

ACCEPTED
OF GRADUATE STUDIES

Ecology of Meadow Communities
in Southeastern British Columbia

by

David Frank Fraser
B.Sc., University of Victoria, 1979

DEAN

June 9, 86

THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
in the Department
of
Biology

We accept this thesis as conforming
to the required standard

M.A.M. Bell

G.A. Allen

E. M. Hagmeier

M. C. R. Edgell

© David F. Fraser, 1985

University of Victoria

December 1985

All rights reserved. This thesis may not be reproduced in whole or in part, by mimeograph or other means, without the permission of the author.

Supervisor: Dr. M.A.M. Bell

ABSTRACT

Using a Braun Blanquet Table Sort Method, 14 meadow communities are described based on 8 differential species groups derived from 180 species found in 178 relevés completed on Harmer and Natal Ridges in the Front Range of the southern British Columbia Rockies. Parent material and moisture regime appear to be important correlates with community type.

Grazing by elk (Cervus elaphus) has altered species composition in several communities. Exclosed areas relieved of grazing pressure showed significant increases in fruit production of Amelanchier alnifolia, conifer seedling establishment, total woody biomass, and litter accumulation. Three herbaceous species, Gentiana amarella, Medicago lupulina, and Chrysanthemum leucanthemum showed higher cover, and surface soil pH was higher in grazed areas. Results indicate that forest succession is slowed or reversed in some low elevation winter range areas by ungulate grazing.

Implication for management of wildlife, reclamation of mine spoils, and species rare to British Columbia are considered.

[Redacted]

M.A.M. Bell

[Redacted]

G.A. Allen

[Redacted]

E. Hagmeier

[Redacted]

M. Edgell

[Redacted]

J. Errington

(Handwritten marks)

TABLE OF CONTENTS

ABSTRACT.....	ii
TABLE OF CONTENTS.....	iv
LIST OF TABLES.....	vii
LIST OF FIGURES.....	viii
CHAPTER ONE - MEADOW VEGETATION ON THE SOUTH- EAST ROCKIES OF BRITISH COLUMBIA.....	1
CHAPTER SUMMARY.....	1
INTRODUCTION.....	2
DESCRIPTION OF STUDY AREA.....	6
Physiography.....	6
Geology.....	6
Surficial Geography.....	6
Climate.....	9
Vegetation.....	10
METHODS.....	13
Field Methods.....	13
Data Analysis.....	13
Floristics.....	14
RESULTS.....	15
Differential Species Groups.....	15
Community Types.....	25
I Vaccinium/Snowbank Community Type.....	<u>25</u>

II Pinus/Sandstone Community Type.....	25
III Pinus/Till Pocket Community Type.....	30
IV Amelanchier/Penstemon Community Type.....	30
V) Astragalus/Kame Terrace Type.....	31
VI Penstemon/Polygonum Community Type.....	34
VII Lithospermum/Shrub Community Type.....	34
VIII Arenaria/Balsamorhiza /Unstable Colluvium Community Type.....	35
IX Balsamorhiza/Xeric Outcrop Community Type.....	35
X Calamagrostis/Soil Pocket Community Type.....	38
XI Balsamorhiza/Pseudotsuga/ Ridgetop Community Type.....	38
XII Agropyron/Sand Deposit Community Type.....	39
XIII Eriogonum/Xeric Shale Community Type.....	39
XIV Selaginella/Shale Depression Community Type.....	42
Summary of Community Types	42
DISCUSSION.....	45
Comparison with Communities Elsewhere....	45
Influence of Grazing.....	48
Relationships Between Substrate, Moisture Regime and Vegetation.....	49

MANAGEMENT IMPLICATIONS.....	53
Wildlife Management.....	53
Mined Land Reclamation.....	55
Rare Plant Species.....	57
REFERENCES CITED.....	62
CHAPTER TWO - UNGULATES AND WINTER RANGE IN THE SOUTHEAST ROCKIES OF BRITISH COLUMBIA.....	68
CHAPTER SUMMARY.....	68
INTRODUCTION.....	69
METHODS AND MATERIALS.....	72
RESULTS.....	75
DISCUSSION.....	82
IMPLICATIONS FOR MANAGEMENT.....	85

LIST OF FIGURES FOR CHAPTER ONE

- | | | |
|---|--|----|
| 1 | TYPICAL STANDS OF MEADOW VEGETATION IN MOUNTAINOUS TERRAIN IN THE SPARWOOD AREA OF SOUTHEASTERN BRITISH COLUMBIA | 4 |
| 2 | LOCATION OF STUDY AREA..... | 8 |
| 3 | CLIMOGRAPH FOR NATAL AND HARMER RIDGES..... | 12 |
| 4 | VACCINIUM/SNOWBANK, PINUS/SANDSTONE PINUS/TILL POCKET, AND AMELANCHIER/PENSTEMON COMMUNITY TYPES..... | 29 |
| 5 | ASTRAGALUS/KAME TERRACE, PENSTEMON/POLYGONUM, LITHOSPERMUM/SHRUB AND ARENARIA/BALSAMORHIZA/-UNSTABLE COLLUVIUM COMMUNITY TYPES..... | 33 |
| 6 | BALSAMORHIZA/XERIC OUTCROP, CALAMAGROSTIS/-SOIL POCKET, BALSAMORHIZA/PSEUDOTSUGA/-RIDGETOP AND AGROPYRON/SAND DEPOSIT COMMUNITY TYPES..... | 37 |
| 7 | ERIOGONUM/XERIC SHALE AND SELAGINELLA SHALE DEPRESSION COMMUNITY TYPES..... | 41 |
| 8 | SCHEMATIC REPRESENTATION SHOWING THE ECOLOGICAL RELATIONSHIPS OF PLANT COMMUNITIES ON A STYLIZED SLOPE..... | 44 |

LIST OF FIGURES FOR CHAPTER TWO

- | | | |
|---|---|----|
| 1 | MAP OF THE STUDY AREA SHOWING PLOT LOCATIONS..... | 74 |
|---|---|----|

ACKNOWLEDGEMENTS

Thanks to James W. Fyles for the encouragement to take on this project and providing much useful discussion in the early data gathering stages. Katherine Gould and Murray Simonson were willing and capable field assistants. Clayton Rouse, Joanne Larson and Helen Fyles provided much assistance in the soils analysis. Jim Rogers and Eric Lofroth were very helpful with many problems in dealing with computer analysis at the University, and Laurence Turney helped in a multitude of ways enabling me to become familiar with my own computer. Stephen Mitchell and Loris Laycock were very helpful in a wide variety of ways. Adolf Ceska, Geraldine Allen (composites), Kathy Gould (grasses), Frank Boas (bryophytes), Edward Dobyms, Katherine Palmer and Joanne Lawrence verified, helped to identify or provided other assistance with plant taxonomic problems. Many thanks to Tony Milligan and Dave Ryder of Environmental Services Dept., Westar Mining for all manner of help: moral, financial and "environmental".

Thanks to Bruce Enns, who did an excellent job of printing the photographic plates, Tracee Geernaert who did much of the drafting and for Eric Lofroth and Leah Ramsay, who spent many hours proof-reading. Special thanks to Leah, for endless hours of reading out numbers, careful checking and most important, moral support.

I would also like to thank Jim and Shirley Fyles, Geraldine Allen, and my supervisor M.A.M. Bell, each of whom, in very different ways, have changed the way I think about what I see.

CHAPTER ONE

MEADOW VEGETATION ON THE SOUTHEAST ROCKIES OF BRITISH COLUMBIA

CHAPTER SUMMARY

Using a Braun Blanquet Table Sort Method 14 meadow communities are described based on 8 differential species groups derived from 180 species found in 178 plots completed in important ungulate range on Harmer and Natal Ridges in the Front Range of the southern British Columbia Rockies. The Vaccinium/Snowbank, the Pinus/Sandstone and the Pinus/Till Pocket Community Types were found on till substrates, the Amelanchier/Penstemon, Penstemon/Polygonum, Lithospermum/Shrub, Balsamorhiza/Xeric Outcrop, Calamagrostis/Soil Pocket and Balsamorhiza/Pseudotsuga/Ridgetop are found on sandstone, mudstone and shale substrates while the Cerastium/Arenaria/Unstable Colluvium, Selaginella/Shale Depression and Eriogonum/Xeric Shale Community Types are restricted to shale substrates. Within each parent material type, moisture regime appears to be an important correlate with community type. Browsing by elk (Cervus elaphus) appears to have altered species composition on the most heavily used areas. Many of the plant communities described are similar to vegetation described from elsewhere in western North America. Implications for management of wildlife, reclamation of mine spoils and plant species on the rare list for British Columbia are considered.

