskatchewan watershed on Alberta provincial lands (Friar et al. 2007);
- Using aversive conditioning (herding elk with dogs and people) to move habituated animals out of the town (Kloppers et al. 2005);

- Periodically blocking wildlife crossing structures across the Trans Canada Highway with fences to keep elk away from the town, and in areas with higher predation risk north of the highway;
- With the assistance of First Nations, selective culling of <20 human-habituated elk per year near the town.

As a result of these actions, elk numbers in the area near Banff townsite declined from over 500 in 1995 to 100 in 2002 (Figure 2.1.1). A large part of this reduction likely occurred due to intense use of wildlife corridors around the Town of Banff by the Fairholme Wolf Pack, moving in from east (Duke et al. 2001). However, after 2002, this pack dispersed, and elk numbers began to increase near the townsite, possibly due to continued elk immigration from nearby zones (Howard 2006). Since 2006, elk numbers near Banff have been maintained at approximately 200, largely due to selective culling.

Hebblewhite (2008) modelled fine scale elk habitat use patterns for the period 1997 to 2000 from a dataset of radio-collared elk (Mckenzie 1999). Key habitat variables influencing habitat use were distance from the town of Banff, distance from roads, degree of habitat openess, elevation and slope. Elk selected open, flat areas near the Town of Banff and near roads (Figure 2.1.2).

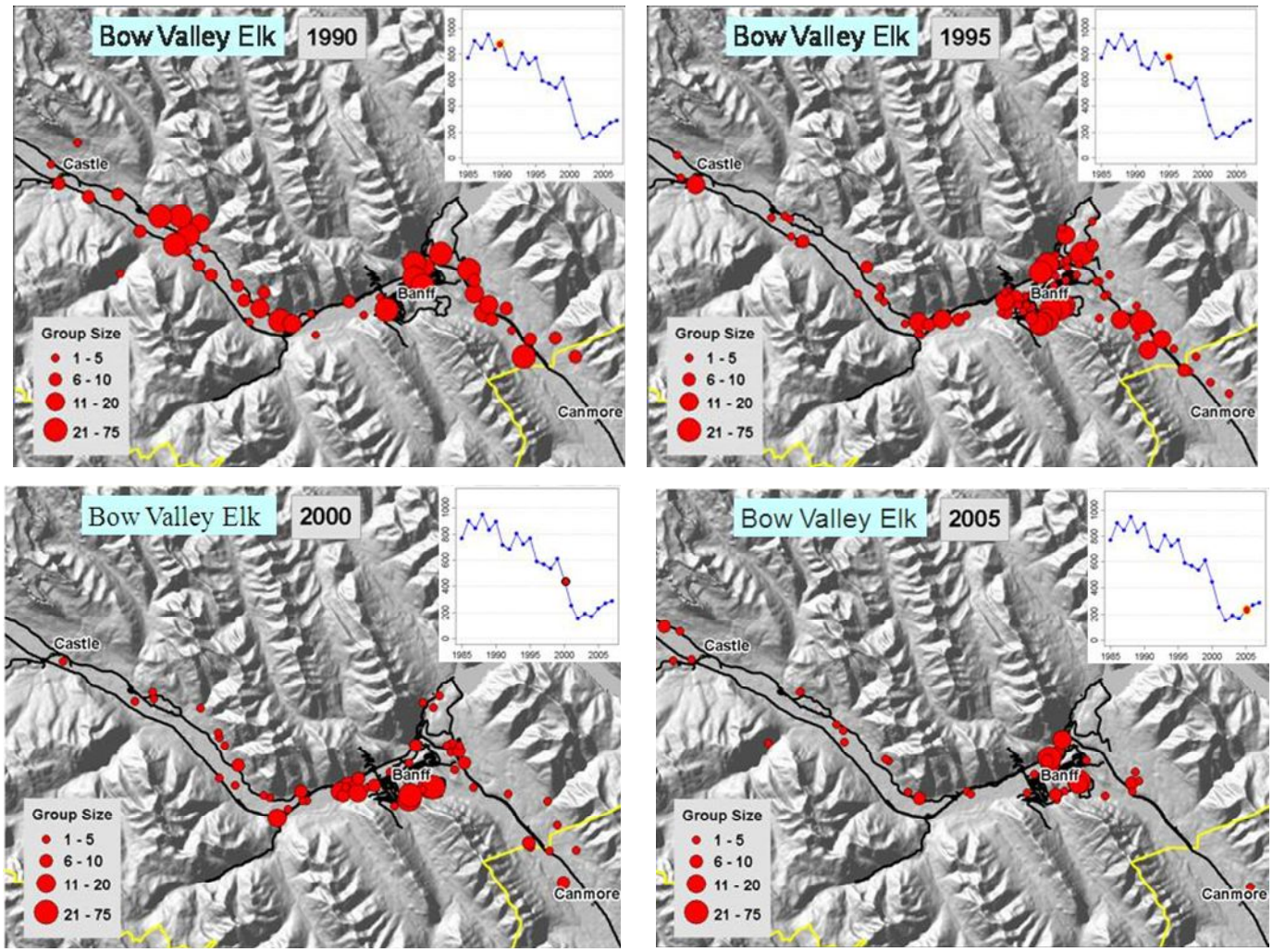

Figure 2.1.1. Elk population and distribution in the Banff Bow Valley from spring wildlife surveys for 1990, 1995, 2000, and 2005 (from Whittington 2006).

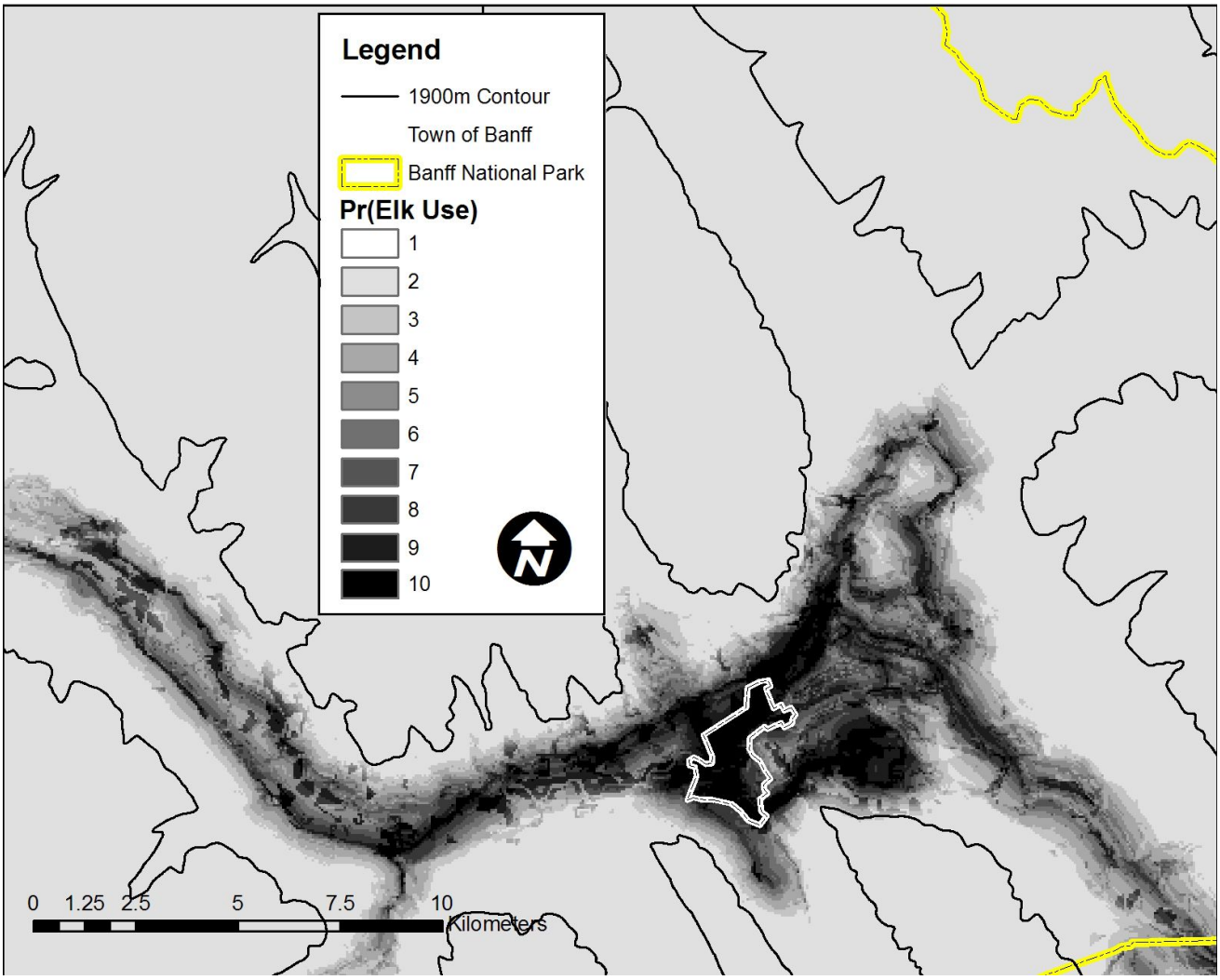

Figure 2.1.2. Resource selection function for elk during winters 1997-2000 in Bow Valley of Banff National Park. Areas above 1900m were not modelled (from Hebblewhite 2007).

2.2 Historical Woody Plant Herbivory Monitoring in the Banff Bow Valley

Over 30 species of wood plants may be influenced by herbivory in the Banff Bow Valley (Table 2.2.1). Quantitative evaluation of elk browsing effects began at the start of the elk culls in the 1940s. Monitoring occurred inside and outside of several wildlife exclosures located along the bottom of the valley (Webb 1957, Trottier and Fehr 1981). Interestingly, although willow cover and height increased outside of exclosures, no large pulse of aspen regeneration occurred during the period of low elk numbers in the 1960s (Trottier and Fehr 1981; White et al. 1998, 2003). In 1996, the herbivory monitoring system expanded to >15 exclosures (Eastern Slopes Rangeland Seeds slope Seeds 1996, 1999, 2001), and also to including using the Trans Canada Highway wildlife exclusion fence as a longitudional transect through the valley for monitoring browsed/unbrowsed effects (White 2001). However, the repeated measures monitoring design provided by the inside-outside wildlife exclosure monitoring system has several weaknesses:

- The existing exclosures are generally on the valley bottom, and may not reflect elevational gradients in changing herbivory patterns;
- The existing exclosures are generally <50m from unfenced roads, railroads, or heavily used trails, and may not reflect herbivore avoidance of these routes that may be heavily used by wolves;
- Few exclosures are located in areas far from Banff townsite where predation effects on elk may be highest;
- The existing exclosures areas may not include relatively rare shrubs or tree species.
- Few exclosures are located in recently burned areas where increased shrub production or downed wood may influence herbivory rates (Ripple and Larsen 2001, White et al. 2003)
- Exclosure monitoring methods (Trottier and Fehr 1983, Eastern Slopes Rangeland Seeds 1996) are relatively complex and time consuming.
- The vegetation response observations may be partially tied to ungulate's response predation risk near exclosures. In areas with low elk and higher predator densities, elk appear to avoid dense vegetation (White et al. 2003), and areas upslope of fences (CW personal observation, the Muleshoe exclosure is a prime example). This effect confounds data from outside exclosure transects.

As a result of these limitations, park biologists explored options for to move from a point-based to an area based monitoring design including most the Banff Bow Valley.

Table 2.2.1. North American (Kufeld 1973, Nelson and Leege 1982) and Alberta (Tannas 2003) ratings ratings of forage value for woody plant species (>.3m in height) present at low elevations (<1900m) observed in the the Bow Valley of Banff National Park (from the Ecological Land Classification Database, Achuff and Corns 1983).

Species/ Code	Common Name	Seasonal Forage Use Rating					Remarks on applicability to Banff National Park
		Win	Spr	Sum	Fall	All	
Abies lasiocarpa ABLA	subalpine fir	M[1]				L[2]	Possibly heavily used where it does occur in montane ecoregion
Acer glabrum ACGL	Douglas maple	M[1]	L[1]	H[1]	M[1]	M[2]	
Alnus crispa ALCR	green alder	L[1]			L[1]	L[2]	
Alnus tenufolia ALTE	river alder						Uncommon in Banff Bow Valley
Amelanchier alnifolia AMAL	Serviceberry	H[1]	M[1]	H[1]	M[1]	H[2]	
Betula glandulosa BEGL	bog birch	M[1]				M[2]	
Betula pumila BEPU	dwarf birch					M[2]	
Betula occidentalis BEOC	water birch					M[2]	
Betula papyrifera BEPA	white birch					M[2]	
Cornus stolonifera COST	red osier dogwood	M[1]		H[1]	M[1]	H[2]	
Eleagnus commuta ELCO	wolf willow	H[1]				M[2]	Only moderately palatable in Banff
Juniperus communis JUCO	common juniper	L[1]				L[2]	
Juniperus horizontalis JUHO	creeping juniper	L[1]				L[2]	
Juniperus scopularum JUSC	Rocky Mtn. Juniper	M[1]	L[1]		L[1]		May be consistently moderately used in Bow valley
Ledum groenlandicum LEGR	Labrador tea	M[1]				L[2]	
Lonicera dioica LODI	twining honeysuckle	M[1]					Easily mechanically damaged by elk at high densities
Lonicera involucrate LOIN	bracted honeysuckle					L[2]	
Menziesia ferruginea MEFE	false azalea			M[1]	L[1]		
Picea glauca PIGL	white spruce					L[2]	Due to fire suppression and low palatability , cover increasing in Banff
Pinus contorta PICO	lodgepole pine	L[1]	L[1]		L[1]	L[2]	May have low palatability but easily killed by even light browsing
Pinus flexilis PIFL	limber pine				L[1]		
Populus balsamifera POBA	balsam poplar	L[1]				L[2]	Moderately used in Bow valley
Populus tremuloides POTR	trembling aspen	H[1]	H[1]	M[1]	H[1]	M[2]	

Potentilla fruticosa POFR	shrubby cinquefoil	L[1]		L[1]	L[1]	L[2]	Very lightly used under even high elk densities in Banff
Pseudotsuga menziesii PSME	Douglas-fir	L[1]	L[1]	L[1]	L[1]	L[2]	May be browsed when elk densities are moderate in Banff
Prunus virginiania PRVI	choke cherry	H[1]	M[1]	M[1]	M[1]	M[2]	
Ribes hudsonium RIHU	wild black gooseberry	L[1]		L[1]		L[2]	
Ribes oxycanthoides RIOX	wild gooseberry					L[2]	
Rosa acicularis ROAC	prickly rose	L[1]		H[1]	H[1]	M[2]	
Rosa woodsii ROWO	common wild rose					M-H[2]	Past episodes of intense herbivory may have reduced cover in Banff
Rubus spp. RUBUS	Raspberry			M[1]		L-M[2]	
Salix spp. SALIX	Willow	M[1]	M[1]	M[1]	H[1]	H[2]	
Salix barrattiana SABA	Barratt willow					H[2]	
Salix bebbiania SEBE	beaked willow	H[1]				H[2]	
Salix brachycarpa SABR	short-capsuled willow					H[2]	
Salix candida SACA	hoary willow					H[2]	
Salix drummondiana SADR	Drummond willow					M[2]	
Salix farriae SAFA						H[2]	
Salix glauca SAGL	smooth willow					H[2]	
Salix maccalliania SAMA	velvet-fruited willow					H[2]	
Salix myrtillifolia SAMY	myrtle-leaved willow					M[2]	
Salix pseudimonticola SAPS	mountain willow					H[2]	
Salix scouleriania SASC	Scouler's willow	M[1]	M[1]	L[1]	M[1]	H[2],VH[3]	
Sambucus racimosa SARA	Elderberry		M[1]	H[1]	L[1]	M[2]	
Shepherdia Canadensis SHCA	Buffaloberry					L-M[2]	Used when elk densities are moderate in Bow Valley
Symphoricarpus albus SYAL	Snowberry	M[1]	L[1]	M[1]	M[1]	L[2]	Easily mechanically damaged by high ungulate densities
Symphoricarpus occidentalis SYOC	Buckbrush					L[2]	
Viburnum edule VIED	highbush cranberry					M[2]	

[1]Kufeld (1973), Nelson and Leege (1982)

[2]Tannas (2003)

3. METHODS

To facilitate its use by Park Volunteer Program, we developed a rapid assessment system for herbivory effects that could be used across the BBV with minimum training or experience.

3.1 Field Procedures

Plot Locations: The primary elk wintering area of the BBV (Figure 2.1.2) was broken into approximately 160- 1 km^2 blocks using the UTM grid. Sampling intensity ranged from nearly every block near the town of Banff, to every other block 2-10 km from Banff to every third block >10 km from Banff. Within each block, depending on vegetation cover, observers attempted to sample each of the following cover types: grassland, aspen, tall shrub, open conifer, closed conifer, and recently disturbed (<20 years) by fire or mechanical harvesting (fire fuel breaks, powerlines, railway right-of-way etc.). In addition, a single plot was done within each of 14 wildlife exclosures in the Banff Bow Valley, and approximately an additional 10 plots were done within the exclosure formed by the Trans Canada Highway wildlife fence.

Plot Size/Configuration: For most cover types, observers used a 10 m^2 radius circular plot with 4 quarter circle subplots (divided by a cross slope and along the slope radii). In grasslands, observers used a circular subplot in the centre of the meadow, with 2 additional 10x10 m subplots at the nearest 2 shrub or tree ecotones. Where variable vegetation conditions were encountered with 100 m of the main plot (e.g. high deadfall, rare shrubs or trees), observers also did 1 or 2 additional subplots.

General Site Characteristics: Made at the centre of the main plot, these included aspect, elevation, slope angle, ecological land classification ecotype and vegetation type (Holland and Coen 1983). Four visibility measures at 1.8m height were made to the nearest meter upslope, downslope, left and right.

Shrub and Tree Observations: The percent cover of all tree and shrub species (Table 1) was ocularly estimated for the main plot. Within each subplot, the mean height of the tallest 3 stems of each species (<6m in height, and <20 years in age for tall species) was estimated to the nearest .1m, and whether each species was heavily browsed (>50% of twigs) in the last year (subscript “b”), or were releasing (>50% of twigs super-elongated) from past herbivory (subscript “r”).

Downed Wood and Rock: Observers estimated the cover of downed wood and rocks within each subplot. Similar to shrubs, the mean height of the 3 highest downed wood branches/logs and rocks was estimated to the nearest .1 m.

Herbivory Condition Class: Observers used a 4-level system based upon the height of the 7 common species (Table 2) to classify current (c. 2006) herbivory levels for plots not done inside exclosures. Using growth rings from cross sections cut at 2m height (aspen, balsam poplar, or willow), branch whorls (Keigley and Frisina 1997), or historic and repeat photographs (White and Feller 2004, White and Hart 2007), plot browsing class was also estimated for the years 1990, and 1998. This usually was not

difficult to classify because in most locations, browsing effects had systematically declined, and thus tree and shrub heights were monotonically increasing. Plots within wildlife exclosures were assigned a condition class of 0.

Elk Density: Winter elk density near the plot (Table 3.1.1) was estimated from pellet counts (for plots done from April through June), and from the spring Bow Valley elk surveys (Hebblewhite et al. 2001, Birch 2006).

Table 3.1.1. Tree and shrub heights (m) for woody species used to determine plot herbivory condition classes. Heights are for plants <6m in height.

Browsing palatability	**Plant Indicator Species (Species Code)**	**Herbivory Condition Class and Elk Density Estimate**			
		1 Low	**2 Mod**	**3 High**	**4 Very high**
		<1 elk/km^2	1-2 elk /km^2	2-4 elk/km^2	>4 elk /km^2
High	Trembling aspen (POTR)	>3	2-3	1-2	<1 or absent
	Willow (SALIX)	>3	2-3	1-2	<1 or absent
Moderate	Balsam poplar (POBA)	>4	3-4	1-3	<1 or absent
	Wolf willow (ELCO)	>3	2-3	1-3	<1 or absent
	Buffalo berry (SHCA)	>1.5	1-1.5	.5-1	<.5 or absent
Low	Shrub-like birch (BEPU, BEGL)	>2	>2	1-2	<1 or absent
	Shrubby cinquefoil (POFR)	>1.5	>1.5	1-1.5	<1

3.2 Data Analysis

All data was entered in an Access Database (Microsoft, Washington, USA) managed by the Banff Field Unit database section. Access query routines were used to generate plot mean heights and cover for species observed in plots observations for the year 2006. For this report, we used NCSS Statistical and Power Analysis Software (Hintze 2004) to prepare graphics of species height and cover.

We used ordinary kriging to interpolate broad scale browsing condition class patterns (for years 1990, 1998, 2006) based on trend removal at 100% local scale (Geostatistical analyst in ArcMap 8.1, Environmental Systems Research Incorporated , California, USA).

4. RESULTS AND DISCUSSION

Between 2005 and 2008, observers collected data on 797 plots including approximately 30 plots done within wildlife exclosures.

4.1 General Height Patterns of Woody Species Response by Browsing Condition Class

The height of the 7 species used to classify the browsing condition classes varies according to the classification rules (Table 3.1.1). Of most interest is how the height of numerous woody plant species change with the condition class assigned, how species heights vary in comparison to other species.