INTRODUCTION

Subalpine meadows are floristically and structurally diverse components of the plant communities in the Rocky Mountains (Figure 1). Many provide important winter habitat for native ungulates and foraging habitat for bears.

Polster (1977) described alpine and subalpine meadow communities in the Akamina water-shed of extreme southeastern British Columbia. Much descriptive information exists in unpublished consultants' reports (e.g. B.C. Research 1977, 1981; Taesco Consultants Ltd. 1982) which emphasizes dominant trees for community differentiation.

Many meadows occur in the coal producing area of the Fernie Basin, where open pit mining disturbs large areas and leads to increasing wildlife management conflicts. Meadows overlying rock outcrops are often disturbed or destroyed by geological exploration activities.

The purpose of this paper is to describe and classify some of the plant communities of open, non-forested slopes of vegetation located on the Front Range of the Rocky Mountains, to correlate vegetation differences with major habitat features and to comment on the implications of the

FIGURE 1

TYPICAL STANDS OF MEADOW VEGETATION IN MOUNTAINOUS TERRAIN
IN THE SPARWOOD AREA OF SOUTHEASTERN BRITISH COLUMBIA

- 1a) Low elevation (1175 m ASL) gravel slopes on the west side of Natal Ridge. Open dry slope with scattered Douglas-fir and trembling aspen.
- 1b) Meadow on shale ridgetop on the north-east of Harmer Ridge surrounded by scattered Douglas-fir and a closed canopy forest of Douglas-fir and western larch.
- 1c) Open sandstone slopes on west side of Natal Ridge. Steep slopes with patches of trembling aspen, Douglas-fir and lodgepole pine.
- 1d) Mid-elevation (1670 m ASL) meadow in open stand of Douglas-fir on Harmer Ridge. Meadow surrounded by scattered Douglas-fir.



above for wildlife management and land reclamation.

This area was selected for several reasons. These meadows provide important forage for Rocky Mountain elk (Cervus elaphus nelsonii), mule deer (Odocoileus hemonius), black bear (Ursus americanus) and occasionally grizzly bear (Ursus arctos); the mountainous terrain is representative of of the region; easy access was available due to extensive network of roads; and the area is floristically interesting, containing elements of northern and southern alpine, prairie and western montane floras.

DESCRIPTION OF THE STUDY AREA

The study was conducted on Natal and Harmer Ridges in the Front Range of the Rocky Mountains in southeastern British Columbia, near the town of Sparwood (Figure 2).

Physiography

The area is characterized by having rugged relief, with broad glaciated valleys and steeply rising slopes strongly affected by tectonic uplift and, more recently, by a complicated pattern of glaciation (Ryder 1981).

The Front Range includes several subsidiary ranges and the Fernie Basin, a series of structurally controlled ridges and valleys which run roughly north to south. Elevations in the study area range from 1128 m ASL (above sea level) at valley bottom to ridgetops at 1890 m ASL.

Geology

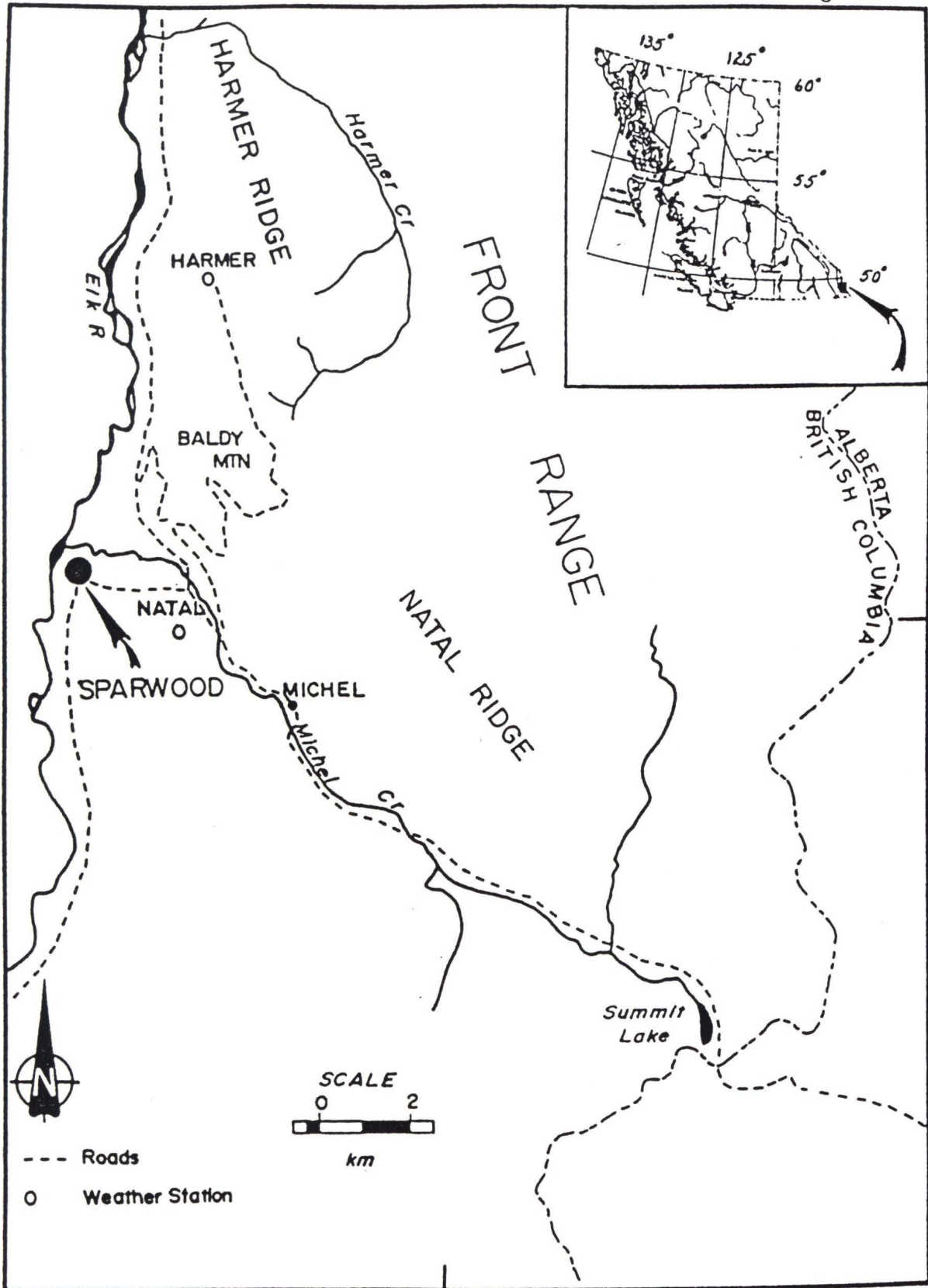
The bedrock of Natal and Harmer Ridges is composed of interbedded limestones, carbonaceous shales, mudstones, and sandstones with small outcroppings of conglomerate rocks (Price 1962, Taylor 1978). Extensive coal deposits in some 20 seams are often associated with carbonaceous shales.

Surficial Geology

Surficial deposits are largely the result of glacial activity, the most recent of which occurred about 13,000

FIGURE 2

LOCATION OF STUDY AREA



114° 44'

49° 40'

years ago (Clague 1975). Except for small pockets, glacial activity scraped bare slopes above 1500 m ASL and surficial deposits have been formed largely by colluvial activity and in situ soil forming processes. At lower elevations, the west side of both Natal and Harmer Ridges have steep southwest-facing kame terraces of coarse gravels. At about 1480 m ASL there is a 10 to 12 m thick deposit of lacustrine silts overcapped with fine sands, the remains of lacustrine deposits on top of the kame terraces (Ryder 1981, Dick 1978).

Climate

The climate of the study area has been classified by Koppen as Dfb, a cold, snowy forest climate, moist all year, with cool, short summers (from Krajina 1965). Continental location, mountainous topography and Pacific frontal systems result in an annual mean precipitation of 840 mm and strong south to southeasterly winds, especially during the winter months. During the summer, local convective storms contribute significantly to precipitation. Winter months are harsh, and are usually accompanied by heavy snowfalls. Local climates are heavily influenced by topography, with wind and precipitation increasing with elevation. The influence on growing season is mitigated on steep south-facing slopes where insolation may be ten times greater than on flat terrain (Bufo et al. 1981), and very much greater

than north-facing slopes. Figure 3 summarizes climate data for two stations in the study area, one near the top of Harmer Ridge (1890 m ASL) and another at Natal (1128 m ASL) in the Michel Valley bottom.

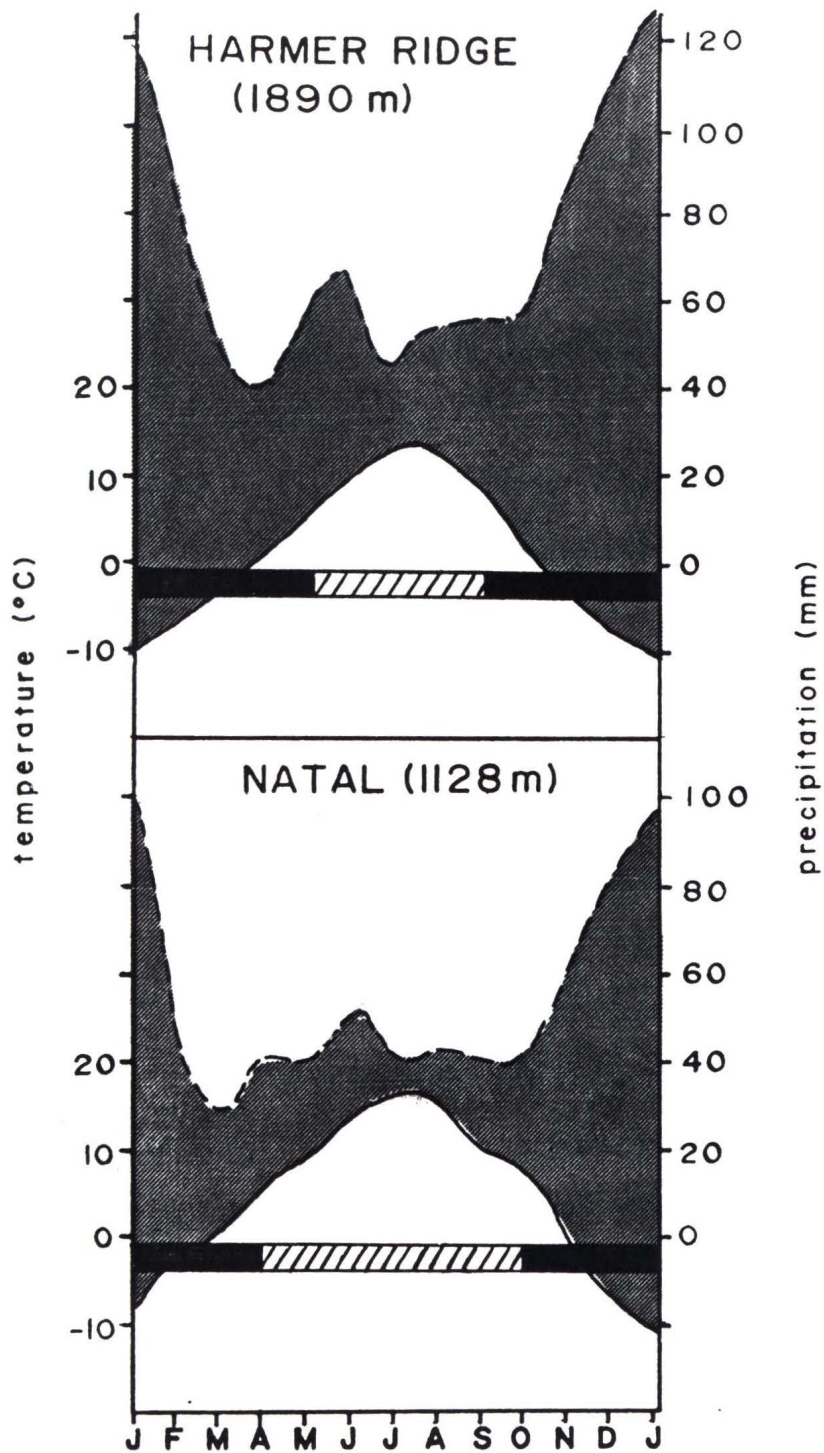
Vegetation

The Natal and Harmer Ridges are dominated by mixed conifer stands of lodgepole pine (Pinus contorta) and Douglas fir (Pseudotsuga menziesii) on southerly slopes and Engelmann spruce (Picea engelmannii) and subalpine fir (Abies lasiocarpa) on northerly slopes corresponding to two biogeoclimatic zones (Krajina 1969), the Montane Spruce Zone and the Engelmann Spruce Subalpine Fir Zone (Utzig et al 1982).

Lea (1980) includes the area as within the Dry Interior Region, Engelmann Spruce-Subalpine Fir Zone. The Lodgepole Pine-Whitebark Pine Subzone which occurs on north aspects from 1520-2130 m ASL and the Rocky Mountain Douglas-fir-Lodgepole Pine Subzone which is found in areas of lower precipitation and warmer temperatures on south and southwest exposures. Though meadows are present in both subzones, the open non-forested stands under study here are more extensive in the drier Rocky Mountain Douglas-fir-Lodgepole Pine Subzone.

FIGURE 3

CLIMOGRAPH FOR NATAL AND HARMER RIDGE
(after Walter and Leith 1967)



- mean monthly temp.
- mean monthly precipitation
- mean dally min. temp. < 0°C /month
- relative humid period
- ▨ absolute min. temp. < 0°C /month

METHODS

Field Methods

One hundred and seventy-eight 200 square m relevés (plots) were established on Natal and Harmer Ridges in the summers of 1979 and 1980 using the Braun-Blanquet approach (Mueller-Dombois and Ellenberg 1974). Plots were subjectively placed in areas that satisfied the criteria of stand homogeneity and less than 30 % cover estimate of conifers. At each plot all plants were listed with a visual estimate of their percent cover, the percent cover of exposed mineral soil, dead woody material and total organic matter. Slope, aspect, and elevation were also recorded from each plot (Appendix I).

In each plot a soil pit was dug to the C layer or to a maximum depth of 1 m. Parent material, and soil horizons (LFH, A, B and C) were recorded if they could be determined visually. Sixty samples (of 5 combined subsamples) of the B layer from up to 5 representative stands of each community type were analyzed for pH (1:1 in water) using a Good Digital pH meter and a glass electrode.

Data Analysis

Floristic reléve data were analyzed using the Table Method (Mueller-Dombois and Ellenberg 1974) facilitated by a computer programme (Češka and Roemer 1971, Češka 1976). This method involves the formation of species/reléve groups

by a simultaneous sorting of the rows and columns of the two-dimensional matrix formed by the species and releves.

Eight groups were chosen on the basis of their strength as determined by the concentration of positive entries within the group, knowledge of the ecological amplitude of the species involved, and the mean similarity of the releves within a species/releve block. These groups were ordinated by Reciprocal Averaging (Ceska and Roemer 1971, Ceska 1976). Final sorting of the table and definition of community types were done by hand.

Elevation, slope aspect, soil pH and soil depths were summarized as means \pm S.D.

Floristics

A species list of all plants encountered on Natal and Harmer Ridges appears in Appendix II. Nomenclature follows Hitchcock and Cronquist (1976) and voucher specimens of vascular plants are deposited in the herbarium of the Biology Department, University of Victoria, B.C.

RESULTS

Differential Species Groups

Of the 180 species encountered 8 species groups including 36 species and 14 community types were selected from computer assisted runs of the original data (Table 1). Twenty-five transitional relevés did not contribute to community typification and were grouped separately (Appendix III).

Species groups were named from the species appearing at the beginning of each group in the species/relevé table, i.e. the species in the group with the highest constancy value in the data matrix (Table 2). This is shortened to just the genus name for that species.

With the exception of Anaphalis margaritacea, all of the species in the Pinus group are typical of cool, moist, subalpine forest stands.

All of the members of the Salix species group are species often found in early stages of lodgepole pine forest succession.

The Penstemon species group includes species typically found in moist to mesic meadows, but absent from xeric sites.

The Comandra species group consists of plants that are restricted to the heavily grazed, dry gravel slopes at the lowest elevations of Natal Ridge.