Trees- Figure 4.1.1 shows patterns of tree heights by condition class. With the exception of white spruce (PIGL) that is influenced only marginally by herbivory, all other tree species heights decline dramatically as herbivory effects increase. Trembling aspen (POTR) and balsam poplar (POBA) have similar heights in exclosures (CC0), but the height of aspen declines more rapidly as herbivory level increases. Lodgepole pine (PICO) heights appear to decline marginally more rapidly than Douglas-fir (PSME), but both species heights decline significantly with herbivory level. This pattern general pattern of response by most tree species indicates that some meadow areas in Banff such as the Green Spot on Mt. Norquay, may be the partially the result product of intense herbivory, and that the general forest cover of the Bow valley indicates a long-term pattern of lower herbivory levels that has allowed species of tress to routinely reach heights over 6m over for many centuries as evidenced by the range of ages found across the valley (Rogeau and Gilbride 1994).

Tall Shrubs- Figure 4.1.2 shows the height patterns of tall shrubs (often reaching heights greater than 2m) by condition class. Almost all shrubs in this group decline consistently with herbivory with the exception of green alder (ALCR) that is very lightly browsed even when other species have been greatly reduced in height. Water birch (BEOC) also is relatively resistant to herbivory compared to the willow genus (SALIX spp), or Scoular's willow (SASC), but at higher herbivory rates it too declines to a condition of where the mean heights of the tallest species in the plots was only about 1m. At CC4, species of tall shrubs that virtually disappear from plots include- red osier dogwood (COST), and all species of the willow genus.

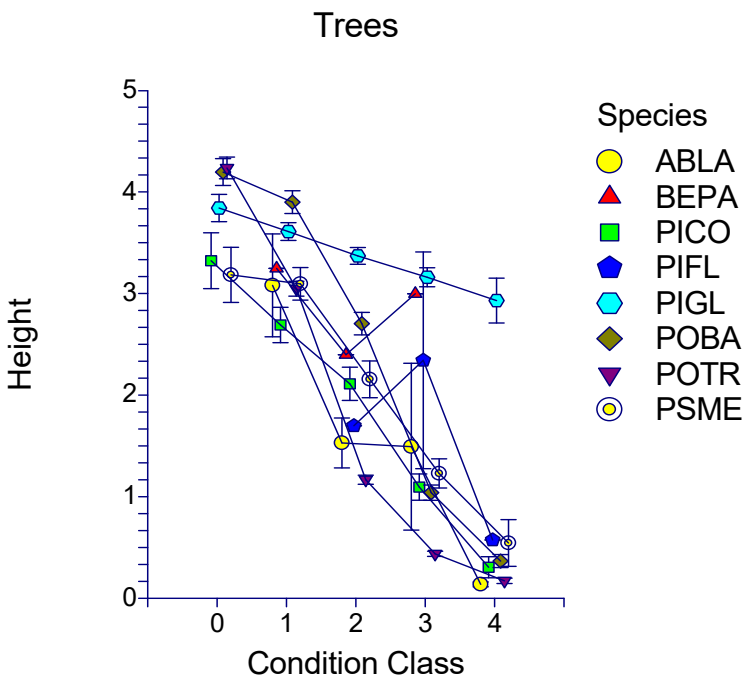

Figure 4.1.1. Mean plot height for tallest individuals of tree species by browsing condition class. Plots within wildlife exclosures are assigned a Condition Class of 0.

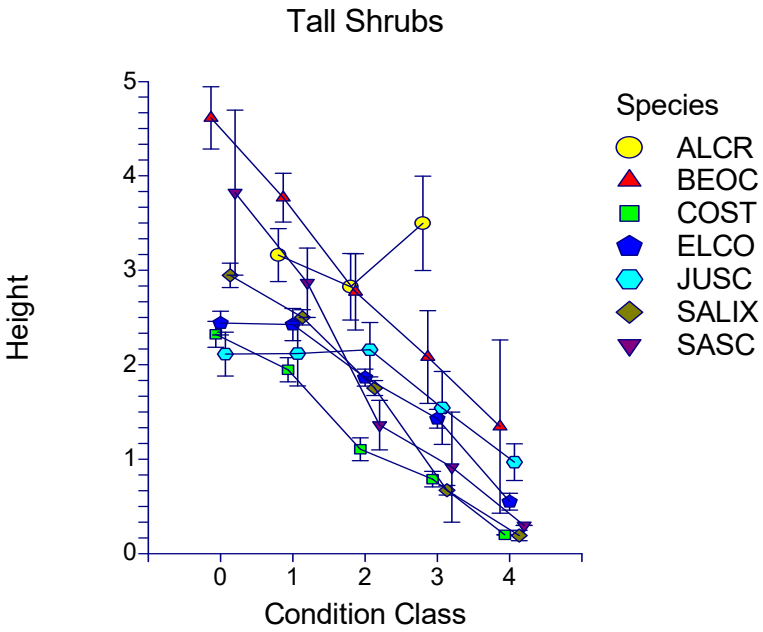

Figure 4.1.2. Mean plot height for tallest individuals of tall shrubs by browsing condition class. Plots within wildlife exclosures are assigned a Condition Class of 0.

Relatively Palatable Shrubs- For illustration of height patterns, palatable shrub species that are usually less than 2m in height are divided into commonly found species (Figure 4.1.3), and rarely found species (Figure 4.1.4). Buffalo berry (SHCA)is the shrub used to help define herbivory class (Table 3.1.1) in the group of shrubs that are most commonly observed. Its height remains relatively consistent in lightly browsed condition classes (0, 1,2), although the heights of other plants such as trembling aspen (POTR) or willow (SALIX) do decline markedly as browsing increases in these classes (Figures 4.1.1, 4.1.2). Saskatoon (AMAL) shows the greatest overall height decline, and was not even observed in areas in condition class 4. Prickly rose (ROAC) also declines in height consistently, and is greatly stunted in growth at CC4. Within the group of rarely found shrubs, Douglas maple (ACGL) appears to show the strongest declines as herbivory rates increase, although its habitat in rocky areas did protect a few individuals in CC4. Other members of rarely found palatable shrubs are observed i n plots classified at this condition class, and are likely nearly eliminated by herbivory in these areas.

Relatively Inpalatable Shrubs- In this group, only the birch species, bog birch (BEGL), and dwarf birch (BEPU) were used to define condition classes. Due to relatively poor palatability, the heights of these two species does not decline markedly (Figure 4.1.5) at lower condition classes (CC0, CC1, CC2) when other more palatable indicator shrubs such as willow (SALIX)are highly used (Figure 4.1.3). However, by CC3, birch heights do decline, and neither species were even recorded in the CC4 plots. A number of inpalatable shrub species persist across the condition class gradient. Most notably is shrubby cinquefoil (POFR) that will persist under all but the highest herbivory impact conditions.

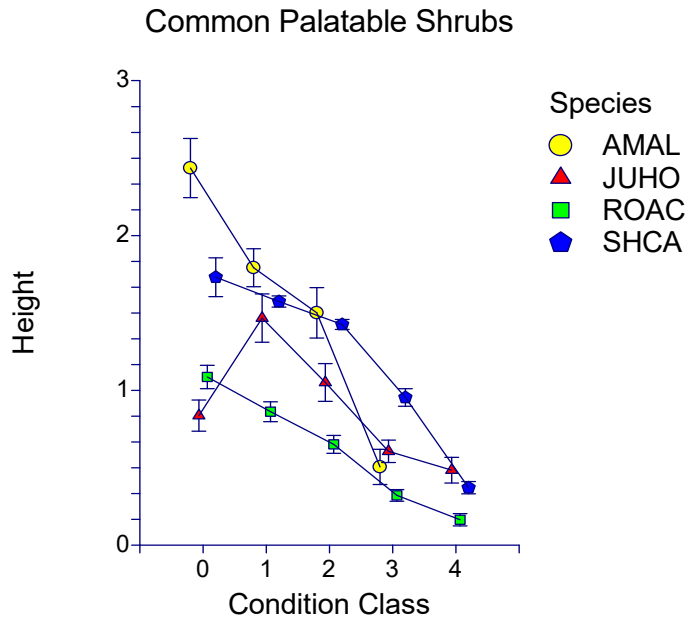

Figure 4.1.3. Mean plot height for tallest individuals of commonly found palatablel shrubs by browsing condition class. Plots within wildlife exclosures are assigned a Condition Class of 0.

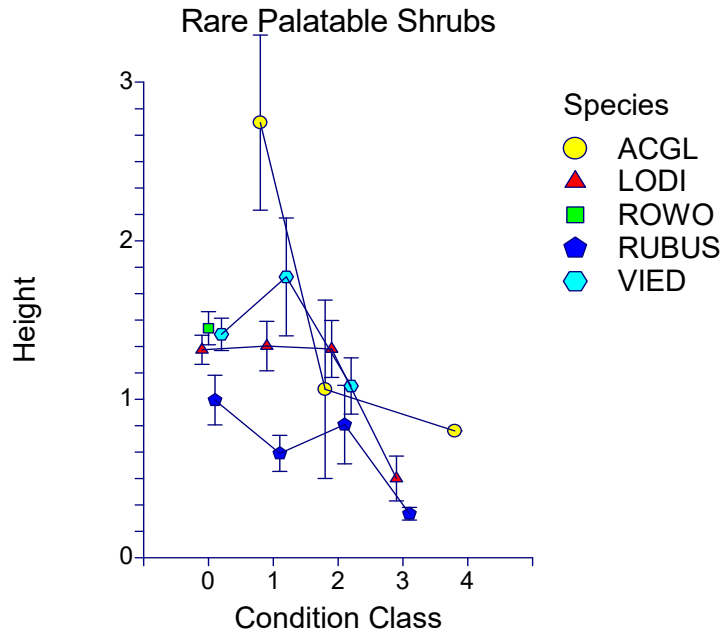

Figure 4.1.4. Mean plot height for tallest individuals of relatively rare palatable shrubs by browsing condition class. Plots within wildlife exclosures are assigned a Condition Class of 0.

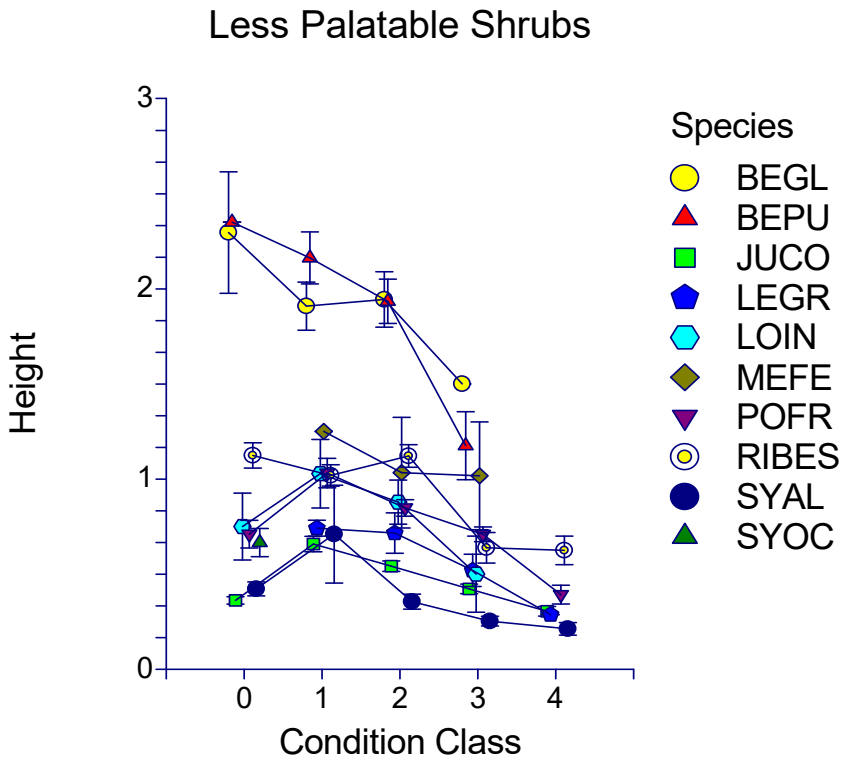

Figure 4.1.5. Mean plot height for tallest individuals of less palatable shrubs by browsing condition class. Plots within wildlife exclosures are assigned a Condition Class of 0.

4.2 Spatial Variability of Herbivory Condition Class over Time

Based upon the year when trembling aspen, balsam poplar or willow changed height classes, Figure 4.2.1 shows condition classes mapped by krige-smoothed Bow valley plots.

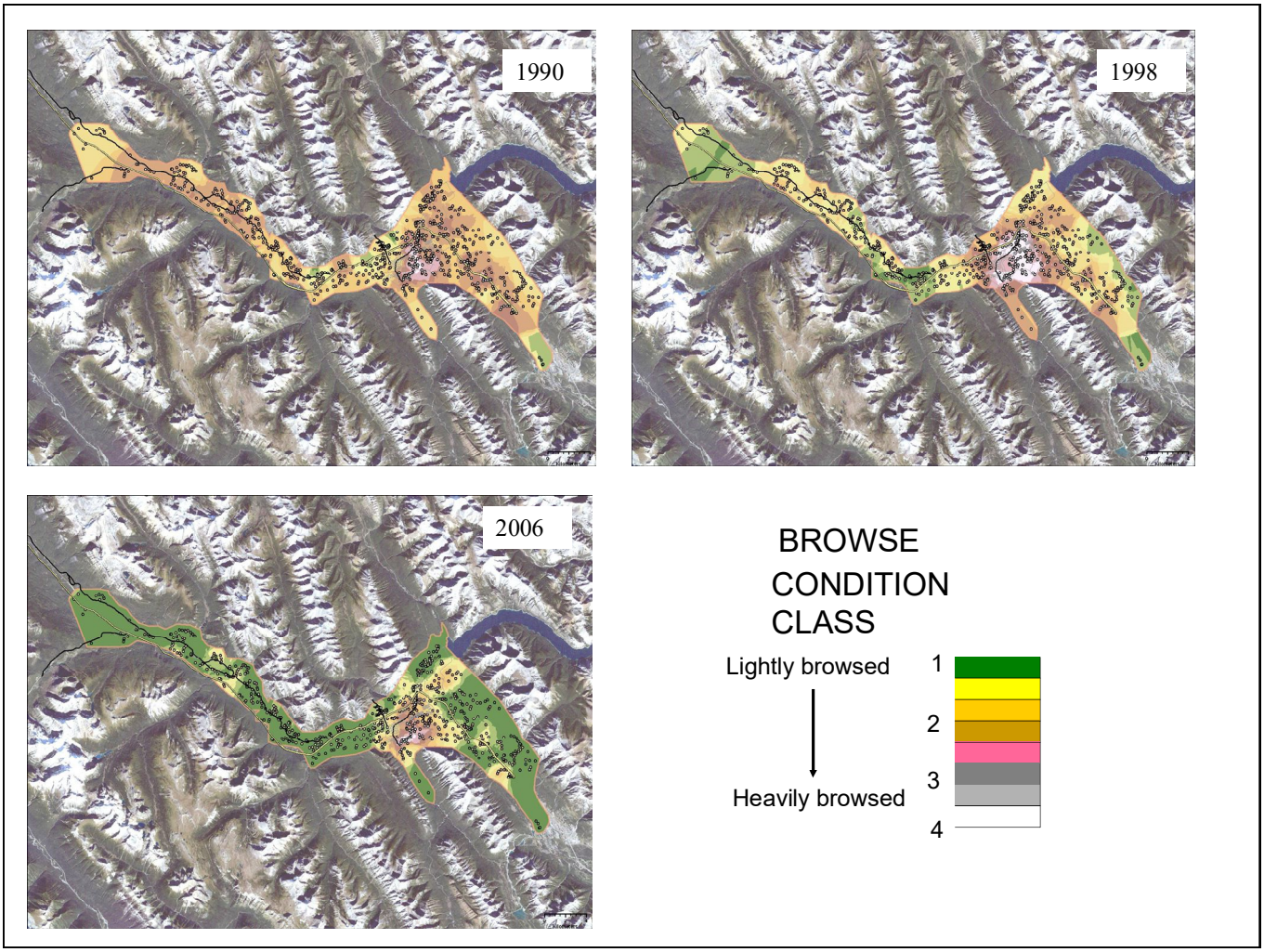

Figure 4.2.1. Browsing condition classes (not including exclosure plots) for the years 1990, 1998, and 2006 extrapolated by kriging from sample plots (black circles, n= approximately 770) in the Banff Bow Valley.

In 1990, the majority of the Bow Valley was moderately browsed (CC2). In almost all areas trembling aspen did not reach heights >2m due to elk browsing (White 2001). In several areas such as near Hillsdale Meadows or Banff townsite, browsing intensity was high enough (CC3) that balsam poplar and willow were likely limited to heights <2m (Figures 4.1.1 and 4.1.2).

By 1996, the high concentration of elk in the middle Bow valley (Figure2.1.1) occurring due to low predation rates near the town of Banff (Hebblewhite et al. 2002, 2005) resulted in a broad area of intense herbivory (CC4) including Johnson Lake, the airport and Indianground Meadows, Tunnel Mountain, and the Golf Course and east end of Vermilion Lakes wetlands. In this area, during this period, almost all woody species were intensely browsed with only species such as white spruce, shrubby cinquefoil, and common juniper persisting in the 1-5m height class. However, elsewhere in the valley, with declining elk abundance (Figure 4.2.1), browsing condition classes were moving from CC3 to CC2, and balsam poplar and willow began to consistently regenerate to heights greater than 2m. The pattern of intense herbivory generally matches the elk resource selection function for the period (Figure 2.1.2, Hebblewhite 2008).

In 2006, broad areas east and west of Banff townsite have moved from CC2 to CC1, indicating that the most palatable species such as trembling aspen, saskatoon, and red osier dogwood would be regenerating with light browsing to heights greater than 2 m. The 5-10 year time lag between when elk densities dropped in these areas in the mid-1990s (Figure 2.1.1) to when strong regeneration of shrubs occurred (c. 2006) is interesting. At least four factors might be influenced this: 1) although elk densities remained consistently relatively low throughout the period, perhaps further behaviour changes such as moving to higher elevations occurred; 2) possibly the abundance of browse available after CC2 was reached began to satiate herbivores, and eventually buffered use of the most highly palatable species; 3) large prescribed burns done west of Banff (1993, 1997), and east of Banff (2003) resulted in large areas of downed wood protecting highly palatable stems; and 4) grizzly bears began to use these areas after 2000 due to attraction to prescribed burns, and highway mitigations that limited bear mortality. This added source of predation risk may have further stimulated behavioural change.

A second change evident in the 2006 map (Figure 4.2.1) is the shrinking of the area of intense herbivory (CC4) around Banff townsite. Howard (2006) describes the process by how this likely occurred. In 2001, when >100 of the most human-habituated elk were trapped near Banff townsite, and translocated, elk using the next concentric zone to the trapped elk promptly (within 2 years) moved into the zone immediately next to the town. This allowed shrub regeneration to CC1 and CC2 levels in areas such as First Vermilion Lakes, Johnson Lake, and the northeast end of the Cascade wildlife corridor.

4.3 Individual Species Herbivory Response

Data was available to monitor the effects of ungulate herbivory on Banff Bow Valley trees and shrubs evaluates height, cover, and browsing occurrence on over 35 woody species ranging from approximately .3m to 6m in height (Table 3.1).

***Abies lasiocarpa* (Hook.) Nutt. (ABLA), subalpine fir-** This tree, most commonly found in the upper subalpine ecoregion descends on in some older forests on northern-facing slopes into the montane ecoregion of the Bow Valley. Subalpine fir is generally rated as having low ungulate palatability (Table 2.2.1, Tannas 2003), although it may be important forage for moose in subalpine areas. In the montane ecoregion of the Banff Bow Valley, isolated individuals are often heavily browsed, likely by both elk and deer, particularly in CC3 and CC4 areas (Figure 4.3.1).