TABLE 1

PARTIAL TABLE INCLUDING DIFFERENTIAL SPECIES GROUPS

Symbol	Actual Cover
5	75- 100 % cover
4	50 - 75 % cover
3	25 - 50 % cover
2	5 - 25 % cover
1	numerous or scattered, 5% cover
+	few, 5% cover rating
-	rare, one or two plants, with negligible cover rating

COMMUNITY TYPES

Number	Name
I	Vaccinium/Snowbank
II	Pinus/Sandstone
III	Pinus/Till Pocket
IV	Amelanchier/Penstemon
V	Astragalus/Kame Terrace
VI	Penstemon/Polygonum
VII	Lithospermum/Shrub
VIII	Arenaria/Balsamorhiza/Unstable Colluvium
IX	Balsamorhiza/Xeric Outcrop
X	Calamagrostis/Soil Pocket
XI	Balsamorhiza/Pseudotsuga/Ridgetop
XII	Agropyron/Sand Deposit
XIII	Eriogononum/Xeric Shale
XIV	Selaginella/Shale Depression

TABLE 2

CONSTANCY CLASSES FOR ALL SPECIES BY COMMUNITY TYPE

Species numbers are assigned in decreasing order of constancy in entire data matrix.

Constancy Class	Constancy (%)
1	0 - 20
2	20.1 - 40
3	40.1 - 60
4	60.1 - 80
5	80.1 - 100

Note: In Community Type III, containing three plots, the number of occurrences within the type are indicated (1 = -, 2 = +, 3 = *).

COMMUNITY TYPE	I	I	I	I	V	V	V	V	I	X	X	X	X	X
	I	I	V		I	I	I	X		I	I	I	I	
		I			I	I					I	I	V	
							I						I	
NUMBER OF PLOTS	0	0	0	3	0	1	1	0	0	1	1	1	0	1
	6	5	3	3	9	8	2	8	9	6	0	0	5	0
PINUS GROUP														
99. Pinus albicaulis	5													
114. Anaphalis margaritacea	5					1								
115. Abies lasiocarpa	5		1											
134. Vaccinium caespitosum	4													
137. Pedicularis racemosa	4													
147. Hieracium albiflorum	4													
166. Habenaria unalascensis	3													
89. Vaccinium scoparium	5	1	*	1										
SALIX GROUP														
60. Salix scouleriana	5	3	+	1		1	1		1		1			
63. Pinus contorta	5	4	*	1	1	1				1				
71. Senecio integrifolius	5	2	*	1					1	1	1		1	
83. Castilleja miniata	3	3		1		1				1				
PENSTEMON GROUP														
02. Penstemon confertus	5	5	*	5	5	3	5	4	5	5	4	2	2	1
04. Amelanchier alnifolia	2	4	-	4	4	4	4	5	4	3	4	1		
03. Aster conspicuus	5	4	*	4	3	4	3	4	4	5	2	1		1
09. Allium cernuum	2	*	2	4	3	4	3	5	3	3				1
COMANDRA GROUP														
85. Comandra umbellata	5									1	1	2		
108. Astragalus crassicaarpus	4			1										
118. Bromus tectorum	3			1								2		
119. Penstemon eriantherus	3											5		
130. Linum perenne	3													
POLYGONUM GROUP														
06. Polygonum douglasii	1	2	+	2	3	5	5	5	5	1		2	5	3
13. Agropyron spicatum			-	1	4	4	5	4	5	2		5	5	
18. Symphoricarpos albus	1		*	2	3	4	1	3	1	2		5		
POTENTILLA GROUP														
29. Potentilla arguta		1	1	1	4	4	2	4	2			5	4	
38. Erigeron speciosus		1	2		3	4	3	4				4	4	
39. Lithospermum ruderales		1			5	2	1	4				3	3	
BALSAMORHIZA GROUP														
58. Balsamorhiza sagittata					4	4		5				4		
59. Arenaria capillaris		1			4	4		2				4	2	
74. Cerastium arvensis					4	4		4				3		
TRISETUM GROUP														
66. Trisetum spicatum		1		1	2			4	1	1				3
73. Lomatium macrocarpum							1	2	4	1		1		5
76. Selaginella densa				1				1	3			1		3
95. Zygadenus venenosus						1			3					3
104. Agoseris glauca	1			1					4					4
117. Dodecatheon conjugens									4		1			4

CONSTANCY TABLE (cont.)

COMMUNITY TYPE	I	I	I	I	V	V	V	V	I	X	X	X	X	X
	I	I	V		I	I	I	X		I	I	I	I	I
		I			I	I			I			I	I	V
	<hr/>													
NUMBER OF PLOTS	0	0	0	3	0	1	1	0	0	1	1	1	0	1
	6	5	3	3	9	8	2	8	9	6	0	0	5	0
ACCOMPANYING SPECIES														
1. <u>Achillea millefolium</u>	5	3	+	4	4	4	5	5	4	5	4	4	3	4
5. <u>Lupinus sericeus</u>	3	3	-	4	3	2	5	4	4	4	2	2	1	1
7. <u>Fragaria virginiana</u>	4	5	*	3	1	3	4	3	3	3	3	2	1	
8. <u>Collinsia parviflora</u>	1	1	-	3	3	3	2	5	4	3	3	2	3	2
10. <u>Calamagrostis rubescens</u>	3	3	*	3		3	3	2	2	3	2	1		1
11. <u>Phleum pratense</u>	2	*	2	3	4	1	1	3	3	2	2	2		
12. <u>Rosa acicularis</u>	2	-	2	3	3	3	1	2	3	1	3	1	1	
14. <u>Campanula rotundifolia</u>	2	2		3		2	5	4	2	3	1	1		
15. <u>Eriogonum umbellatum</u>	1	1		2			4	4	4	2	4	2	3	5
16. <u>Berberis repens</u>	1	2	-	3	1	2	3	2	3	3	2	1		
17. <u>Spiraea betulifolia</u>	3	3	-	3	3	3	2	2	1	1	1	2		1
19. <u>Geranium viscosissimum</u>	1	4		2	1	2	4		3	3	3	1	2	
20. <u>Heuchera cylindrica</u>	1	3	-	1		2	2	2	2	2	1	3	3	2
21. <u>Arabis holboellii</u>	2	+	1	4	2	3	4	3	2	2	1			1
22. <u>Silene menziesii</u>	1	-	2	3	2	2	3	2	2	2	2	2	1	
23. <u>Stipa occidentalis</u>	1		2	2	1	2	1	2	3	2	2	2	2	
24. <u>Festuca idahoensis</u>	1	1		1		1	3	4	4	2	2		3	3
25. <u>Deschampsia cespitosa</u>	1	3	-	2	2	2	3	2		3	2		1	
26. <u>Tragopogon dubius</u>	1		1	2	2	2	2	2	3	3	1	1	2	2
27. <u>Shepherdia canadensis</u>	5	3	*	2	1	2	2	1		1			1	
28. <u>Castilleja cervina</u>	1	3		2	4	2	1	2	2	1	1	2	2	
29. <u>Potentilla arguta</u>	3	1	-	3		2	2	1		2				
30. <u>Epilobium angustifolium</u>	1	1	-	1	4	3	1	2	1	2	1	2	1	1
31. <u>Phacelia hastata</u>	1		-	1	4	3		2	2	1	1	1		1
32. <u>Penstemon fruticosus</u>	2		2	3	2	1	2	1	1		2	1		
33. <u>Aster laevis</u>	2	1	-	1	1	2	1		3	1	1	2		1
35. <u>Taraxacum officinale</u>				1	1	2	1	3	2	1	2	1	1	2
36. <u>Antennaria microphylla</u>	1			1	2	2	1	2	2	1	2	2	2	
37. <u>Populus tremuloides</u>	4			2		1	1		1	2		1	1	
40. <u>Sedum lanceolatum</u>	1	2		2		1		2	3		2	1	1	3
41. <u>Medicago lupulina</u>	1	3	-	1	1	2	1		2	1	1			
42. <u>Poa compressa</u>	1	-	1	2	1	1	2	1	1	1	2			1
43. <u>Carex brevicaulis</u>	1	1	-	1		2	1	2	2	1	1	2	1	1
44. <u>Prunus virginiana</u>				-	1	3	2	1		1	5			1
45. <u>Lomatium triternatum</u>					1	2	1	2	2	3	1	3	1	2
46. <u>Vicia americana</u>	1	2	+	1	2	2	1			2	2	2	1	
47. <u>Peltigera rufescens</u>		1	-	2		1		2	2	1			3	1
48. <u>Senecio canus</u>				1	5	1			1	1		2		
49. <u>Rubus parviflorus</u>	1	3		2		1	1	1		1				
50. <u>Collomia linearis</u>				1		2	1	1	2	1	1	1	2	2

CONSTANCY TABLE (cont.)

COMMUNITY TYPE	I	I	I	I	V	V	V	V	I	X	X	X	X	X
	I	I	V		I	I	I	X		I	I	I	I	
		I				I	I				I	I	V	
							I						I	
NUMBER OF PLOTS	0	0	0	3	0	1	1	0	0	1	1	1	0	1
	6	5	3	3	9	8	2	8	9	6	0	0	5	0
51. <u>Calochortus apiculatus</u>	1	-	1		1	1	2	2	1	2			1	2
52. <u>Carex hoodii</u>			1		1	1	2	2	2	2				1
53. <u>Chrysanthemum leucanthemum</u>	1	3	-	2	1				1	1	1			
54. <u>Pseudotsuga menziesii</u>	4		1	2	1		1	1	1	2	1			1
55. <u>Poa pratensis</u>		1	-	1	2	1			1		1			
56. <u>Bromus carinatus</u>				1	1	2	3	2	1	1	1			1
57. <u>Arnica cordifolia</u>	3			1	1	1		1	1		1			
58. <u>Thalictrum occidentale</u>	2		-	2		1	1		1					
59. <u>Acer glabrum</u>		2	-	1	1	1	1	1	1			1		
60. <u>Gallium boreale</u>		1	+	1	2	1	1	1	2			1		
61. <u>Epilobium paniculatum</u>		1	-	1	2	1	1		1	1	1			
62. <u>Solidago missouriensis</u>		1	+	1	3	2	1		1	1		1		
63. <u>Smilacina stellata</u>	1		-	1	1	1		2	1				1	
64. <u>Bryum caespiticium</u>	1		-	1	1	1		1	1	1	1			1
65. <u>Linaria vulgaris</u>		2	-	1	2	1		1						1
66. <u>Cladonia spp.</u>	1	1		1		1	1	2	1					1
67. <u>Verbascum thapsus</u>		2		1	2	2			1	2				
68. <u>Poa nervosa</u>				1	3		1	1		1	1	1	1	
69. <u>Populus trichocarpa</u>	2			1	1	1				1		1		1
70. <u>Viola adunca</u>		1	-	1	1	1			1			1		
71. <u>Rosa woodsii</u>		1		1	2			1	1	1	1	1		
72. <u>Danthonia parryi</u>	2							1	1		1	1	1	2
73. <u>Juniperus communis</u>	2			1		1		1	1				1	1
74. <u>Koeleria cristata</u>				1	2	1	1	1		1	1			
75. <u>Cirsium arvense</u>		1		1									1	1
76. <u>Poa scabrella</u>				1	1					1	2			
77. <u>Tortula ruralis</u>				1	1	1			1		1	1		1
78. <u>Arctostaphylos uva-ursi</u>	1	1		1	2		1		1		1			
79. <u>Anemone multifida</u>		1		1	2				1	1	1	1		
80. <u>Agrostis scabra</u>		1	-	1	1							1		1
81. <u>Polytrichum juniperinum</u>				1	1		1		1	1			1	1
82. <u>Apocynum androsaemifolium</u>		1		1	2	1			1		1			
83. <u>Osmorhiza occidentalis</u>				2		1								
84. <u>Elymus glaucus</u>		1		1							1			
85. <u>Erythronium grandiflorum</u>	1			1	1							1	1	1
86. <u>Aster foliaceus</u>	1			1		1		1			1			1
87. <u>Pachistima myrsinites</u>				1		2	2			1	1			
88. <u>Medicago sativa</u>				1	1				1	1				
89. <u>Lomatium dissectum</u>				1		1		2						1

The Polygonum species group contains species that are typically found on eroded sites subject to heavy browsing.

The Potentilla and Balsamorhiza species groups both consist of species typically found on shale or sandstone colluvium and outcrops, with the latter on drier and unstable areas.

The Trisetum group consists of species typical of the most xeric sites found in the study area. All grow in the early spring and are summer dormant.

Community Types

The 14 community types defined using the differential species groups were generally named using one or more species typical of that community type and a physical feature associated with that type. Table 3 summarizes the occurrence of each species group within community types, and some of the physical features of each community type.

I Vaccinium/Snowbank Community Type (Figure 4a)

This community type is found on gently sloping pockets of podzolized glacial till that retain snow cover until late May. Dominant species (single, noticeable species with high cover sensu Meuller-Dombois and Ellenburg 1974 pp.171-173) are Calamagrostis rubescens, Vaccinium scoparium and Shepherdia canadensis. This community is differentiated by the presence of the Pinus, Penstemon and Salix species groups. The presence of conifer saplings and a patchy ground-cover of Vaccinium scoparium and Vaccinium caespitosum interspersed with Carex concinnoides, Pedicularis racemosa and Castilleja rhexifolia is characteristic of this community type.

II Pinus/Sandstone Community Type (Figure 4b)

This community is usually found on gently sloping sandstone colluvium, and rarely on thin till over sandstone

TABLE 3

DISTRIBUTION OF SPECIES GROUPS IN PLANT COMMUNITIES AND
SUMMARY OF SITE DESCRIPTION DATA

Solid line indicates that at least 50% of the group members may be expected in any one stand of that community type, broken line indicates that approximately 20-50% of the group may be expected to occur. Environmental parameter summaries indicate the mean \pm one standard deviation.

Community type Species groups	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
<i>Pinus albicaulis</i>														
<i>Salix acouleriana</i>														
<i>Penstemon confertus</i>														
<i>Comandra umbellata</i>												---		
<i>Polygonum douglasii</i>														
<i>Potentilla arguta</i>														
<i>Balsamorhiza sagittata</i>														
<i>Trietum spicatum</i>														
Elevation (m)	1671 ± 132.6	1701 ± 214.9	1484 ± 97.7	1576 ± 215.7	1312 ± 22	1466 ± 195	1711 ± 401	1697 ± 142.6	1690 ± 106.5	1574 ± 217.0	1620 ± 64.2	1344 ± 19.7	1705 ± 194.9	1675 ± 186.8
Parent material	till	till or sandstone	deep pockets of till	sandstone conglom. fluvial	kame terrace gravels	alkali sandstone & shales	sandstone shales & sand	shale colluvium	sandstone or shale colluvium	sandstone or siltstone	sandstone shale on ridgetop	fluvial sands	sandstone shale	loose shale
Slope (%)	22.6 ± 14.2	46 ± 16.3	29 ± 9.3	47 ± 15.9	56 ± 10	50 ± 20	57 ± 18.2	53 ± 14.2	48 ± 19.4	45 ± 22.7	44 ± 12.8	58 ± 26.2	34 ± 15.8	22.75 ± 9.3
Aspect (degrees)	249 ± 31.8	231 ± 36.8	222 ± 45.4	211 ± 32.7	185 ± 9.5	215 ± 63.1	184 ± 36	209 ± 15.4	190 ± 36.4	200 ± 31.9	166 ± 58.5	212 ± 21.7	202 ± 27.9	211.3 ± 34.9
Soil pH	4.5±1.0	5.2±0.6	6.1±0.2	7.1±1.1	8.2±0.2	7.2±0.9	6.8±0.4	6.7±0.5	6.1±0.2	6.7±1.6	6.3±0.3	6.7±0.1	6.4±0.5	6.4±0.6

FIGURE 4

- 4a) Vaccinium/Snowbank Community Type. Gentle slope and Pinus albicaulis, and Salix scouleriana saplings are typical for this type. Browse damage is restricted to Salix branch tips and snow accumulation protects the base of the shrub. Herbaceous cover includes Calamagrostis rubescens and Pedicularis racemosa.
- 4b) Pinus/Sandstone Community Type. Understory typical of this community type includes Castilleja spp., Lupinus sericeus, and Aster conspicuus. Dead woody material represents remains of a burned Pinus albicaulis stand.
- 4c) Pinus/Till Pocket Community Type. Understory of this community type shows Shepherdia canadensis, Salix, and Juniperus communis. Herbaceous species include Aster conspicuus, Geranium viscosissimum and Senecio streptanthifolius with a dense stand of Pinus contorta in the background.
- 4d) Amelanchier/Penstemon Community Type. Prominent browse line is visible on the young Pseudotsuga menziesii in the background. Herbaceous species include Aster conspicuus, Erigeron peregrinus, Calamagrostis rubescens and Phleum pratense.



d



c



b



a

colluvium. It is dominated by Calamagrotis rubescens, Pinus contorta and Shepherdia canadensis and differentiated by the presence of the Salix and the Penstemon species groups. Salix is always heavily browsed in this community type and many stands contain dead plants of Ceanothus velutinus, presumably killed by overbrowsing.