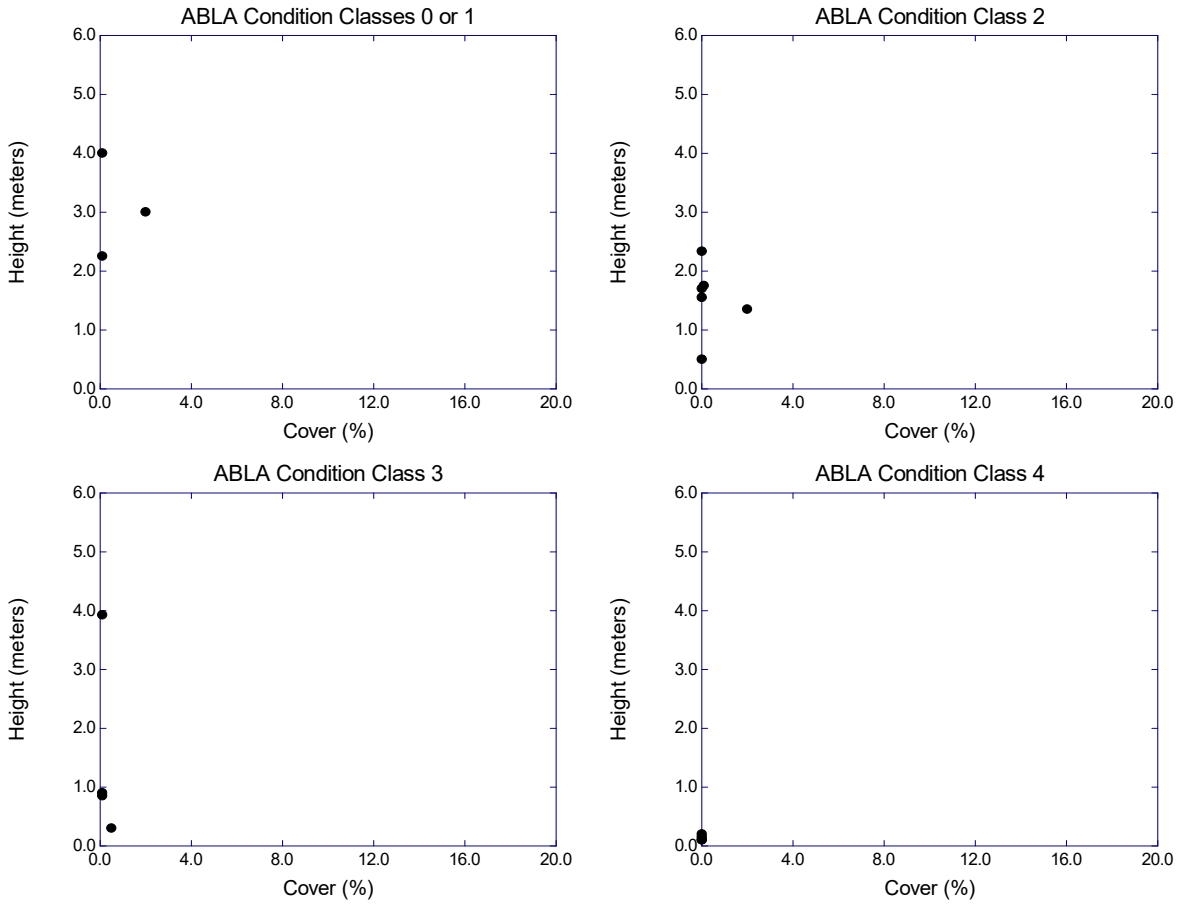

Figure 4.3.1. Height and cover for *Abies lasiocarpa* by browsing condition class in the Banff Bow Valley.

***Acer glabrum* Torr. (ACGL), Douglas maple-** This shrub is more common on the western slopes of the Rockies than the eastern slopes. In the Banff Bow Valley it is uncommon with <10 observations in both the Shrubwatch 2008 database (Figure 4.3.2) and Ecological Land Classification database. It occurs on the eastern slopes of Tunnel Mountain, Stoney Squaw, Rundle in rocky areas with low ungulate density and browsing intensity (e.g., CC1) that may protect its highly palatable red-barked stems and maple-shaped leaves from browsing. In the one location where it was found in a high browsing class area (Figure 4.3.2), the stems were heavily browsed to less than 1m in height.

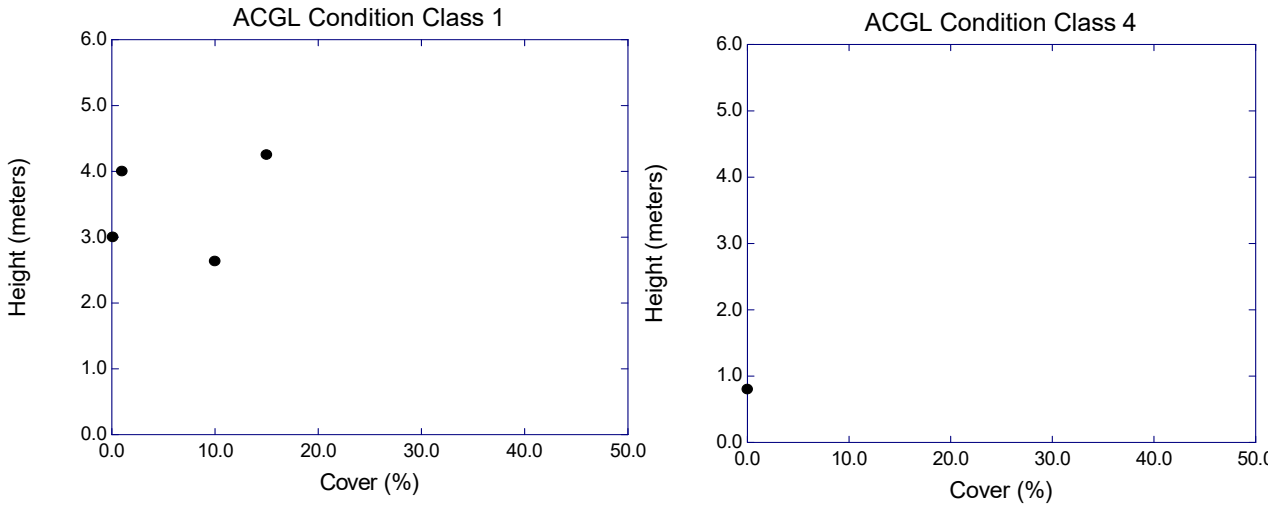

Figure 4.3.2. *Acer glabrum* height and cover by browsing condition class in Banff Bow Valley. No plants were observed in plots rated Condition Class 0 (exclosure plots), 2, or 3.

***Alnus crispa* (Ait.) Pursh, ssp. sinuata (Regel) Hult. (ALCR), green alder**- In Banff and Jasper national parks, green alder often occurs in lodgepole pine forests on north aspects in the montane to lower subalpine ecoregions (Achuff and Corns 1983). It may be favoured by relatively frequent fires from lower elevations spreading across a sharp transitional zone into cooler and moister conditions such as on the northeast slopes of Mt. Norquay and Cascade Mountain. Green alder stems often form dense thickets, and due to low palatability are rarely browsed.

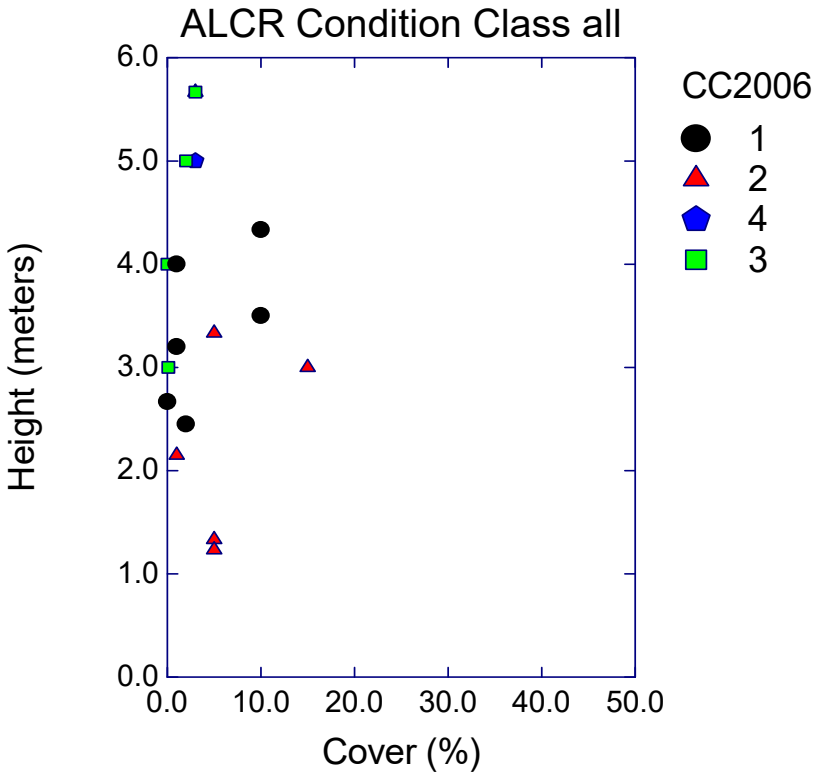

Figure 4.3.3. Height and cover for *Alnus crispa* by browsing condition class. No plant observations occurred in condition class 0 (exclosure plots).

***Alnus tenuifolia* Nutt. (AMAL), river alder-** This alder species is rare in Banff's Bow Valley, but has been recorded in a few locations such as on the lake shoreline in Devils Gap beyond end of Lake Minnewanka (ELC database).

Amelanchier alnifolia **Nutt. (AMAL), serviceberry, saskatoon-** Saskatoon is relatively widespread in the montane ecoregion of the Banff Bow Valley, across a range of elevation and moisture conditions, but particularly on river bottoms and south-facing slopes. This shrub is highly palatable to ungulates (Table 2.2.1), with height and cover in the Bow valley varying relatively consistently with the browsing class rating for Shrubwatch plots (Figure 4.3.4). Due to intense herbivory and other disturbances, saskatoon has been nearly eliminated from several areas near Banff townsite including the golf course, Tunnel Mountain campground, and Indiangrounds. Prior to park establishment, saskatoon thickets in these areas may have provided First Nations with a source of berries near heavily used campsites.

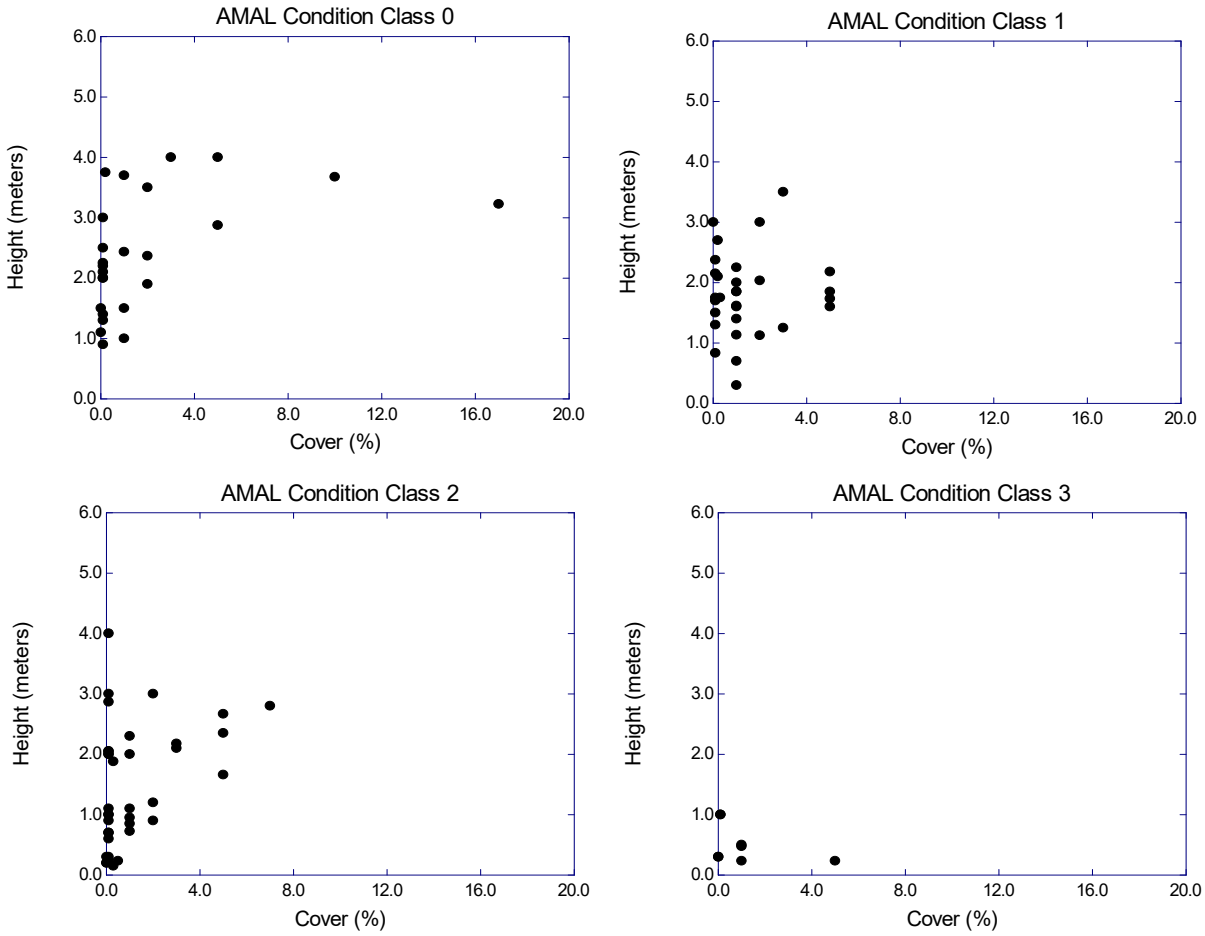

Figure 4.3.4. *Amelanchier alnifolia* height and cover by browsing condition class for the Banff Bow Valley. No plant observations occurred in Condition Class 4.

***Betula glandulosa* Michx., bog birch (BEGL) and *Betula pumila* L. Var *glandulifera* Regel., dwarf birch (BEPU)-** These two relatively short shrub (<3m) birch species grow on moist sites in the Bow valley and are relatively lightly browsed. Due to their similar habitat, growth form, and palatability, they are combined for analysis.

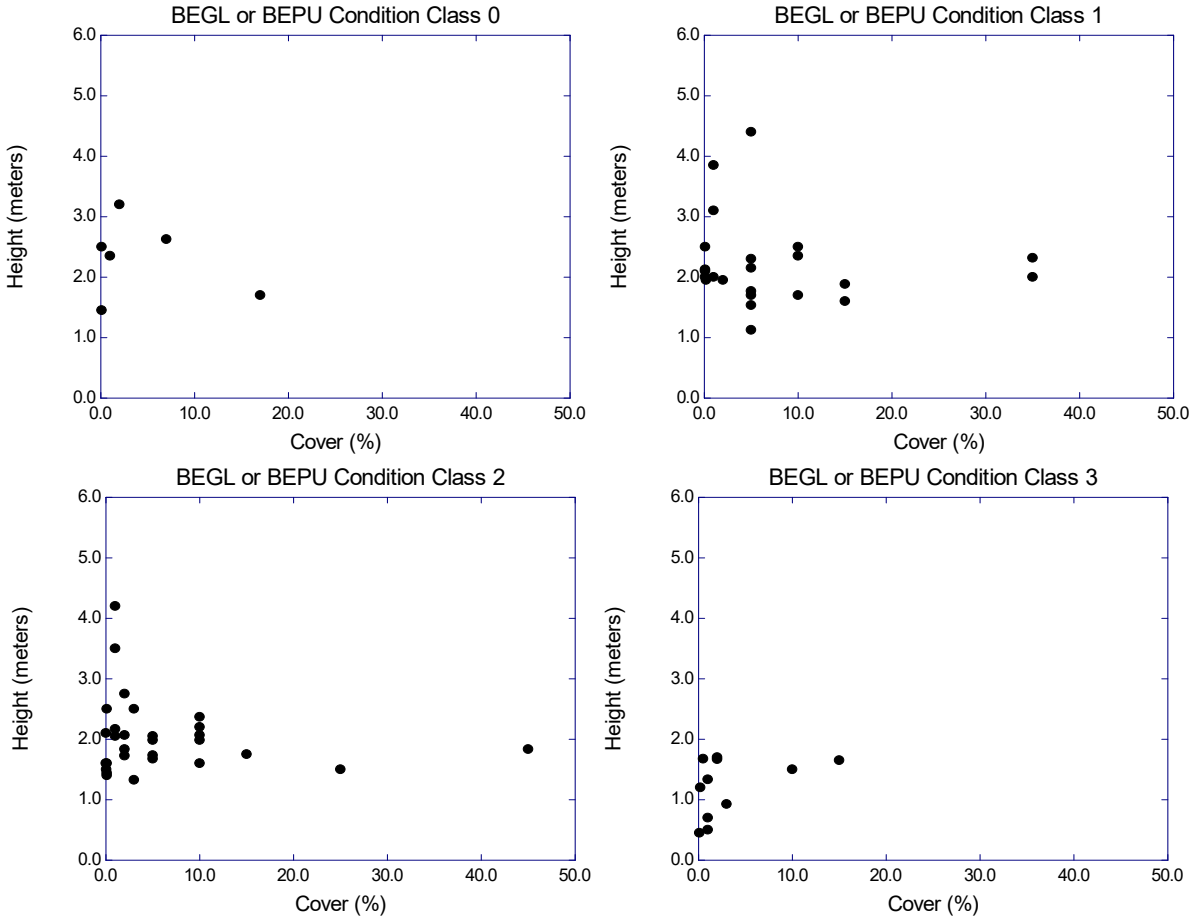

Figure 4.3.5. Height and cover for *Betula glandulosa* and *B. pumila* by browsing condition class for the Banff Bow Valley. No plant occurrences occurred in Condition Class 4.

***Betula occidentalis* Hook. (BEOC), water birch and *Betula paprifera* Marsh. (BEPA), white or paper birch-** Water birch is commonly found near waterways in the lower Bow valley. Paper birch is occasionally found along streams in narrow draws on northerly aspects. Where the two species co-occur they reportedly hybridize (Moss 1959). Although water birch shrubs may reach 5-7 m in height, in heavily browsed (CC4) areas few remnant tall shrubs from previous periods of light browsing exist, and current sprouts are held to low heights (<1m) with low cover (Figure 4.3.6). Similarly, in areas intensely browsed (CC4) paper birch saplings less than 4m in height do not occur.

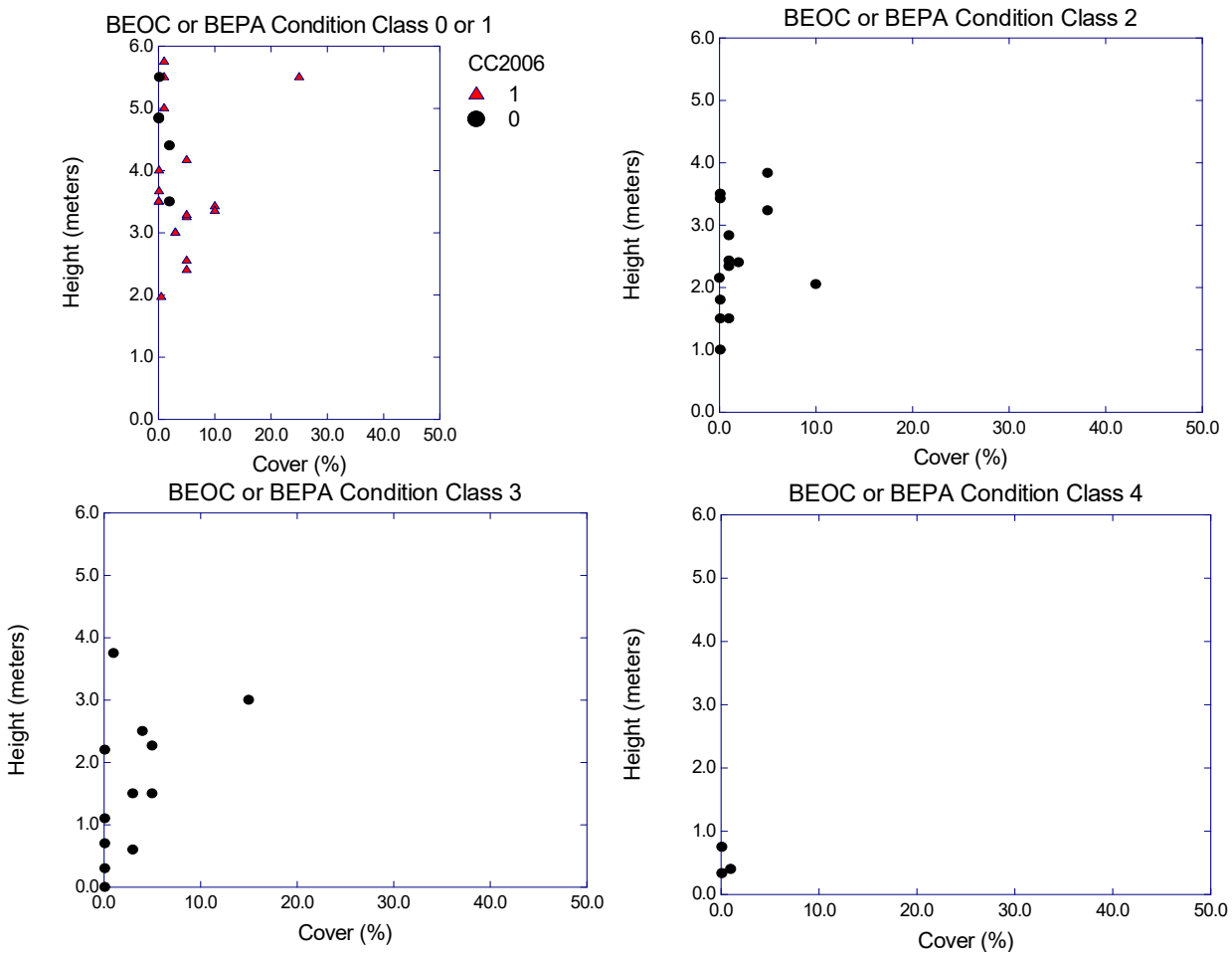

Figure 4.3.6. *Betula occidentalis* and *P. paprifera* height and cover by browsing condition class for the Banff Bow Valley. This dataset is dominated by water birch (BEOC) observations .

***Cornus stolonifera* Michx. (COST), red osier dogwood-** Dogwood is usually found next to slow moving streams on the bottom of the Bow Valley east of Healy Creek. Dogwood is highly palatable forage (Table 2.2.1), and its occurrence, height and cover declines sharply with increased browsing intensity (Figure 4.1.3). By 2006, the species appeared to have been locally extirpated in Condition Class 4 areas (Figure 4.3.7) with high elk use such as along Whiskey Creek through the Indiangrounds, and along the channels of the Bow River from near Banff townsite through the golf course nearly as far as the confluence with the Cascade River.

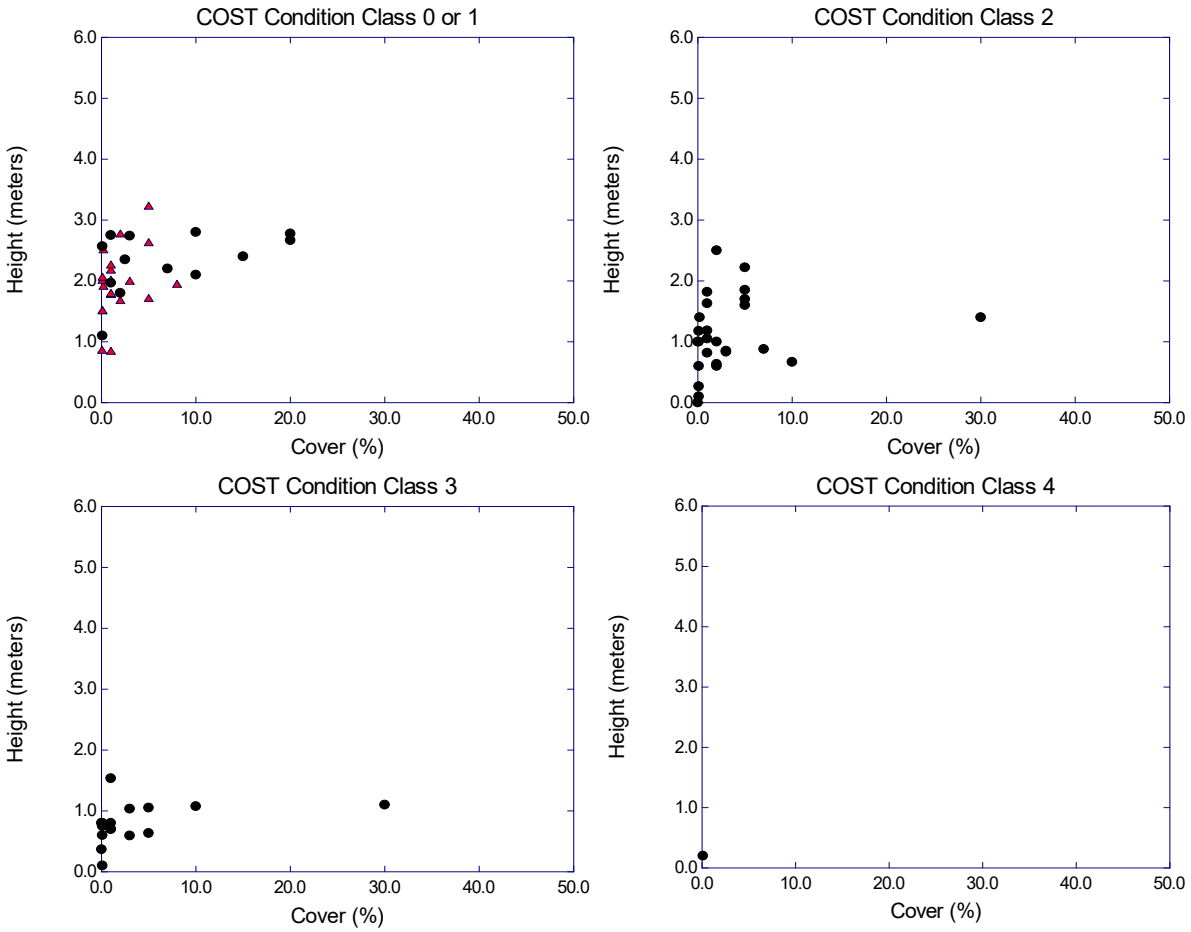

Figure 4.3.7. Height and cover for *Cornus stolonifera* by browsing condition class in the Banff Bow Valley. Class 0 (exclosure plots) are indicated by triangles, Class 1 by circles

***Eleagnus commuta*, wolf willow (ELCO)-** This shrub commonly lines streams with rocky banks in the Bow Valley montane ecoregion. It is moderately unpalatable to ungulates (Table 3.1.1), but receives increasing levels of browsing in areas with CC3 and CC4 (Figure 4.3.8). Cover and height of wolf willow is low along the channels of the Bow River near the golf course due to intense browsing in these areas. When wolf willow shrub patches are released from high browsing levels, they often reach heights of >3m and dense cover (>10%) in thickets that protect more palatable species such as balsam poplar (P. balsamifera) from browsing. Where browsing levels persist at moderately high levels (e.g., CC3), wolf willow cover may increase (Tannas 2003) and displace over more palatable willow (Salix spp.) species.

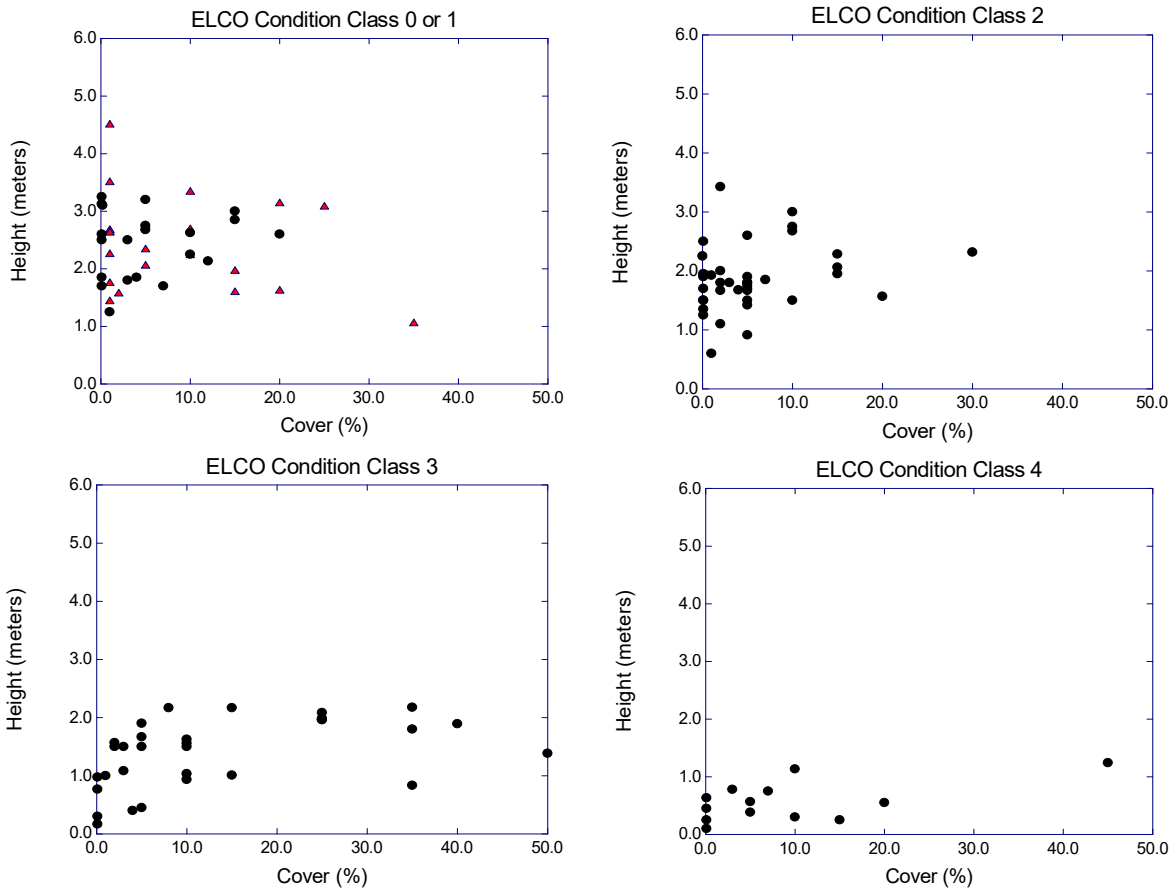

Figure 4.3.8. Height and cover for *Eleagnus commuta* by browsing condition class for the Banff Bow Valley. Class 0 (exclosure plots) are indicated by circles, Class 1 by triangles.

***Juniperus communis* L. (JUCO), common juniper**- One of the most abundant shrubs in Banff National Park, common juniper is found generally on dry ecosites, or dry microsites within wetter areas from the montane up to the upper subalpine ecoregion. Its needle-like leaves and leathery twigs are poor browse for ungulates (Table 3.3.1). As a result, cover and height do not vary substantially between browsing condition classes (Figure 4.3.9), and the species remains common across all suitable habitats in the Banff Bow Valley. Common juniper cover increases with time-since-fire. The foliage is highly flammable, and during burns triggers patches of crown fire that opens up montane forests for the regeneration other, more palatable species.

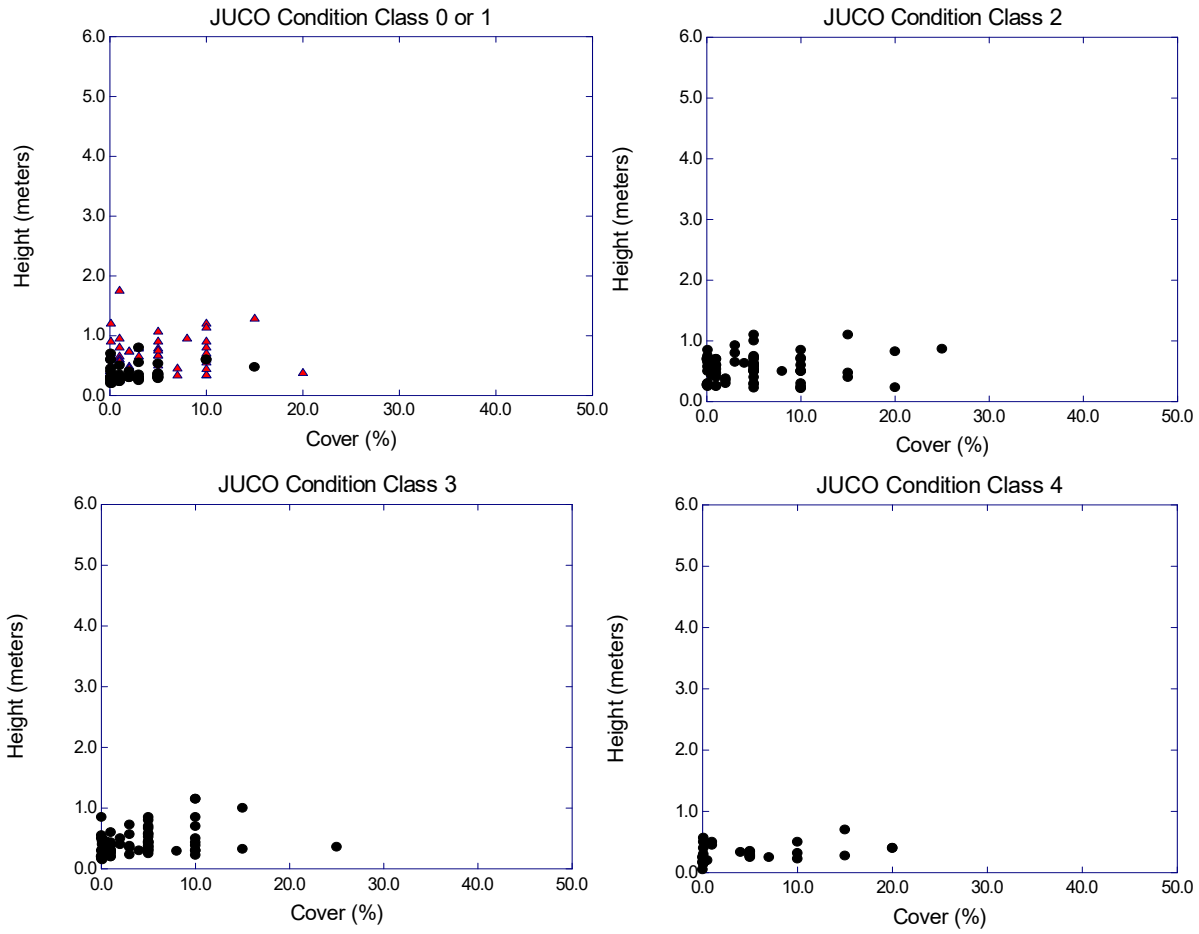

Figure 4.3.9. Height and cover for *Juniperus communis* by browsing condition class. Class 0 (exclosure plots) are indicated by circles, Class 1 by triangles.

***Juniperus horizontalis* Moench (JUHO), creeping juniper and *Juniperus scopulorum* Sarg. (JUSC), Rocky Mountain juniper**- These two species of juniper are relatively common on dry sites in the Bow Valley, and hybridize (Parish et al. 1996). The twigs and soft needles are browsed occasionally by deer and elk (Figure 2.2.1). Browsing intensity reduces overall average shrub heights (Figures 4.1.2, 4.3.10), likely by focussing on *J. scopulorum*. However, at high browsing levels, at least *J. horizontalis* persists at relatively low heights (<2m) at moderate cover levels (~3-5%).

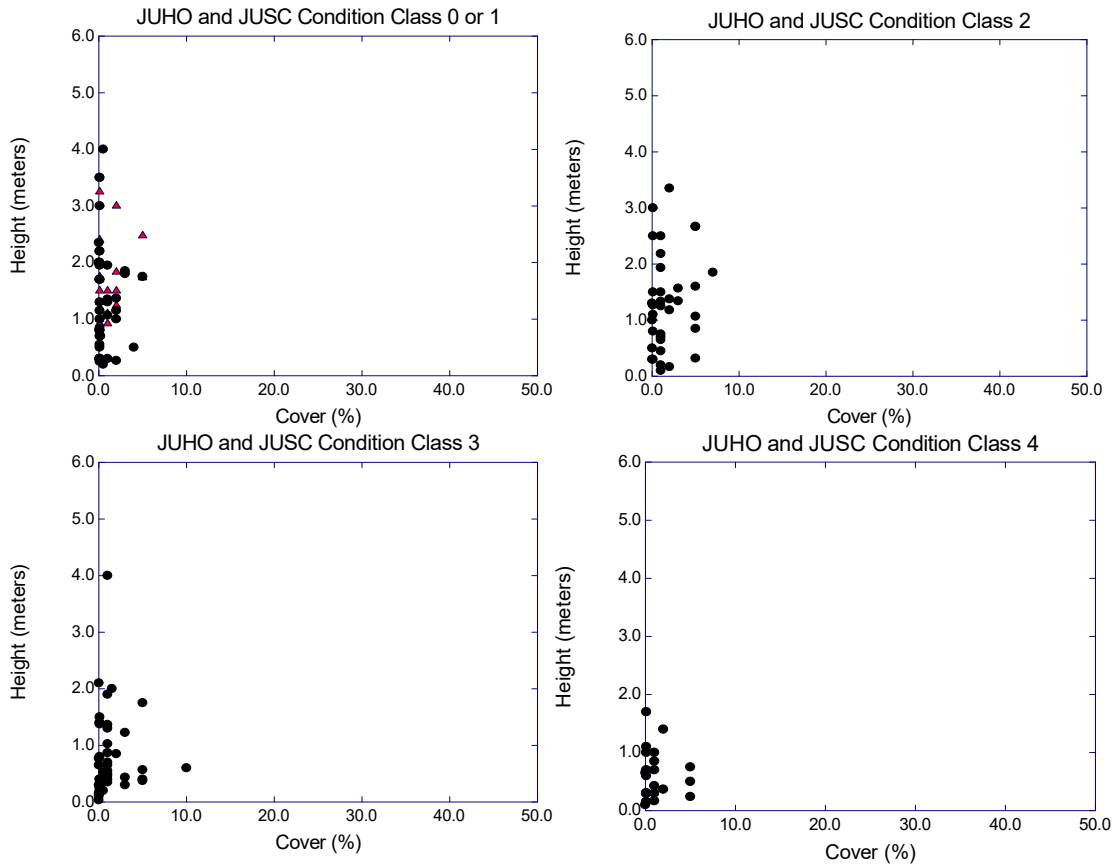

Figure 4.3.10. Height and cover of Juniperus horizontalis and Juniperus scopularum by browsing condition class in the Banff Bow Valley. Class 0 (exclosure plots) are indicated by circles, Class 1 by triangles.

***Ledum groenlandicum* Oeder (LEGR), Labrador tea**- This shrub occurs most frequently in the subalpine ecoregion (Achuff and Corns 1983, ELC database). In the montane ecoregion, Labrador tea is infrequently found on cool, moist north facing slope, and within wetland areas. Generally Labrador tea is <2m in height and its leaves and stems are only lightly browsed by ungulates (Table2.2.1). From a single observation make near Mt. Rundle on the golf course, it appears high levels of herbivory (CC4) may reduce its height (Figure 4.3.11).

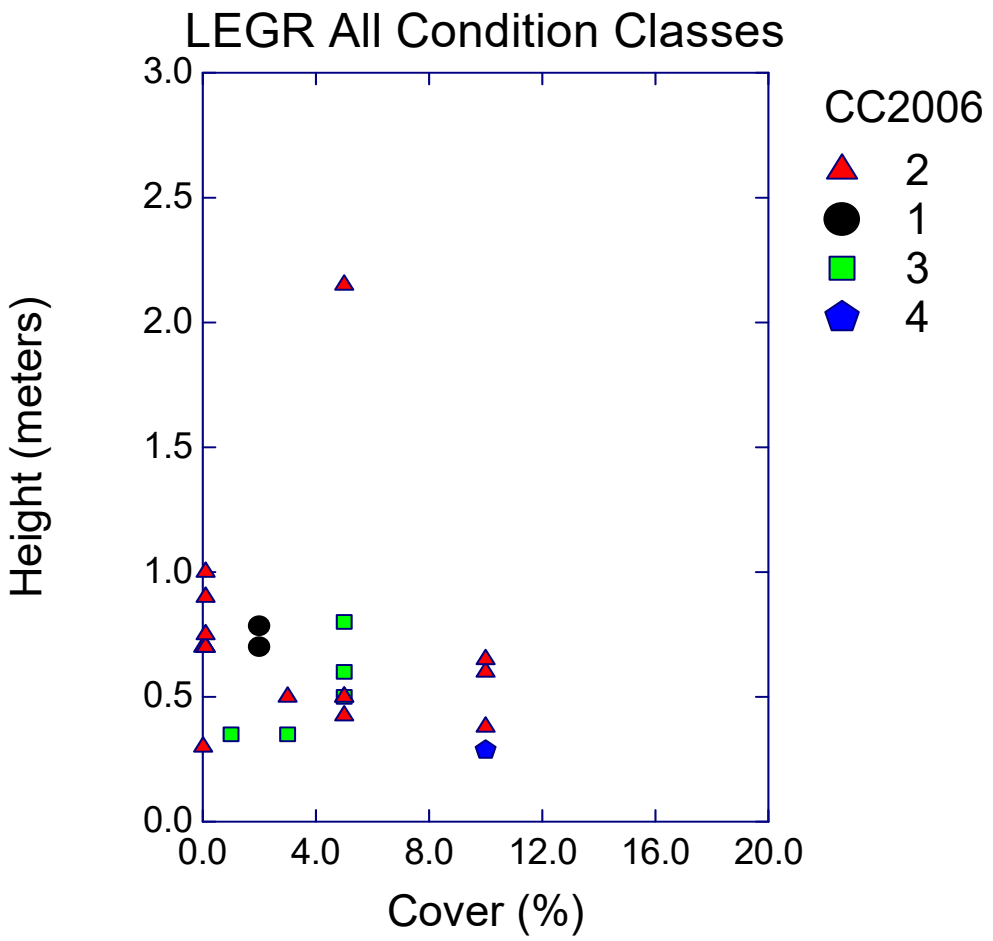

Figure 4.3.11. *Ledum groenlandicum* height and cover by browsing condition class in the Banff Bow Valley. No plants were observed in Condition Class 0 (exclosure) plots.

***Lonicera dioica* L. var. *glaucescens* (Rydb.) Butters (LODI), twining honeysuckle-** This delicate shrub has relatively low cover (<5%), periodically found in moist aspen woods in the Bow Valley. Although most studies do not rate it as high quality forage (Figure 2.2.1), its occurrence, height and cover in the Bow Valley declines sharply as browsing condition class increases (Figure 4.3.12). This may occur for 3 reasons: 1) direct browsing by ungulates; 2) the shoots of this shrub often twine around other shrubs whose height and cover is impacted by herbivory, and 3) the fragile stems of twining honeysuckle are easily damaged by high traffic. These effects are so significant that no individuals of this twining honeysuckle were observed in Condition Class 4 areas although habitats near Banff townsite and golf course should be optimal for twining honeysuckle occupancy.