III Pinus/Till Pocket Community Type (Figure 4c)

This community type is represented by only three plots, all on gently sloping pockets of till over 1 m deep. Dominant species include 20 to 30 year old Pinus contorta from 3 to 8 m in height. Understory cover tends to be dominated by Symphoricarpos albus and Phleum pratense. This type is differentiated by the presence of the Salix, the Penstemon and the Polygonum species groups. All sites showed evidence of heavy use by ungulates in both winter and summer. Growth is typically lush in these sites.

IV Amelanchier/Penstemon Community Type (Figure 4d)

This community occurs on a wide range of slopes and parent materials and is heavily browsed, especially in the winter months. Dominant species are Lupinus sericeus, Calamagrostis rubescens, and Phleum pratense, with moister sites being often dominated by shrubby Populus tremuloides

and Populus trichocarpa or Osmorhiza occidentalis. On unstable gravels Apocynum androsaemifolium dominates the understory. This type is differentiated by the presence of the Penstemon species group. Dead, overbrowsed Ceanothus velutinus shrubs are often encountered. In two relevés the remains of Populus tremuloides clones were encountered. Rapid conifer establishment occurs in this type in the absence of ungulate browsing (see Chapter 2).

V Astragalus/Kame Terrace Community Type
(Figure 5a)

This type is restricted to the steep, dry, hot, gravel slopes found at low elevations along the west side of Natal Ridge. Dominant species in this community type are Astragalus crassicaarpus, Comandra umbellata, Phleum pratense and Poa nervosa. It is differentiated by the Penstemon and the Comandra species groups and characterized by the presence of Senecio canus. This community type is also heavily used by ungulates during the winter months, causing damage to Populus tremuloides, P. trichocarpa and Prunus virginiana stands. Senecio canus and Campanula rotundifolia often form dense patches in this community type.

FIGURE 5

) Astragalus/Kame Terrace Community Type. Steep, open slopes with scattered shrubby stands of Prunus virginiana and Populus tremuloides are shown with herbaceous species including Astragalus drummondii, A. crassicaarpus, Lupinus sericeus, Phleum pratense and Linum perenne.

) Penstemon/Polygonum Community Type. Dead and dying Salix scouleriana and Ceanothus velutinus are shown with an understory including Phleum pratense, Erigeron peregrinus, Gentiana amarella and Amelanchier alnifolia.

) Lithospermum/Shrub Community Type. The background shows Douglas-fir and lodgepole pine, with the foreground dominated by Phleum pratense and Lithospermum ruderale. Scattered Amelanchier alnifolia have been browsed into globe-shaped bushes.

) Arenaria/Balsamorhiza/Unstable Colluvium Community Type. Penstemon confertus, Lupinus sericeus, Balsamorhiza sagittata form are the dominant cover species with scattered clumps of Cerastium arvensis and Arenaria spp. Small patches of mineral soil with Polygonum douglasii are visible in the foreground.

VI Penstemon/Polygonum Community Type
(Figure 5b)

This community type is found on eroded sandstones, mudstones and shales with basic soils (Table 2). Dominant species include Phleum pratense, Agropyron spicatum, Rosa acicularis, Amelanchier alnifolia, and Symphoricarpos albus. It is differentiated by the Penstemon and Polygonum species groups. This type is subject to heavy browse pressure by native ungulates, and Salix scouleriana and Ceanothus velutinus tend to be present as dead or dying individuals.

VII Lithospermum/Shrub Community Type
(Figure 5c)

This type is found on dry sandstone and shale ridges as well as on well drained sand deposits. The dominant species include Agropyron spicatum, Lupinus sericeus, Festuca idahoensis and Stipa occidentalis. It is differentiated by the presence of the Penstemon, Polygonum and Potentilla species groups. Shrub cover can be up to 30 %, most commonly consisting of Amelanchier alnifolia, and Populus tremuloides. Browse pressure is heavy on most shrubs.

VIII Arenaria/Balsamorhiza/Unstable Colluvium Community Type
(Figure 5d)

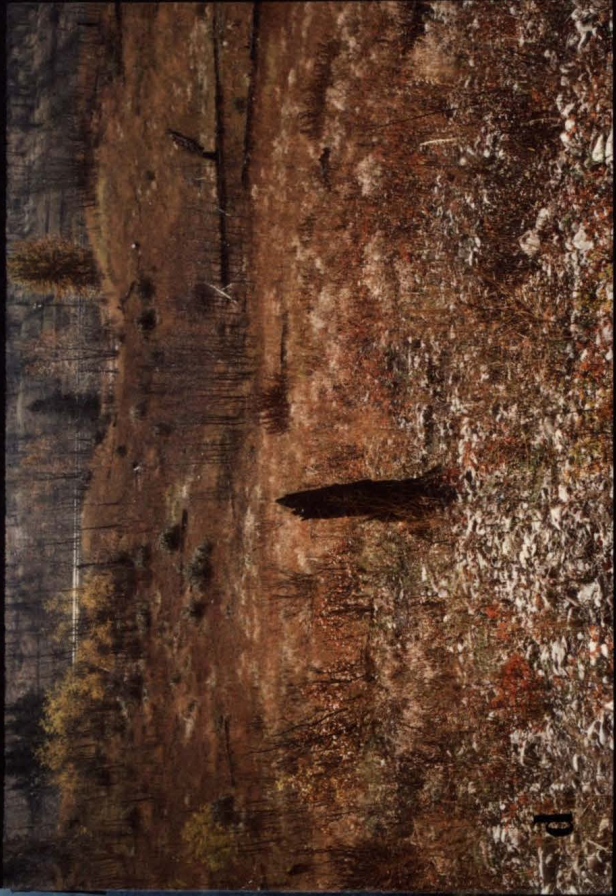
This type is restricted to regosols on unstable slopes of shale colluvium influenced by gravity or high winds on ridgetops. Dominant species in this community type are Balsamorhiza sagittata, Festuca idahoensis, Agropyron spicatum and Amelanchier alnifolia. It is differentiated by the presence of the Polygonum, Penstemon, Balsamorhiza and the Potentilla species groups. Clumps of Eriogonum umbellatum and Lupinus sericeus are common in this community type.

IX Balsamorhiza/Xeric Outcrop Community Type
(Figure 6a)

This type is found on well drained shale or sandstone outcrops over a narrow elevational range from 1500 to 1700 m ASL. This type is floristically similar to the Arenaria/Balsamorhiza/Unstable Colluvium Community Type with dominant species including Festuca idahoensis, Balsamorhiza sagittata, Trisetum spicatum, Agropyron spicatum and Amelanchier alnifolia. This type is differentiated by the presence of the Penstemon, Polygonum, Balsamorhiza and the Trisetum species groups and the absence of the Potentilla group. This community type consists of small openings in closed canopy forests of lodgepole pine and Douglas-fir (Figure 1b).

FIGURE 6

- 6a) Balsamorhiza/Xeric Outcrop Community Type. Scattered clumps of Balsamorhiza sagittata, Antennaria spp., and Eriogonum umbellatum are visible against a background of Douglas-fir. Other herbaceous species include Festuca idahoensis, Trisetum spicatum, and Agropyron spicatum.
- 6b) Calamagrostis/Soil Pocket Community Type. Calamagrostis rubescens, Lupinus sericeus and Agropyron spicatum are the dominant species with scattered clumps of Carex phaeocephala and Castilleja spp.
- 6c) Balsamorhiza/Pseudotsuga/Ridgetop Community Type. Showing an open stand of 240+ year old Douglas-fir on a sandstone ridgetop with Balsamorhiza sagittata and Agropyron spicatum. Other prominent species include Lupinus sericeus and Stipa occidentalis.
- 6d) Agropyron/Sand Deposit Community Type. This view of a steep site on the west side of Natal Ridge. Note the gravel, resulting from Columbia Ground Squirrel burrows undermining the roadbed immediately above this community. Symphoricarpos albus, Prunus virginiana and Amelanchier alnifolia are visible in the foreground, with a view of the Ground Plum/Kame Terrace Community Type in the background with Astragalus crassicus, and A. drummondii visible. The dead aspen stand in the center of the photo has been girdled by elk.



X Calamagrostis/Soil Pocket Community Type.
(Figure 6b)

This type occurs on soils in sandstone and siltstone depressions. The soils may be residual and have high humus content. This community is lush, with a well developed turf layer. Calamagrostis rubescens and Agropyron spicatum are the dominant species in these meadows, often with Carex phaeocephala. This community type is differentiated by the presence of the Penstemon and the Potentilla species groups. Although Agropyron spicatum is a member of the Polygonum species group, most of the other members of this group are not found in this community type.

XI Balsamorhiza/Pseudotsuga/Ridgetop Community Type
(Figure 6c)

This community type occurs on sandstone or shale ridgetops with shallow soils and fractured bedrock at or near the surface. Dominants here are Pseudotsuga menziesii, Amelanchier alnifolia and Balsamorhiza sagittata. It is differentiated by the presence of the Penstemon, Trisetum and Balsamorhiza species groups and some elements of the Polygonum species group may also be present. Large, scattered Douglas-fir, survivors of past fires, occur in or near all stands of this type. In many of the plots sampled, the overall appearance was of a savannah-like vegetation.

XII) Agropyron/Sand Deposit Community Type
(Figure 6d)

This community type is found on a narrow band of sand and silt soils with poorly differentiated horizons at about 1350 m ASL on Natal Ridge. Linum perenne, Phleum pratense, Symphoricarpos albus and Agropyron spicatum are common dominants in this community type. This type is differentiated by the presence of the Penstemon and Polygonum species groups. Elements of the Comandra species group may also be present. On finer textured sands Polygonum douglasii is absent from stands of this type and there is considerable Columbia Ground Squirrel (Spermophilus columbianus) burrowing activity leading to erosion.

XIII Eriogonum/Xeric Shale Community Type
(Figure 7a and 7b)

This type is found on shale outcrops that shed water more quickly than other shale substrates due to compacted, convex bedrock layering. It has little vegetation cover except for Eriogonum umbellatum and Selaginella densa which dominate most stands. Occasionally a dense mat of mosses such as Bryum caespiticium, and Ceratodon purpureus are mixed with the Selaginella densa. This community type is differentiated by the presence of the Potentilla species group and the absence of the Penstemon species group. The absence of the nearly ubiquitous Penstemon species indicates the xeric nature of this site. Trampling by deer and elk may

FIGURE 7

- 7a) Eriogonum/Xeric Shale Community Type. Abundant Balsamorhiza sagittata and Festuca idahoensis are visible. Other important species include Eriogonum umbellatum, and Potentilla arguta. Juniperus communis is present in the foreground and a dense stand of lodgepole pine forms the background.
- 7b) Eriogonum/Xeric Shale Community Type (foreground) and Selaginella/Shale Depression Community Type (left). The foreground is dominated by Eriogonum umbellatum, Festuca idahoensis and Bryum spp., note the extent of exposed mineral soil. To the left, is a depression area showing Balsamorhiza sagittata, Arnica sororia, and Agoseris glauca. Early spring blooming plants such as Lomatium macrocarpum and Dodecatheon conjugens are present as seed heads only.



a



b

also be a factor causing the low cover found on these sites, as these outcrops are favoured "loafing" sites for these species.

XIV) Selaginella/Shale Depression Community Type
(Figure 7b)

This community type is restricted to depressions in shale outcrops which are receiving areas for meltwater, but tend to dry out quickly after snowmelt has ceased. Typically they support a heavy vegetation cover in early spring, mostly of Selaginella densa and many varieties of annuals, including Mimulus floribundus, Collinsia parviflora and Collomia linearis. This community type is characterized by the presence of the Trisetum and Potentilla groups. The Polygonum and Balsamorhiza species groups may or may not be present.

Summary of Community Types

A generalized ecological series is presented in Figure 8, summarizing parent material type, site shape, slope position and some common dominants associated with each community type.

FIGURE 8

SCHEMATIC REPRESENTATION SHOWING THE ECOLOGICAL
RELATIONSHIPS OF PLANT COMMUNITIES ON A
STYLIZED SLOPE



colluvium, moister sites may contain aspen and cottonwood stands.	relatively narrow band of high pH sandstone.	moisture receiving areas on slopes.	xeric outcrop, midslope	soil pockets high in humus over sandstone, and siltstone.	ridgetops with fractured bedrock at or near surface	pockets of till, snow collections, soils acidic.	vener of till over sandstone, sloping, soils acidic	deep pockets of till, soils slightly acidic	loose slop
---	--	-------------------------------------	-------------------------	---	---	--	---	---	------------

PARENT MATERIAL



glacial till



gravels



sandstone



sand



shale



humus



moisture



unstable

PLANT

SPECIES



Abies lasiocarpa



Pseudotsuga menziesii



Pinus spp.