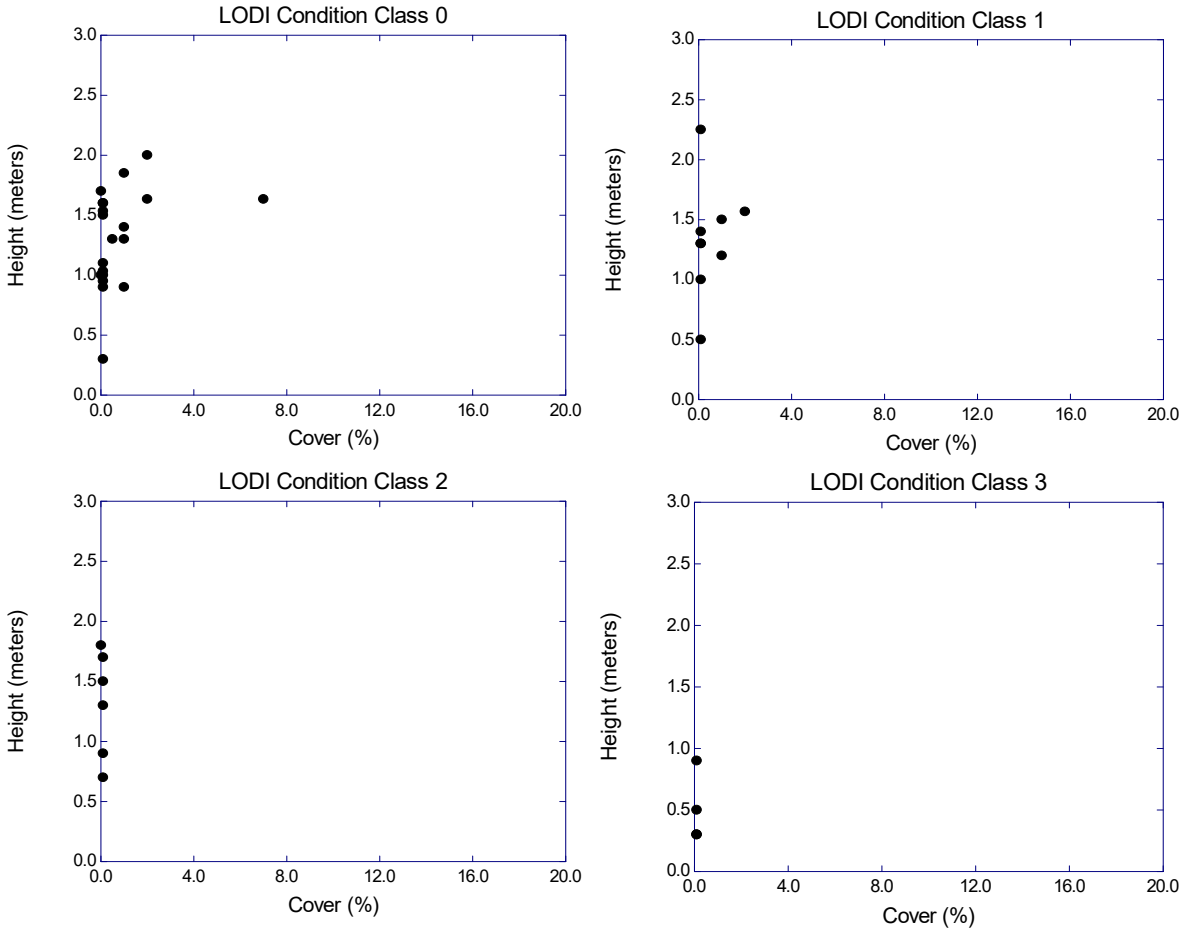

Figure 4.3.12. *Lonicera dioica* height and cover by browsing condition class in the Banff Bow Valley. No plants were observed in Condition Class 4 plots.

***Lonicera involucrata* (Richards.) Banks (LOIN), bracted honeysuckle-** This member of the honeysuckle family is most commonly found in the subalpine ecoregion in Banff (Achuff and Corns 1983, ELC Database). In the montane ecoregion, it has relatively low cover and height, even in areas with light browsing. Although it is rated as low forage potential (Table 2.2.1), occurrence, height, and cover does appear to decline in areas with highest herbivory impacts (Figure 4.3.13).

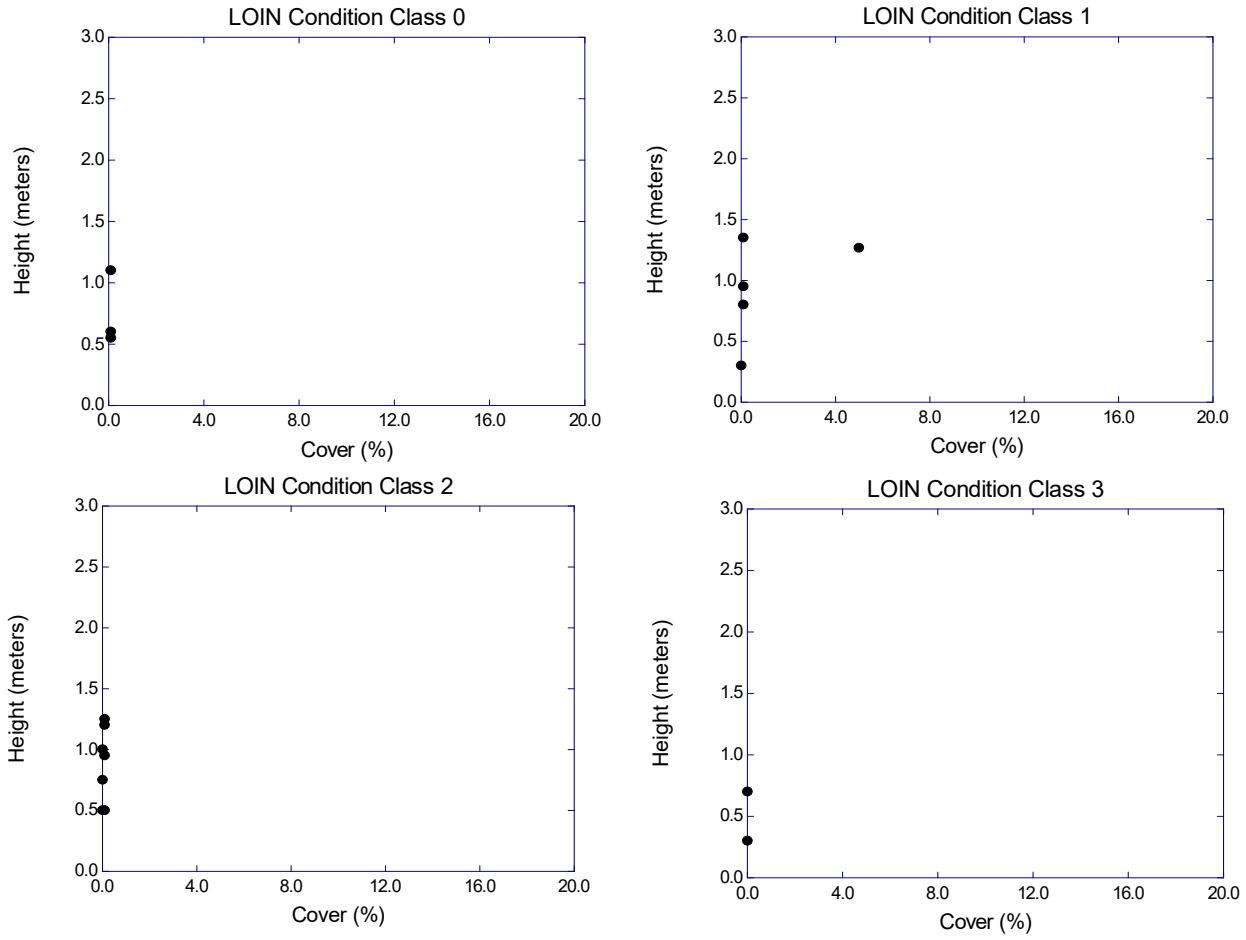

Figure 4.3.13. *Lonicera involucrata* height and cover by browsing condition class. No plants were observed in the highest browsing intensity areas (condition class 4).

***Menziesia ferruginea* J.E. Smith var. *glabella* (A. Gray) Peck (MEFE), false azalea-** This shrub is most common in moist subalpine forests, but does occur periodically in mature montane forests on north facing sites. It is rated by other studies (Tannas 2003) as not palatable for ungulates (Table 2.2.1), and in the Bow Valley montane ecoregion, its cover or height appears to not vary by browsing condition class rating (Figure 4.3.14). However, no individuals were observed in any high browsing intensity class (4) plots such as near the golf course below the north face of Mt. Rundle where some occurrence might be expected.

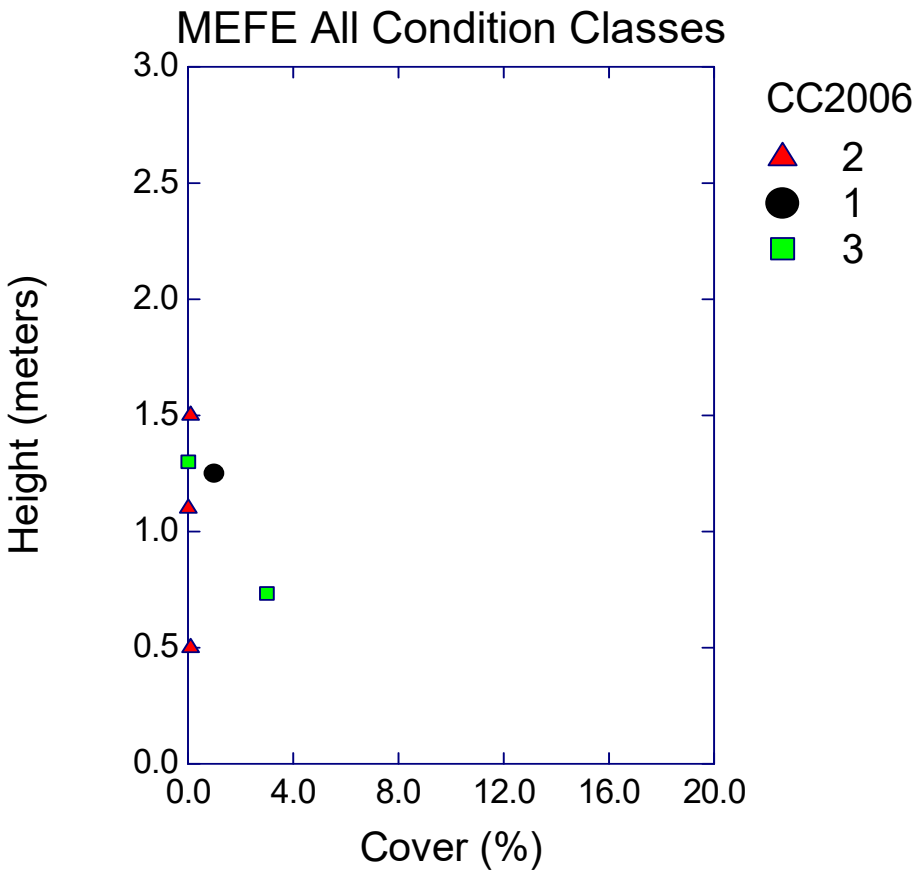

Figure 4.3.14. *Menziesii ferrigunea* height and cover by browsing condition class in the Banff Bow Valley. No plants were observed in condition class 0 (exclosures) or 4 (high intensity) browse classes.

***Picea glauca* (Moench) Voss (PIGL), white spruce-** One of the most common plants in the .5 to 6 m height class in the Banff montane ecoregion are white spruce seedlings and saplings. They are found on almost all types of sites from the edges of dry grasslands, to aspen stands, to moist conifer forests. Although they are highly flammable, spruce abundance increases dramatically when areas remain unburned for more than 20 to 40 years. Further, white spruce is very unpalatable to ungulates (Table 2.2.1), so it increasingly dominates the mid-story of forests as more palatable tree species such as balsam poplar or aspen are removed by browsing in condition class 2 to 4 areas (Figure 4.1.1). Most significantly, in old white spruce stands with ongoing high herbivory, few other woody and herbaceous species occur, even when these sites appear to have had very high plant diversity in former times (CW pers. obs.)

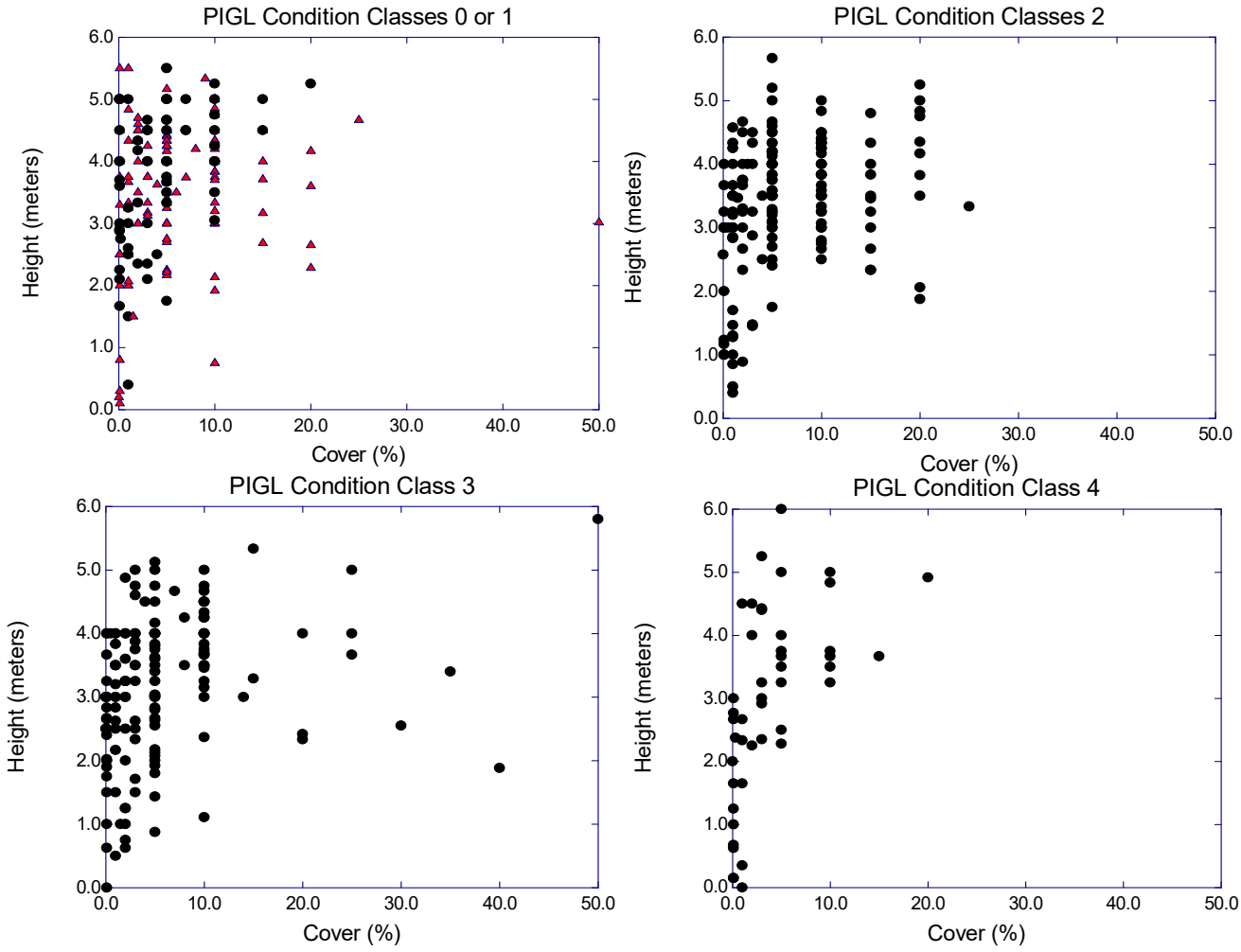

Figure 4.3.15. *Picea glauca* height and cover by browsing condition class in the Banff Bow Valley montane ecoregion. Browsing condition class 0 (exclosures) are indicated by circles, condition class 1 by triangles.

***Pinus contorta* Dougl. Ex Loud. (PICO), lodgepole pine**- Historically, under a regime of frequent fires and low herbivory, lodgepole pine was likely had the highest cover of any plant in .5 to 6 m height class in the Banff montane ecoregion. By 2006, ongoing fire suppression alone had dramatically reduced the abundance of the species. Today, First Nations would be hard pressed to find tipi poles in most areas of the Banff Bow Valley. In addition, although it has relatively low palatability for ungulates (Table2.2.1), lodgepole seedlings and saplings are killed by even light browsing (McClean 1996). Thus lodgepole pine occurrence, cover and height decreases sharply as browsing condition class increases (Figure 4.3.16).

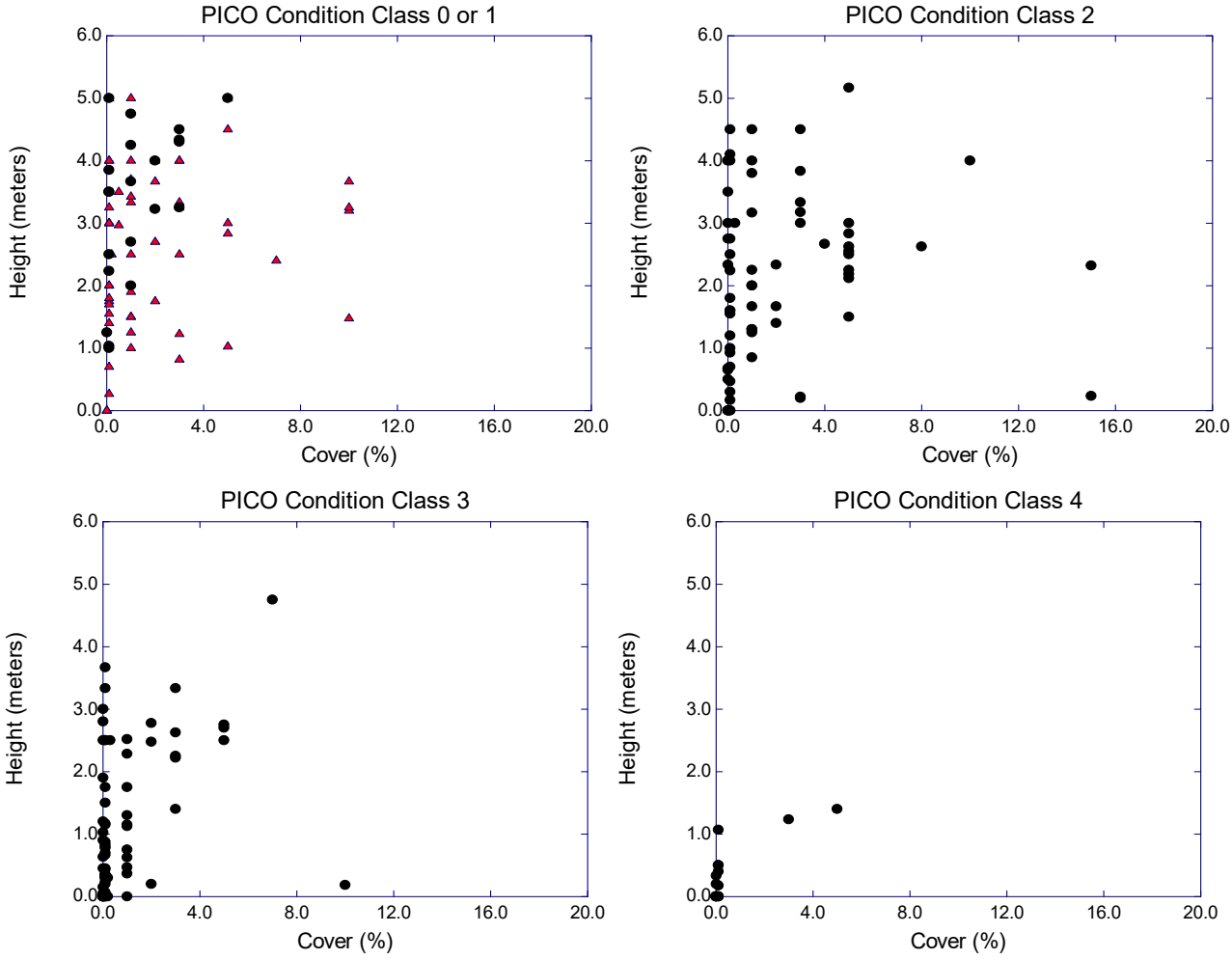

Figure 4.3.16. Pinus contorta height and cover by browsing class in the montane ecoregion of the Banff Bow Valley. Class 0 (browsing exclosures) are indicated by circles), Class 1 by triangles.

***Pinus flexilis* James (PIFL), limber pine**- This shrub-like member of pine family is found on steep south glacial till slopes, such as near the hoodoos directly above the Bow and Cascade Rivers. These are fairly unique areas in area, thus the sample size is limited. Although these dry slopes are heavily used by elk due to low snow coverage, limber pine has low palatability to ungulates (Table 2.2.1), and appears to have high resistance to any mechanical damage that might occur due to high ungulate densities (periodic browsing, antler brooming etc.). No response pattern to increasing browsing classes is apparent from the limited number of observations made during the Shrubwatch project (in Figure 4.3.17)

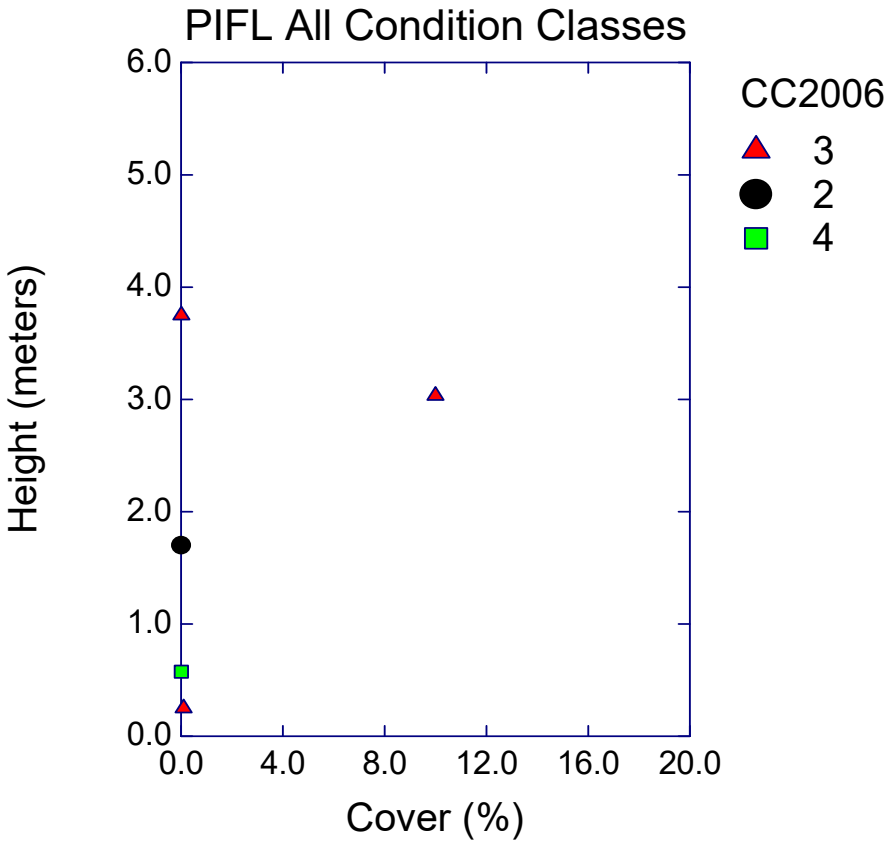

Figure 4.3.17 *Pinus flexilis* height and cover by browsing condition class in the Banff Bow Valley.

***Populus balsamifera* L. (POBA), balsam poplar-** This member of the poplar family has only moderate palatability for ungulates compared to trembling aspen (Table 2.2.1), its close relative with which it occasionally hybridizes. In the Bow Valley balsam poplar is widespread, but particularly common on valley bottom floodplains near meandering channels of streams. Due to its moderate palatability, balsam poplar occurrence, height, and cover remain consistent through condition classes 0, 1, and 2. However, the number individuals between .5 to 6 m declines sharply has herbivory rates increase, and at condition class 4 only remnant clones with heights consistently <1m occur (Figure 4.3.18). With release from high elk herbivory, balsam poplar has made a strong recovery across many areas of the Bow valley. However, near Banff townsite, intense browsing combined with increasing densities of white spruce may limit recovery potential.

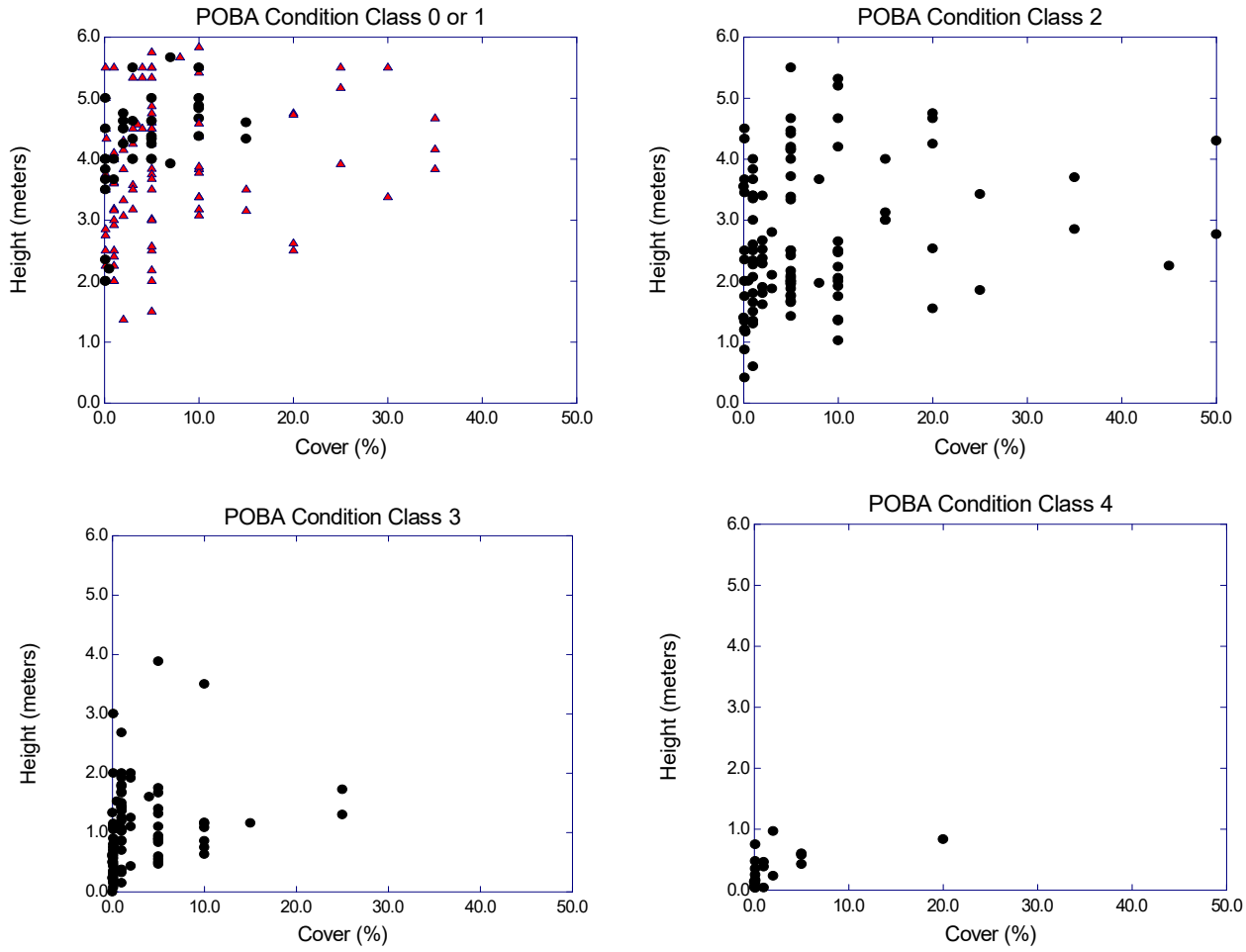

Figure 4.3.18. *Populus balsamifera* height and cover by browsing condition class in the Banff Bow valley. Class 0 (browsing exclosures) is indicated by circles, Class 1 by triangles.

***Populus tremuloides* Michx. (POTR), trembling aspen-** The historic widespread occurrence of long-lived trembling aspen clones across the montane zone of the Bow Valley is a good indicator of the long-term, characteristic conditions of frequent fire and low herbivory (Kay et al. 1997). Both of these factors have been dramatically altered by current anthropogenic effects (White et al. 1997, 2003). Aspen is highly palatable to ungulates (Table 2.2.1), and its occurrence, height, and cover declines consistently as browsing condition class increases (Figure 4.3.19). Some aspen clones, including their ancient root systems, have likely already been eliminated in condition class 4 areas (near the golf course, on Tunnel Mountain and Mt. Norquay) by intense herbivory combined with fire suppression. However, recent declines in elk density across much of the rest of the Bow valley, combined with prescribed burns have allowed a major pulse of regeneration to occur (Figure 4.3.20). Aspen regenerates particularly well in areas where fire-killed trees have blown over creating deadfall maizes (Figure 4.3.21) infrequently used by ungulates (Ripple and Larsen 2001, White et al. 2003).

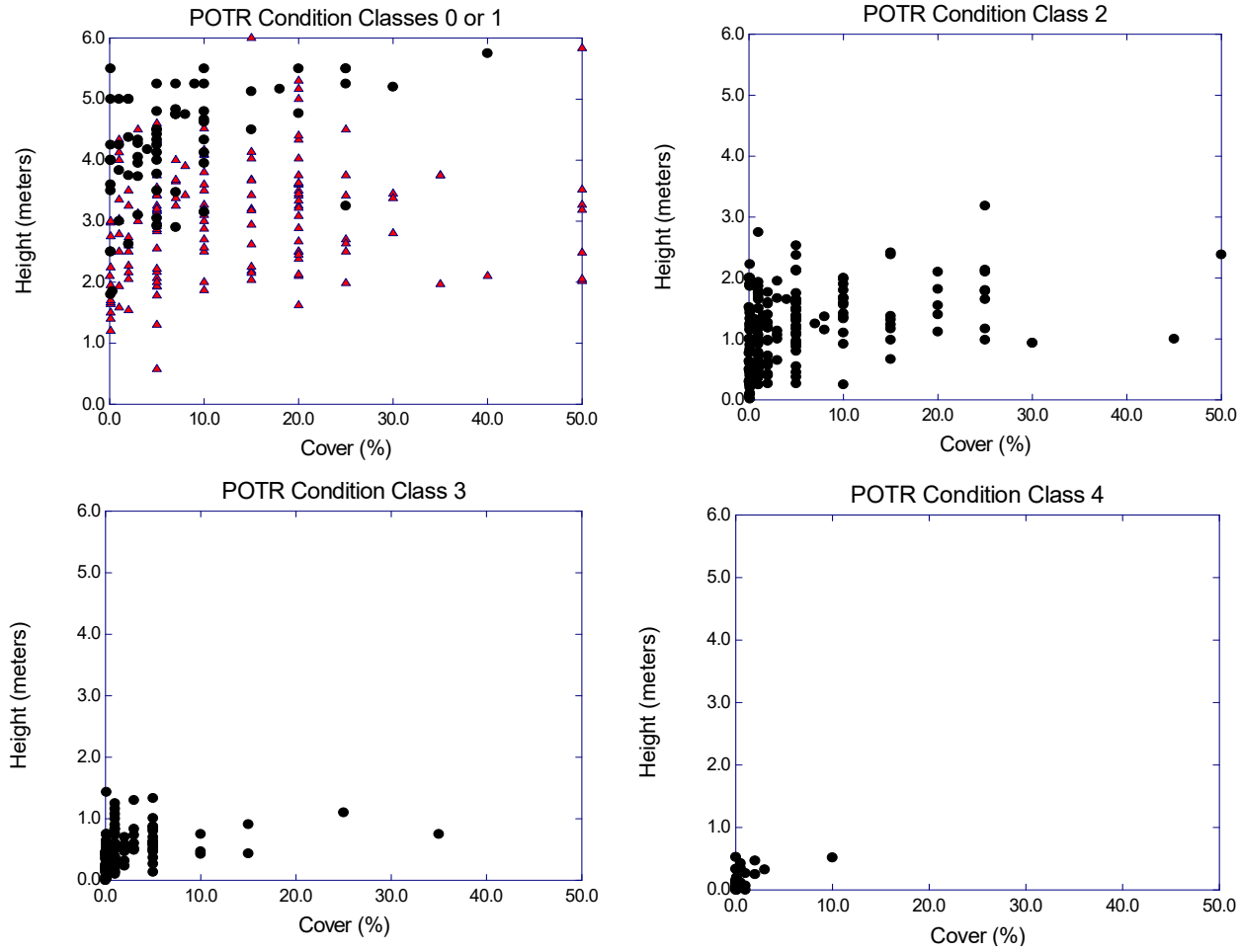

Figure 4.3.19. Populus tremuloides height and cover by browsing condition class. Class 0 (ungulate exclosure) is indicated by circles, Class 1 by triangles.

Lloyd Harmon, 1948,WMCR V227-3066

Cliff White, 2008, CW-2008-09A-28

Figure 4.3.20. Mature trembling aspen (*Populus tremuloides*) stems >6m and saplings (<6m) near the 10 and 1/2 Mile Wildlife Exclosure, Banff Bow Valley in 1948 and 2008. Castle Mountain is visible in the distance. In 1948 the area was heavily browsed by elk with species such as aspen, willow, and buffaloberry all hedged to heights <2m. By 2008 the area was lightly browsed and trembling aspen was reaching heights >2m as referenced by the 2m high range pole at the right of the photograph.

Cliff White photograph

Figure 4.3.21. Trembling aspen suckers regenerating to heights >3m near downed wood resulting from the 1993 described burn on the Sawback Range, Bow Valley, Banff National Park. Willow and aspen are also regenerating to heights >2m near the rock bands in the mid-ground of the photograph.

***Potentilla fruticosa* L. (POFR), shrubby cinquefoil-** This yellow-flowered, commonly observed shrub occurs on a wide range of habitats in the Bow valley from dry grasslands to moderately dense forests to bogs (Achuff and Corns 1983, ELC database). Cinquefoil is extremely unpalatable, and in the absence of fire, its cover and height of individual plants will increase. Although range ecologists describe it as "an increaser, invasive, and persistant in native rangelands" (Tannas 2003), in many cases this could be simply be the result fewer burns due to fire suppression and potential for fire-spread due to removal herbaceous fuels by intense grazing. In montane grasslands, the shrub's presence in grasslands is also an indicator that the native plants community has not been totally destroyed by mechanical disturbances such as tilling or blading. In the Bow Valley, shrubby cinquefoil presence, height and cover remains high across browsing condition classes 1 to 3. In areas mapped as condition class 4--often dry grasslands at low elevations—cinquefoil may have reduced cover and height due to both herbivory and site conditions (Figure 4.3.22).

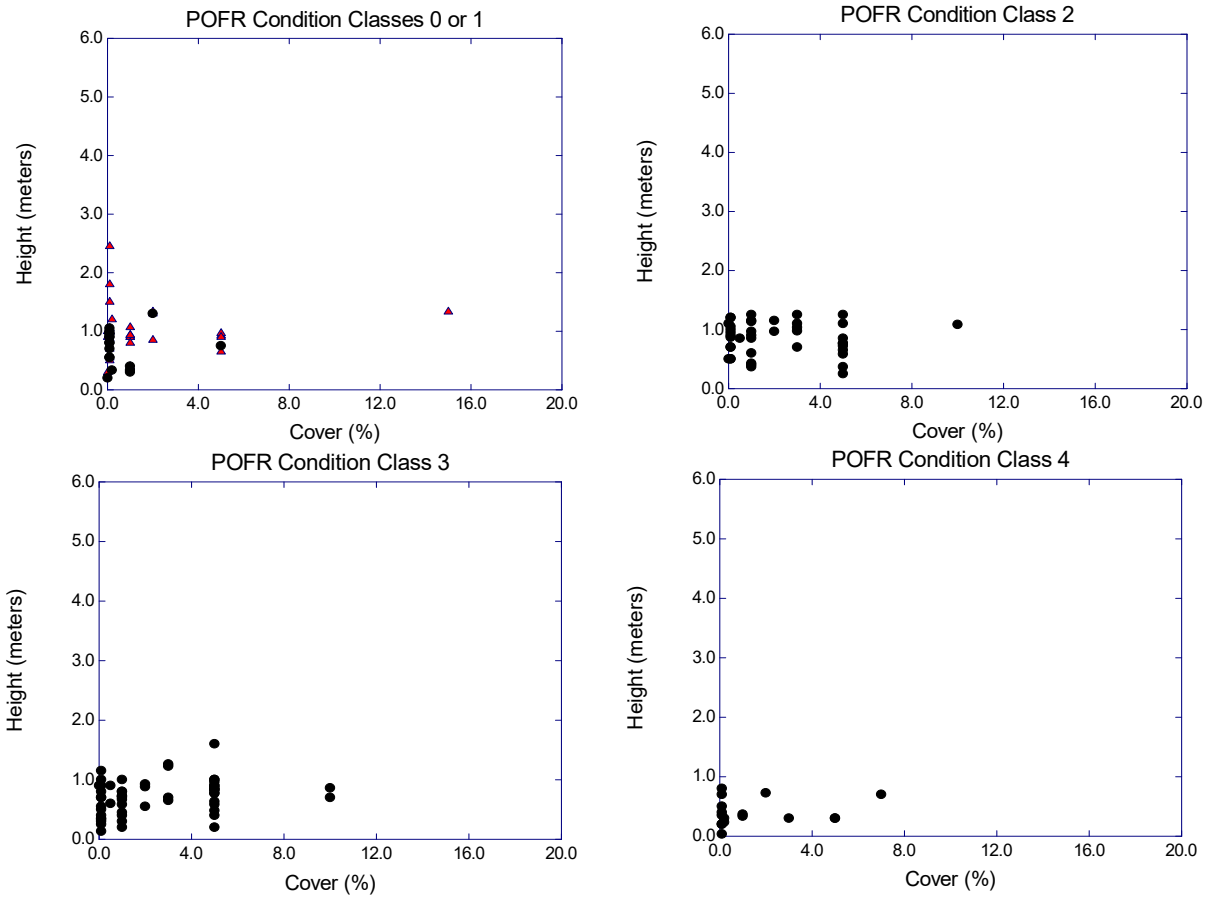

Figure 4.3.22. *Potentilla fruticosa* height and cover by browsing condition class. Class 0 (exclosures) is indicated by circles, Class 1 by triangles.

***Pseudotsuga menziesii* (Mirb.) Franco (PSME), Douglas-fir-** The foliage and twigs <3m in height have long provided forage for elk, deer and sheep populations in the Bow Valley, particularly during deep-snow winters. In comparison to lodgepole pine (*Pinus contorta*), Douglas-fir seedlings and saplings appear to routinely survive browsing. This differential survival rate may partially result in a long-term pattern where Douglas-fir is relatively common along the edge of grasslands occupied commonly by ungulates (such as the "Green Spot" along the Mt. Norquay Road), but lodgepole pine does not occur within 100 to 200 m of these edge of these meadows. However, under the heavy herbivory of Condition Class 4 areas (Figure 4.3.23), the occurrence, height and cover of Douglas-fir declines dramatically, even in areas where historically the tree was relatively common as evidenced by its presence in the forest overstory.

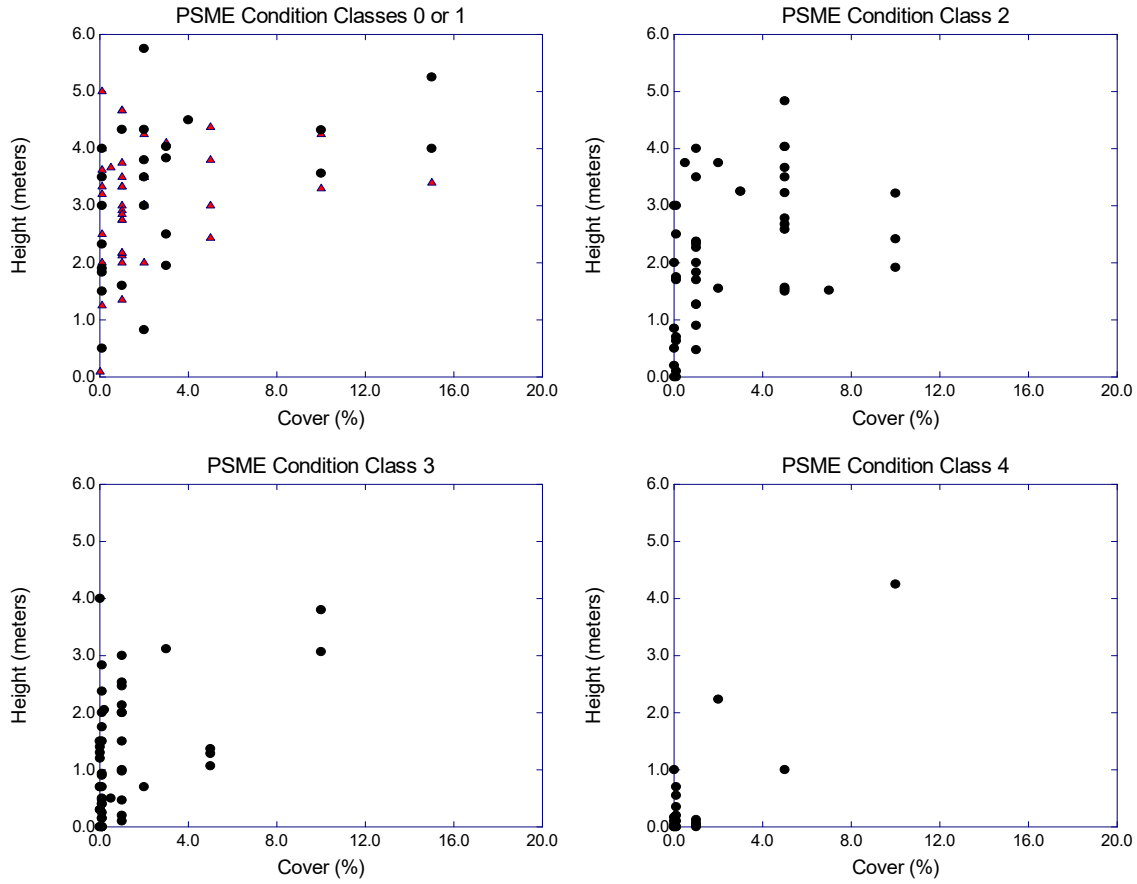

Figure 4.3.23. *Pseudotsuga menziesii* height and cover by browsing condition class. Class 0 (exclosures) is indicated by circles, Class 1 by triangles.

***Prunus virginiania* L. (PRVI) , chokecherry-** Chokecherry is rare within the BBV (no ELC BBV observations), although dense thickets of shrubs up to 5m in height found immediately near Lac des Arcs (Exshaw). Shrubwatch surveys found isolated PRVI shrubs on Trans Canada Highway rock cuts near the Cascade Power Plant. They are protected from browsing by the highway wildlife fences and steep rocky terrain.

***Ribes oxycanthoides,* wild gooseberry and *R. hudsonianum* Richards., wild black gooseberry (RIBES)-** These two gooseberry species are found in the Bow Valley. They are relatively unpalatable to ungulates (Table 2.2.1), although height and cover appear reduced in Condition Class 4 areas (Figure 4.3.24).

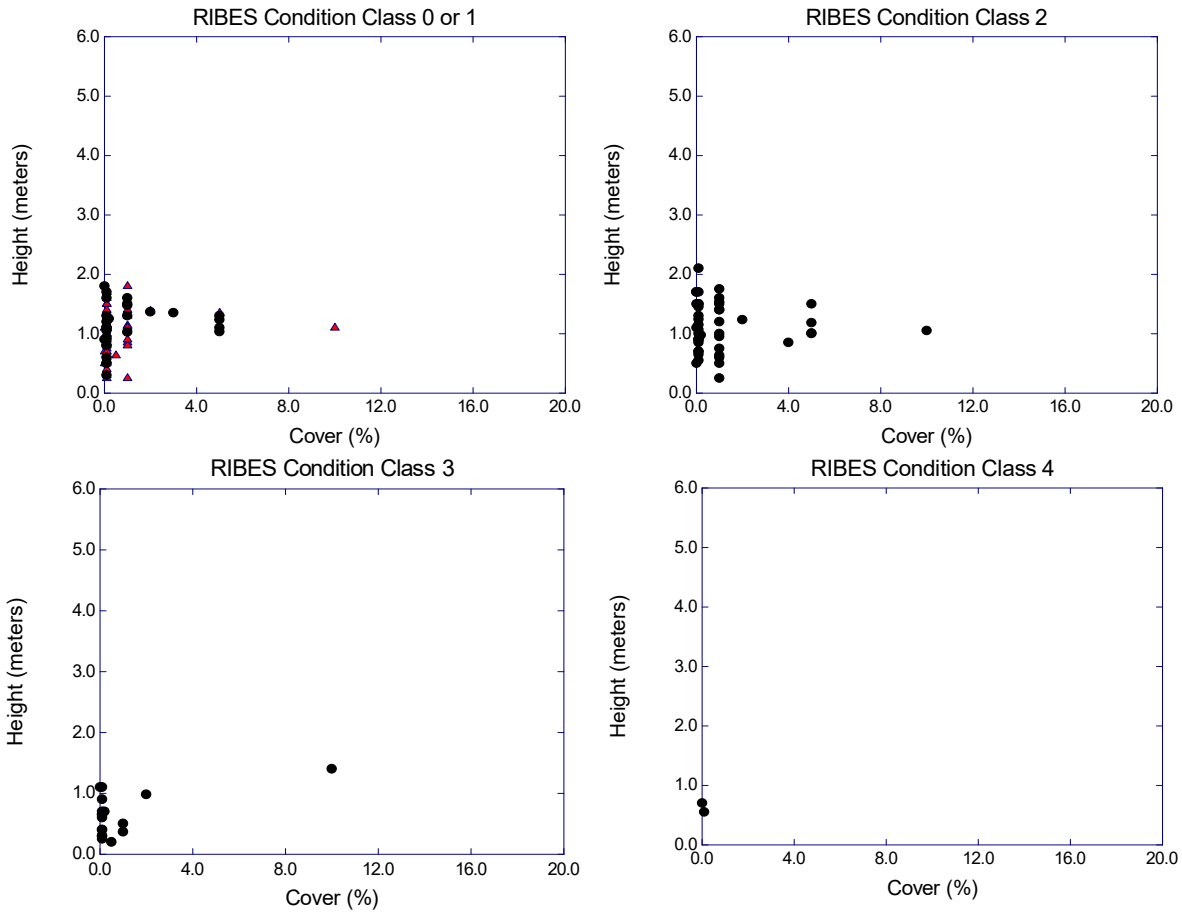

Figure 4.3.24. *Ribes spp.* height and cover by browsing condition class. Class 0 (exclosures) is indicated by circles, Class 1 by triangles.

***Rosa acicularis* Lindl. (ROAC), prickly rose and *Rosa woodsii* Lindl. (ROWO), common wild rose-** Prickly rose, the floral emblem of Alberta, occurs across a wide range of forest and open forest areas in the Banff Bow Valley (Achuff and Corns 1983, ELC database). In contrast, common wild rose, is only infrequently recorded within Banff National Park although it is more frequently observed outside the park. Significantly, *Rosa woodsii* was recorded only a total of 15 times (Shrubwatch database verson 2007), but only in exclosure plots (Condition Class 0) where its height frequently approached 2m. When intensely browsed, these shrub species are difficult to distinguish between, and Figure 4.3.25 combines observations for both species. Clearly the presence, cover, and height of rose shrubs are greatly influenced by herbivory. Likely the occurrence common wild rose will increase in areas outside of exclosures in areas of Condition Class 1 and 2, and its presence will continue to decline in Condition Class 3 and 4 areas. Possibly common wild rose, which has fewer thorns than prickly rose and is thus likely more susceptible to browsing, will be extirpated from many high herbivory areas.

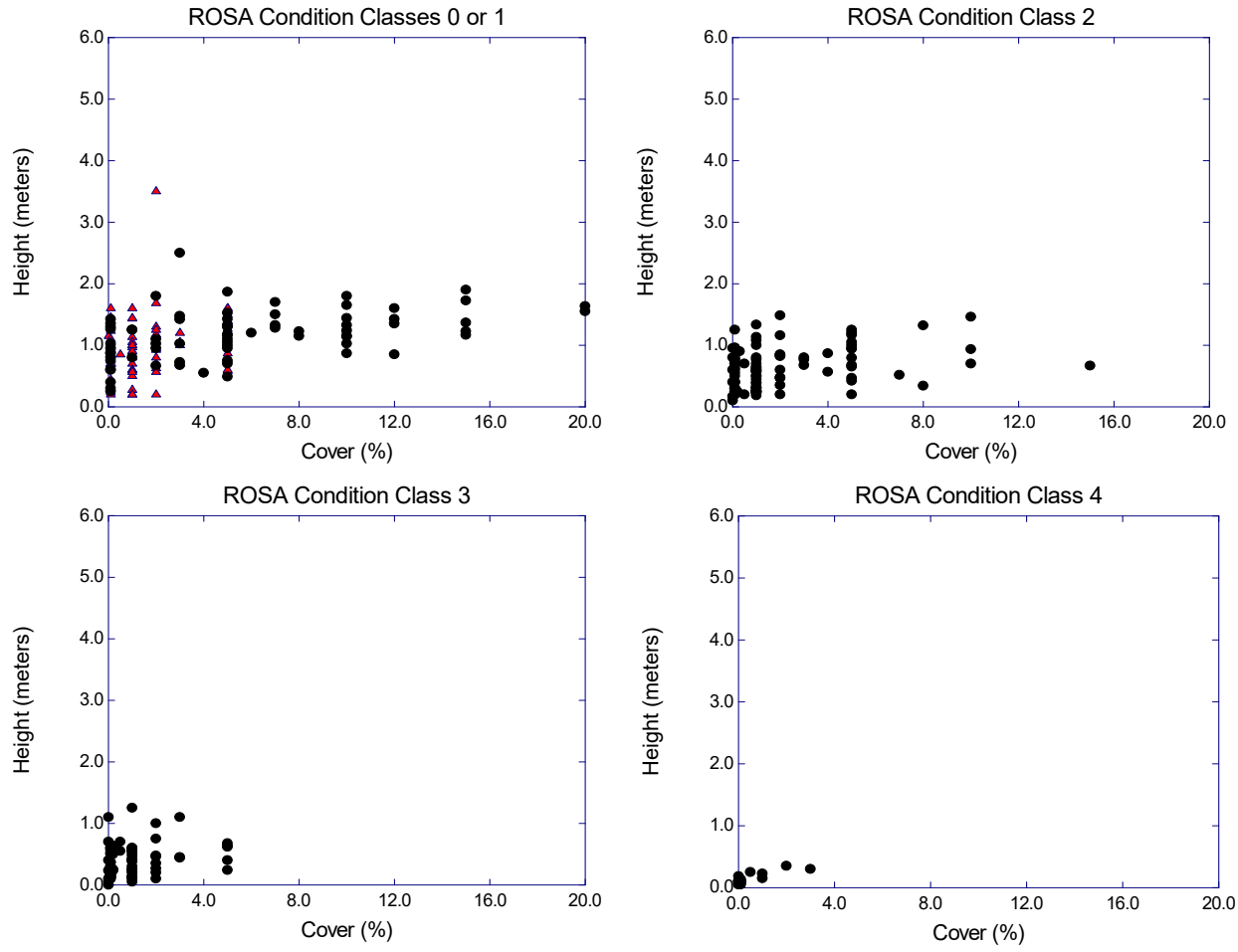

Figure 4.3.25. *Rosa* spp. height and cover by browsing condition class. Class 0 (exclosures) is indicated by circles, Class 1 by triangles.

***Rubus idaeus* L. spp. *Melanolasius* Focke, wild red raspberry**- In most areas of the Rocky Mountain eastern slopes, raspberry is very common in moist woods along the edges of forests, and disturbed areas such as near roads. However, it is not frequently observed in the Banff Bow Valley (Achuff and Corns 1983, ELC Database). During the Shrubwatch baseline study, it was observed periodically, particularly in recently burned areas with light or moderately light browsing (condition classes 0, 1, or 2). The species is likely extremely rare or extirpated in areas with condition classes >3 (Figure 4.3.26) such as along Whiskey Creek near Banff townsite, or moist areas near golf course or Tunnel Mountain campground.

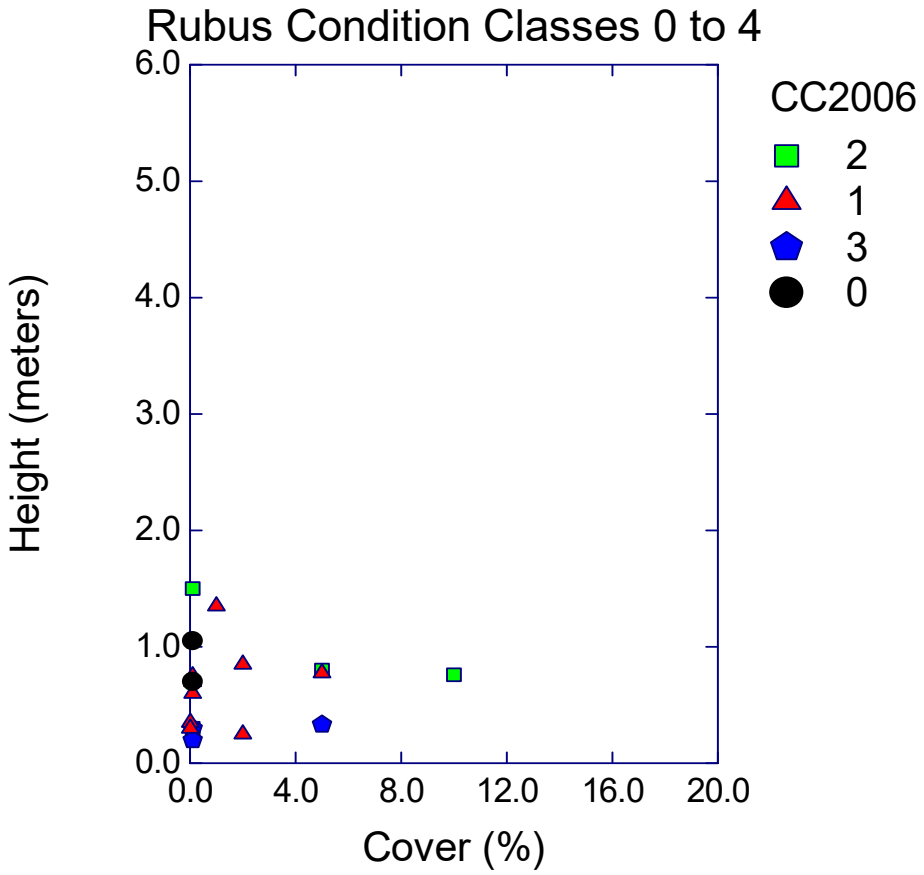

Figure 4.3.26. *Rubus idaeus* height and cover by browsing condition class. Class 0 (exclosures) is indicated by circles, Class 1 by triangles.

***Salix* spp. (SALIX), willows**- There are over 10 species of the willow family found in the Bow valley. More common species (Achuff and Corns 1983, ELC Database; Eastern Slope Seeds 1996, 1999, 2001) are:

- *S. barrattiana*- low shrub (<2m) commonly found in wetland areas at all elevations (ELC database);
- *S. bebbiana* Sarg.- uncommon on uplands sites, but found within exclosures (ESRS 1996)
- *S. brachycarpa*- uncommon across wetland meadows at a range of elevations
- *S. candida*- wetlands such as Vermilion Lakes
- *S. drummondiana*- forests and wetlands at all elevations from Johnson Lake wetlands to
- *S. farriae*- across a range of habitats from Vermilion Lakes to upper elevation forests, a common at upper elevations (ELC database, ESRS 1996);
- *S. glauca*- very common across a range of habitats from the Banff railroad Y to cool moist forests at all elevations (ELC database, ESRS 1996);
- *S. maccalliana*- wetlands such as Vermilion Lakes and near Johnson Lake (ESRS 1996);
- *S. myrtillifolia*- wetlands in the lower Bow valley in Banff including the eastgate, behind Johnson Lake, and the Banff Railroad Y (ELC database, ESRS 1996);
- *S. pseudimonticola*- range of habitats from river valley bottoms to the slopes of Mt. Norquay (ELC database, ESRS 1996).
- *S. scouleriania*- moderately common as isolated individuals across a range of montane and lower subalpine forested habitats.

Willows are generally highly palatable to ungulates (Table 2.2.1), and there is likely some variability by species. However this is difficult to evaluate because of the difficulty of identifying individual Salix species, hybridization between species, and relatively fine differences in herbivory levels. Tannas (2003) proposes that that Salix species with hairy foliage and high twig growth-rates are more palatable than *Salix drummondiana* and *S. myrtillifolia* , willow species that have stiff, smooth leaves and and twigs (Table 2.2.1). Figure 4.3.27 shows that for all willow species combined, presence, cover, and height declines sharply as the herbivory condition class increases from low to high. Significantly, willow has been nearly eliminated from areas heavily used by elk such as along channels of the Bow River passing near the Banff Springs Hotel Golf Course. However, reductions in elk densities near Banff townsite have allowed a dramatic increase in Salix cover and height near First Vermilion Lake (Figure 4.3.29).

Salix scouleriana is the tallest of Banff's willows, and often occurs as individual on moist areas within montane forests. It regenerates well after fire, and is highly palatable (Tannas 2003). Figure 4.3.28 indicates that the species has increasingly less cover and heights as browsing impacts increase, with only one observation of an individual <1m in height in a condition class 4 area.

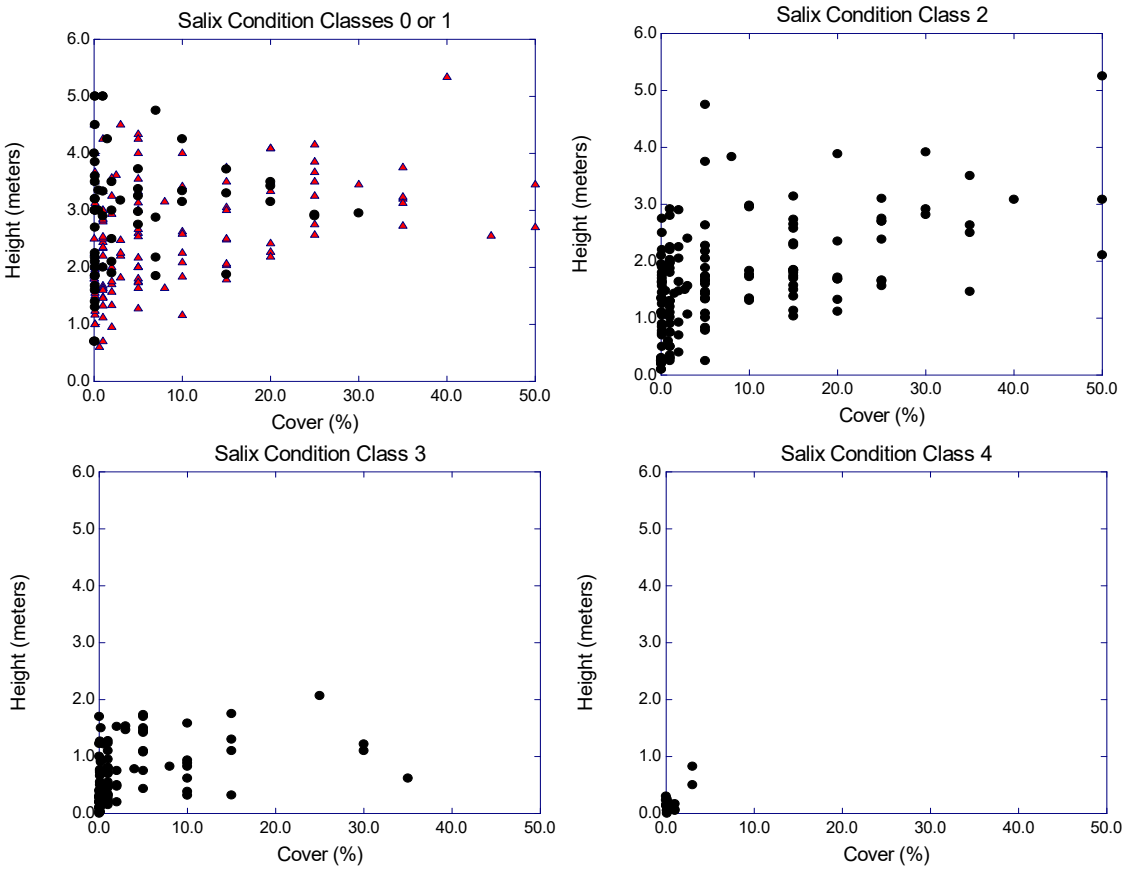

Figure 4.3.27. *Salix* spp. height and cover by browsing condition class. Class 0 (exclosures) is indicated by circles, Class 1 by triangles.

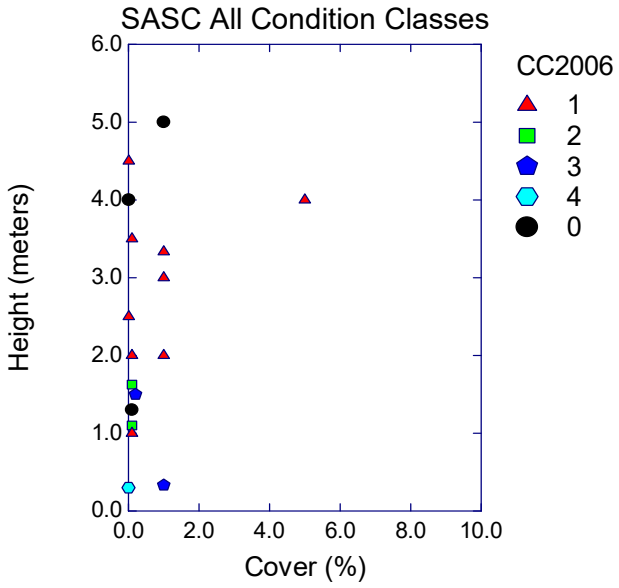

Figure 4.3.28. Cover and height of *Salix scouleriana* by browsing condition class.

1999, Cliff White photograph

2008, Cliff White photograph

Figure 4.3.29. Recovery of *Salix candida, S. farrine, S. maccalliana* and the hybrid *S. farriae x maccalliana* the First Vermilion Lake exclosure, Banff National Park between 1999 and 2008. See ESRS 1996 for further data on this site.

***Sambucus racemosa* L. (SARE), elderberry-** Elderberry is common on the western slopes of the Rocky Mountains in Yoho and Kootenay, but occurs rarely in the Banff Bow Valley (<5 ELC and Shrubwatch observations) where it is infrequently found at lower elevations on north facing slopes such Sulphur Mountain or the Massive Range. Regeneration by sprouting may be stimulated by forest disturbances such as fire and avalanching. SARE is a highly favoured browse species, with occurrence in the lower Bow Valley possibly locally reduced by past periods of high elk and moose density.

***Shepherdia canadensis* (L.) Nutt. (SHCA), buffaloberry-** This is one of Banff's most common deciduous shrub species, and occurs across most forested habitats in the montane and lower subalpine ecoregions. Shrub twigs have moderate palatability for ungulates (Table 2.2.1), and buffalo berries are important late summer food for grizzly and black bears (Hamer and Herrero 1987a,b). Buffalo berry production declines with time-since-fire (Hamer 1996), and the cover and height of shrubs declines dramatically with herbivory condition class (Figure 3.4.30). Cumulative effects of herbivory and fire suppression might thus be reducing bear habitat quality in areas around Banff townsite, particularly near the Golf Course and within Tunnel Mountain Campground. The transition towards lower herbivory class levels (Figure 4.2.1), and ongoing prescribed burns are likely improving habitat quality across much of the rest of the valley.

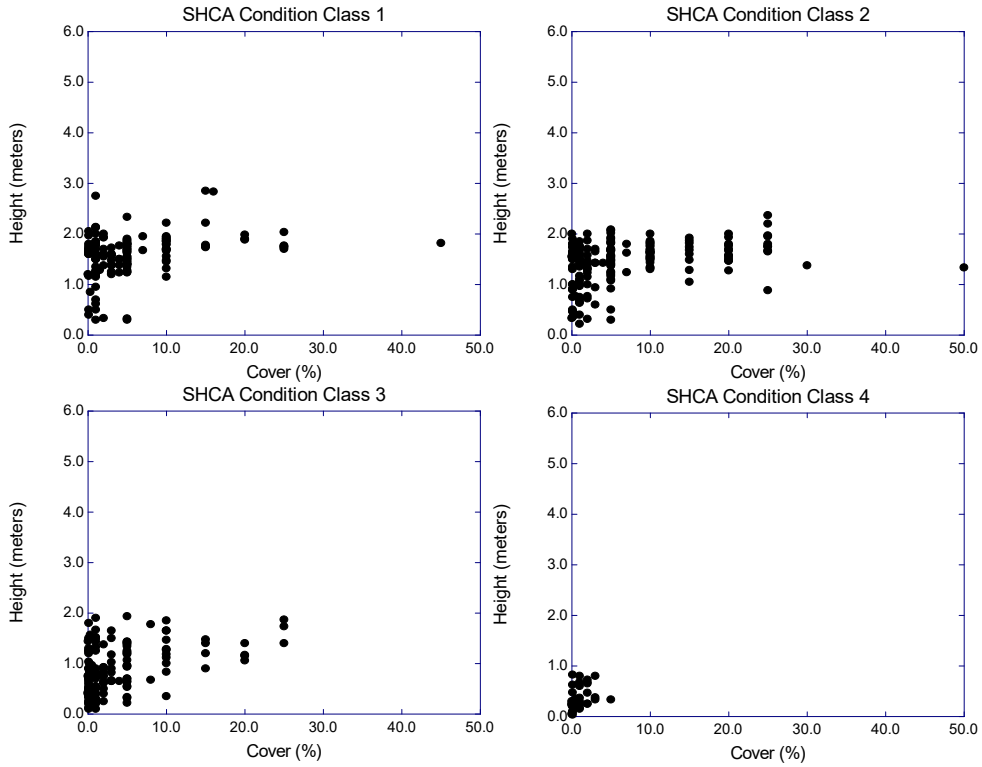

Figure 4.3.30. *Shepherdia canadensis* cover and height by condition class in the Bow Valley of Banff National Park.

***Symphoricarpus albus* (L.) Blake, snowberry and *S. occidentalis* Hook., buckbrush-** Both these species are found in the Bow Valley, although snowberry occurs most frequently, particularly in aspen woodlands. Figure 4.3.31 shows how the presence, cover and height of the two species declines as herbivory condition class increases. Although both species are relatively unpalatable to browsing (Table 2.2.1), this decline likely occurs because both species have brittle hollow stems that may be mechanically damaged when ungulate densities are relatively high. Due to low heights and lack of fruiting structures, the species are generally indistinguishable when CC>3. Within heavily browsed aspen woodlands, the decline of a suite shrub and tall shrub species including *Symphoricarpus* spp. and *Rosa* spp. is a major vegetation structure and plant community change that contrasts these areas with the high biological diversity of aspen communities areas outside the national park.

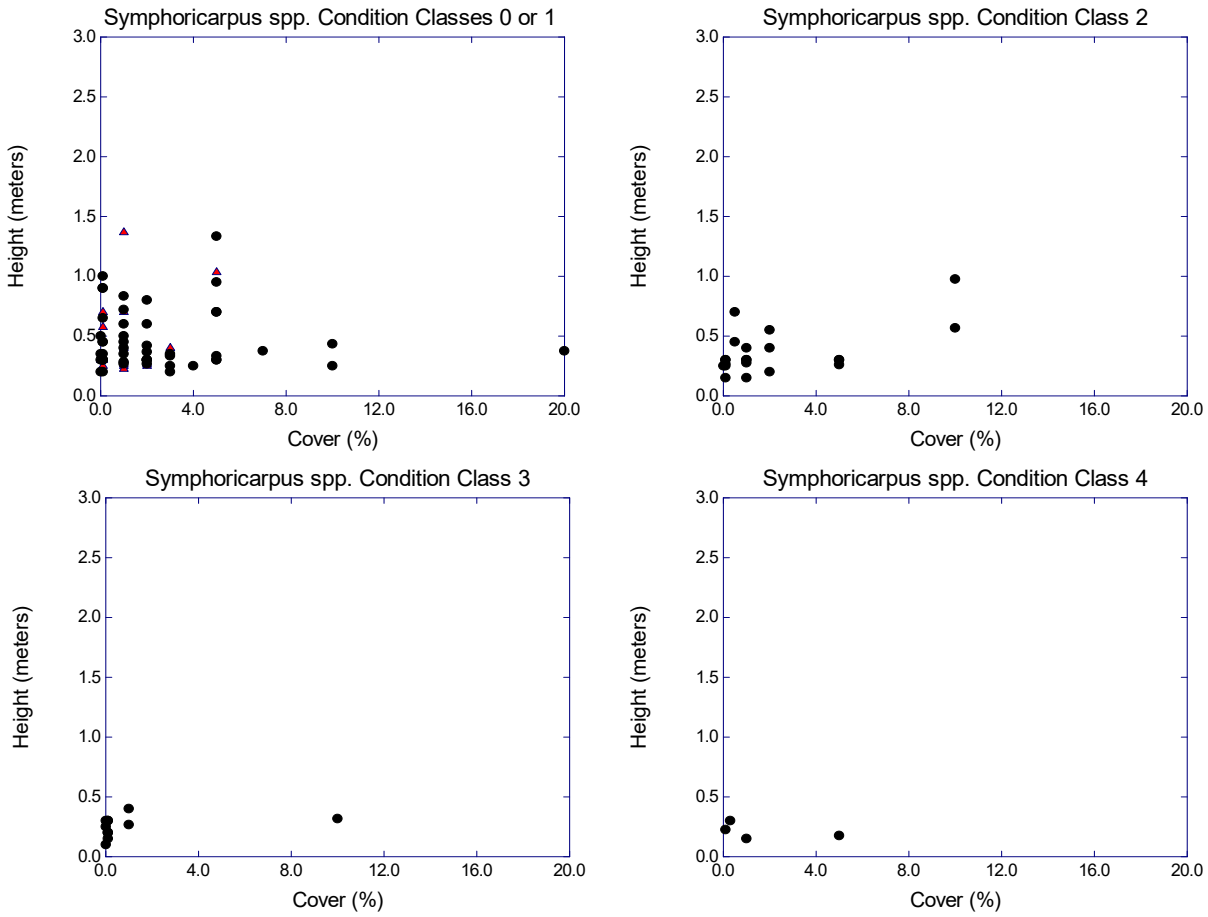

Figure 4.3.31. *Symphoricarpus* spp. height and cover by herbivory condition class area in the Banff Bow Valley. Class 0 (exclosures) is indicated by circles, Class 1 by triangles.

***Viburnum edule* Michx., VIED, highbush cranberry-** In the Bow Valley outside of Banff National Park where herbivory levels are lower, this red-orange berried shrub is usually fairly abundant in moist woodlands. However, within the park it occurs only within condition class 0 areas (e.g., ungulate exclosures such as within the highway fences near the Cascade Powerplant), or in other areas with relatively low levels of herbivory (Figure 4.3.32). It was never observed in Condition Class 4 areas where it would otherwise be expected to occur such in moist woodlands near the bottom of steep slopes near the Golf Course.

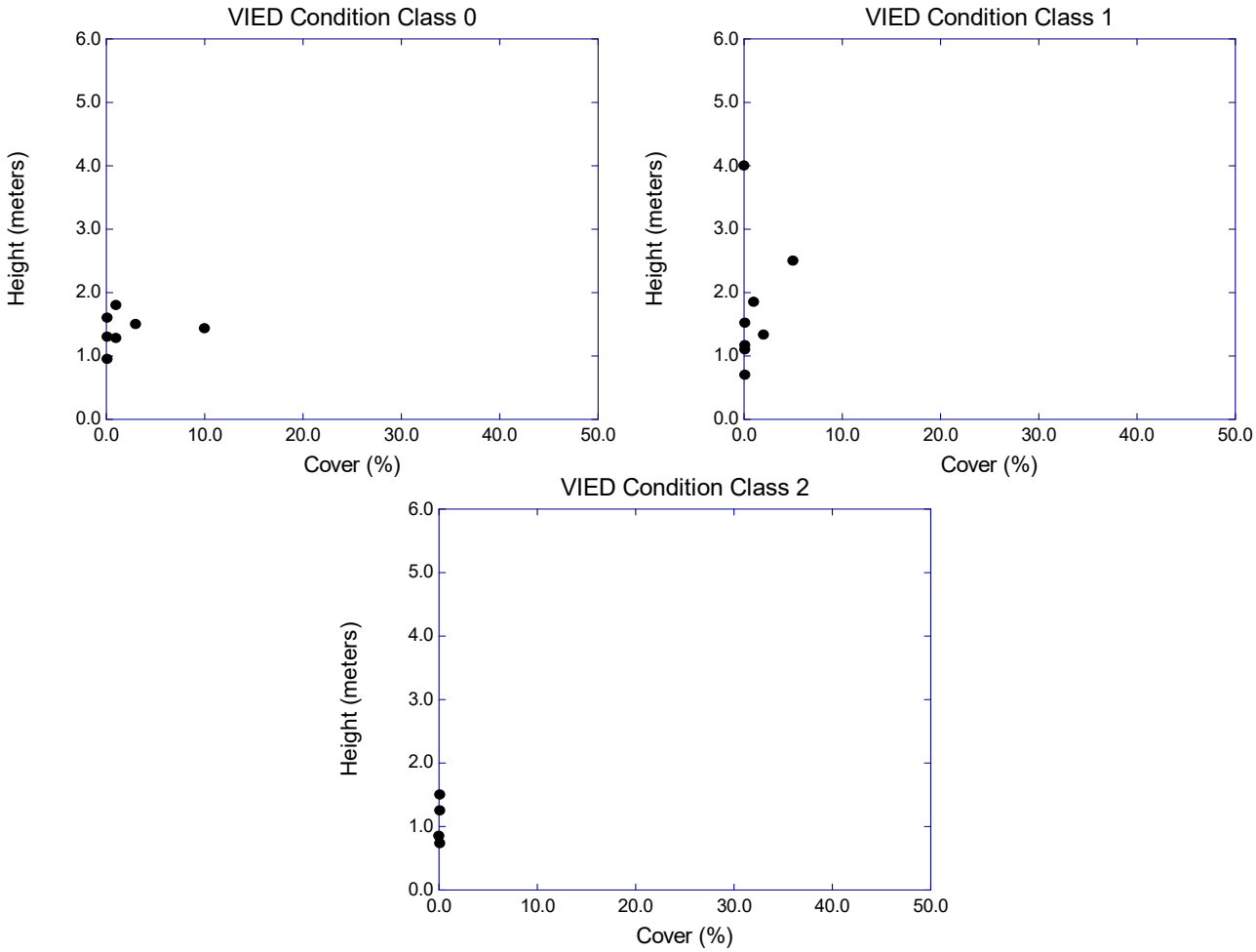

Figure 4.3.32. High-bush cranberry (*Viburnum edule)* height and cover by herbivory condition class in the Banff Bow Valley. No observations occurred at Condition Class 4.

5. Literature Cited

Achuff, P. L., and I. G. W. Corns. 1982. Vegetation. Pages 71-156 *in* W. D. Holland and G. M. Coen, general editors. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume II: soil and vegetation resources. Alberta Institute of Pedology Publication SS-82-44.

Achuff, P. L., I. Pengelly, and J. Wierzchowski. 1996. Vegetation: cumulative effects and ecological futures outlook. Chapter 4 *in* J. Green, C. Pacas, S. Bayley and L. Cornwell, editors. A Cumulative Effects Assessment and Futures Outlook for the Banff-Bow Valley. Department of Canadian Heritage. Ottawa, Ontario, Canada.

Augustine, D. J. and S. J. McNaughton. 1998. Ungulate effects on the functional species composition of plant communities: herbivory selectivity and plant tolerance. Journal of Wildlife Management 62:1165(1183.

Banff-Bow Valley Study. 1996. Banff-Bow Valley. At the crossroads. Technical report of the Banff-Bow Valley Task Force. Department of Canadian Heritage. Ottawa, Ontario, Canada. 432pp.

Byrne, A. R. 1968. Man and landscape change in the Banff National Park area before 1911. Studies in Land Use History and Landscape Changes, National Park Series, No. 1. University of Calgary, Calgary, AB. 173 pp.

Cahalane, V. H. 1941. Wildlife surpluses in the national parks. Transactions of the North American Wildlife Conference 6:355(361.

Clevenger, A. P., B. Chruszcz, and K. Gunson. 2001. Highway mitigation fencing reduces wildlife-vehicle collisions. Wildlife Society Bulletin 29: 646(653.

Cole, G.F. 1971. An ecological rationale for the natural or artificial regulation of native ungulates in parks. Transactions of the North American Wildlife Conference 36:417-425.

Cowan, I. M. 1947. Range competition between mule deer, bighorn sheep, and elk in Jasper National Park, Alberta. Transactions of the North American Wildlife Conference 12:223(237.

Duke, D, M. Hebblewhite, P.C. Paquet, C. Callaghan and M. Percy. 2001. Restoration of a large carnivore corridor in Banff National Park. Pages 261-275 *in* Large mammal restoration: ecological and social challenges in the 21st century. *Edited by* D. Maehr, R.F. Noss, and J.L. Lavlin. Island Press. Covelo, CA. 336pp.

Eastern Slopes Rangeland Seeds. 1996. Analysis of ungulate browse on selected sites, Banff National Park. Report to Parks Canada. Banff, AB.

Eastern Slopes Rangeland Seeds 1999. Analysis of ungulate browse on selected sites in Banff National Park. Report to Parks Canada. Banff, AB.

Eastern Slopes Rangeland Seeds 2001. Analysis of ungulate browse on select sites in Banff National Park. Report to Parks Canada. Banff, AB.

Flook, D. R. 1964. Range relationships of some ungulates native to Banff and Jasper National Parks, Alberta. Symposium of the British Ecological Society 4:119(128.

Friar, J.L., E.H. Merrill, J.R. Allen and M.S. Boyce. 2007. Know thy enemy: experience affects elk translocation success in risky landscapes. Journal of Wildlife Management 71: 541-554.

Hamer, D., and S. Herrero. 1987a. Wildfire's influence on grizzly bear feeding ecology in Banff National Park, Alberta. International Conference on Bear Research and Management 7:179–186.

Hamer, D., AND S. Herrero. 1987b. Grizzly bear food and habitat in the Front Ranges of Banff National Park, Alberta. International Conference on Bear Research and Management 7:199–213.

Hamer, D. 1996. Buffaloberry [Shepherdia canadensis (L.) Nutt.] fruit production in fire-successional bear feeding sites. Journal of Range Management 49:520–529.

Hebblewhite, M. 2008. Winter resource selection by elk in the Bow Valley of Banff National Park, 1990 to 2006. Wildlife Biology Program, University of Montana, Missoula, MT. 18pp.

Hebblewhite, M., D. H. Pletscher, and P. C. Paquet. 2002. Elk population dynamics in areas with and without wolves in Banff National Park. Canadian Journal of Zoology 80. 789(799.

Hebblewhite, M., White, C. A., Nietvelt, C., McKenzie, J. M., Hurd, T. E., Fryxell, J. M., Bayley, J. M. and Paquet, P. C. 2005. Human activity mediates a trophic cascade caused by wolves. Ecology 76: 2135-2144.

Hintze, J. 2004. NCSS 2004 and PASS 2002. Number Cruncher Statistical Systems. Kaysville, UT.

Holroyd, G. L. and K. J. Van Tighem. 1983. Ecological (biophysical) land classification of Banff and Jasper National Parks: Volume III: The wildlife inventory. Canadian Wildlife Service for Parks Canada, Western Region, Calgary, Alberta.

Howard, B. 2006. Elk monitoring and population dynamics in Banff National Park. Betula Environmental Services report to Parks Canada. Banff, AB. 59pp.

Kay, C.E., and C.A. White. 1995. Long-term ecosystem states and processes in the Central Canadian Rockies: A new perspective on ecological integrity and ecosystem management. George Wright Society Annual Conference on Research and Resources in Parks and on Protected Lands 8:119(132

Kay, C.E., C.A. White, I.R. Pengelly, and B. Patton. 1999. Long-term ecosystem states and processes in Banff National Park and the central Canadian Rockies. Occasional Report 9. National Parks Branch, Parks Canada Ottawa, Ontario.

Kay, C.E., B. Patton, and C.A. White. 2000. Historical wildlife observations in the Canadian Rockies: implications for ecological integrity. Canadian Field Naturalist 114: 561-583.

Keigley, R.B. and M. R. Frisina. 1998. Browse evaluation by analysis of growth form. Montana Fish, Wildlife and Parks. Bozeman, MT.

Kloppers, E.L., C. Cassidy St. Clair, and T.E. Hurd. 2005. Predator-resembling conditioning for managing habituated elk. Ecology and Society 10.1.

Lloyd, H. 1927. Transfers of elk for restocking. Canadian Field Naturalist 41:126(127.

McKenzie J.A. 2001.The selective advantage of urban habitat use by elk in Banff National Park. M.Sc. Thesis. University of Guelph, Guelph, ON.

Morgantini, L. E., and R.J. Hudson. 1988. Migratory patterns of the wapiti, *Cervus elaphus*, in Banff National Park, AB. Canadian Field Naturalist 102: 12-19.

Moss, E. H. 1959. The flora of Alberta. University of Toronto Press, Toronto. 546pp.

Nelson, J. R., and T. A. Leege. 1982. Nutritional requirements and food habits. Chapter 8 *in* J. W. Thomas and D. E. Toweill, editors. Elk of North America: ecology and management. Stackpole Books, Harrisburg, Pennsylvania. 698 pp.

Nietvelt, C. N. 2001. Herbivory interactions between beaver (*Castor Canadensis*) and elk (*Cervus elaphus*) on *Salix* spp. in Banff National Park Alberta. M.Sc. thesis. University of Alberta. Edmonton

Packard, F. M. 1942. Wildlife and aspen in Rocky Mountain National Park, Colorado. Ecology 23:478(482.

Paquet, P., J. Wierzchowski, and C. Callaghan. 1996. Effects of human activity on gray wolves in the Bow River Valley, Banff National Park, Alberta. Chapter 7 *in* J. Green, C. Pacas, S. Bayley and L. Cornwell, editors. A cumulative effects assessment and futures outlook for the Banff-Bow Valley. Department of Canadian Heritage. Ottawa, Ontario, Canada.

Parks Canada. 1997. Banff National Park management plan. Department of Canadian Heritage. Ottawa, Ontario.

Parks Canada. 1999. Elk management strategy in the Bow Valley, Banff National Park. Banff National Park. Banff, Alberta. 69pp.

Ripple, W. J. and E. J. Larsen. 2000. Historic aspen recruitment, elk, and wolves in northern Yellowstone National Park, USA. Biological Conservation 95:361-370.

Ripple, W. J. and E. J. Larsen. 2001. The role of postfire coarse woody debris in aspen regeneration. Western Journal of Applied Forestry 16: 61-64.

Rogeau, M.P. and D. Gilbride. 1994.

Rounds, R.C. 1979. Height and species as factors determining browsing of shrubs by wapiti. Journal of Applied Ecology 16:227(241.

Tannas, K. Common plants of the western rangelands. Volume 2. Trees and shrubs. Olds College and Alberta Agriculture, Food, and Rural Development. Edmonton, AB. 192pp.

Trottier, G. and A. Fehr. 1982. Re-evaluation of four range exclosures in Banff National Park, 1981. Canadian Wildlife Service. Edmonton, AB. 49pp.

Webb, R. 1957. Range studies in Banff National Park, Alberta, 1953. Wildlife Management Bulletin Series 1-Number 13. Canadian Wildlife Service. Ottawa, ON. 24pp.

White, C.A. 2001. Elk, fire and aspen in the Canadian Rockies. Dissertation. University of British Columbia. 201pp.

White C.A. and M.C. Feller. 2004. Repeat photography of trembling aspen in the Canadian Rockies. Tall Timbers Fire Ecology Conference 22:2-22.

White, C.A. and E. Hart. 2007. The lens of time: a repeat photography of the Canadian Rockies. University of Calgary Press. Calgary, AB. 302pp.

White, C.A., C.E. Olmsted, and C.E. Kay. 1998. Elk, fire and aspen in the Rocky Mountain national parks of North America. Wildlife Society Bulletin 26: 449-462.

White, C.A., M. C. Feller, and S. Bayley. 2003. Predation risk and the functional response of elk-aspen herbivory. Forest Ecology and Management 181: 77-97.

White, C.A., T.E. Hurd, M. Hebblewhite, and I.R. Pengelly. 2007. Mitigating fire suppression, highway, and habitat fragmentation effects in the Banff Bow Valley Ecosystem: Preliminary evaluation of a Before-After-Control-Impact (BACI) design with path analysis. In: J. Innes and J. Timko editors: Monitoring the Effectiveness of Biological Conservation. Forrex. Univerisity of British Columbia, Vancouver, BC.

Whittington, J. 2006. Bow Valley elk management options. Presentation to Banff Montane Advisory Group. Parks Canada. Banff, AB.