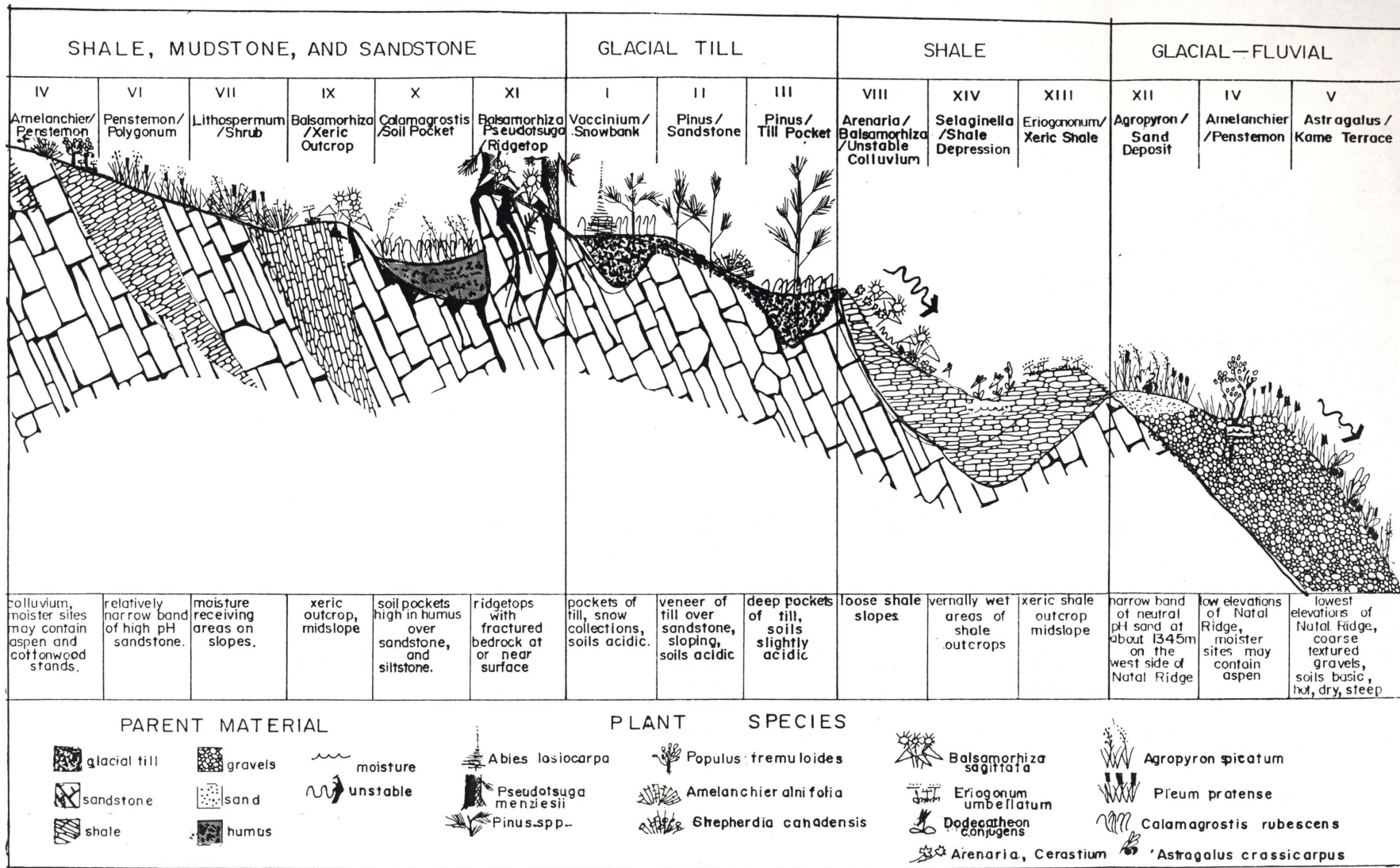
Populus fremuloides

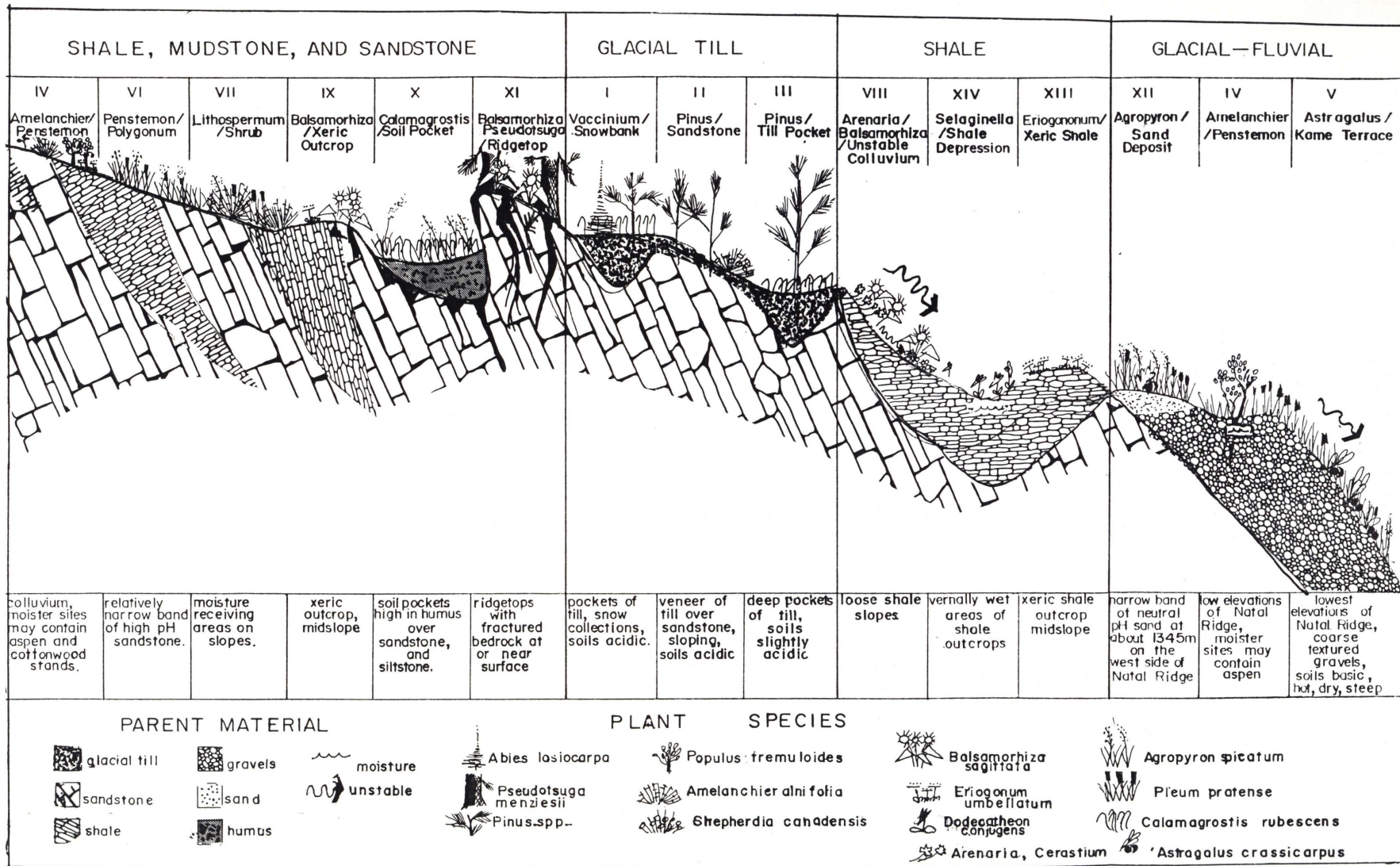


Amelanchier alni folia



Shepherdia canadensis





DISCUSSION

Comparison with Communities Elsewhere

Polster (1977) described several community types analagous to those here from the Akamina-Kishenena region approximately 50 km south of the study area. However, most of the drier community types and half the species did not occur in the Akamina Mountains, probably due to higher elevation, moister climate and different parent materials (op. cit.). These differences emphasize the highly variable nature of plant communities in the Canadian Rockies and cautions against extrapolating results of local studies beyond even the valleys in which they have been made.

Many of the successional communities described here are similar to other grasslands in western North America. The Agropyron spicatum-Festuca spp. Association in south central British Columbia described by Nicholson et al. (1982) with the dominant species of Agropyron spicatum, Koeleria macrantha (= crinata), Lupinus sericeus and Festuca spp. is floristically similar to some of the drier community types of this study, including the Astragalus/Kame Terrace, Penstemon/Polygonum, Eriogonum/Xeric Shale and Selaginella/-Shale Community Types.

They found F. scabrella in drier sites and F. idahoensis in moister, forest edge areas where snow pack

protection occurs. This is very similar to the pattern found 20 km north of here where F. idahoensis is replaced on drier ridges with F. scabrella (Dobyns, Fraser and Bell, unpublished data).

Looman's (1982) review of the Fescue grasslands of western Canada, includes the *Agropyron spicatae* grasslands of the study area where the occurrence of F. campestris (= F. scabrella) and F. idahoensis is noted as being typical of these grasslands. He suggests that a plant Association may exist where F. idahoensis occurs in the absence of F. campestris. If this is the case, then some of the drier plant communities of this study as well as many of the published accounts of Fescue grasslands of southern British Columbia (McLean and Holland 1958, van Ryswyk et al. 1966, McLean 1970, McLean and Tisdale 1972) could be classified in this Association . Looman points out that this would be justified only if "...the absence of F. campestris is real, and not due to overgrazing."

The Astragalus/Kame Terrace and Agropyron/Sand Deposit Community Types also show similarities with grasslands found in south-central British Columbia and resemble the Agropyron spicatum-Koeleria macrantha-(Artemisia frigida) Association of Nicholson et al. (1982). They noted that increased abundance of Artemisia frigida seems to be correlated with heavy grazing or physical disturbance, both of these factors

being present on this ungulate winter range of steep, unstable gravel and sand deposits.

These slopes also have British Columbia's only known stands of Astragalus crassicaarpus (Taylor 1974) and Astragalus drummondii, two species more common in the prairies of Alberta (Looman and Best 1981). The occurrence of Castilleja cervina, Penstemon eriantherus, and P. lyallii, which are on the rare species list for British Columbia (Straley et al. 1985) makes this Community Type unique in British Columbia.

Tisdale's (1982) review of grassland associations in the Pacific Northwest recognized a Festuca idahoensis type of grassland as occurring in Washington (Daubenmire 1942, 1975), Idaho (Tisdale 1979), Oregon (Poulton 1955, Johnson 1981 cited in Tisdale 1982) and Montana (Mueggler and Stewart 1980). Festuca idahoensis grasslands here are probably at the north-east edge of their extent. These small south-facing meadow communities could represent relict grasslands left from the warmer drier postglacial period 6,000 years ago when grasslands were more widespread in British Columbia than at present (Hebda 1982). Activities such as mining, logging, burning and ungulate grazing appear to have extended both the range and individual size of these meadow communities (see Chapter 2).

Influence of Grazing

The study area supports large year round populations of elk and deer that increase dramatically between October and April. The total number of deer and elk are increasing with three times as many animals in 1984 as in 1974 (C. Gibson, in prep., Dept. of Resource Management, University of British Columbia). Conservative estimates based on visual counts indicate that over 800 animals use a 25 square km portion of the study area at times during the winter months. The range is considered to be in a degraded condition (Westar Mining, unpublished data, Sparwood, B.C.).

The food preferences of Rocky Mountain Elk are extremely variable (Nelson and Leege 1982). Of the more than 300 species of vascular plants found in the study area, over 230 have been reported as forming over 1% of the diet of elk somewhere in North America, the list includes trees, shrubs, and herbaceous material all used (Kufeld 1973, Nelson and Leege 1982). Elk have been implicated in changing vegetation patterns in aspen stands (Olmsted 1977) and on winter range in Yellowstone National Park (Cole 1978).

Grazing pressure may have altered the floristic composition of several communities. The Amelanchier/Penstemon and Lithospermum/Shrub Community Types are found on a wide variety of parent materials (Table 2), and also occur in some of the most heavily used areas of elk winter range.

Remnant stands and earlier collections (L. Laycock, pers. comm. 1981, Westar Mining, Sparwood) of heavily browsed species such as Salix scouleriana, Ceanothus velutinus and Populus tremuloides indicate that these species, and probably others, were once more widely established on these slopes. Browse pressure may be overriding the effect of other site conditions on these plant communities, preventing further subdivision.

Relationships Between Substrate, Moisture Regime and Vegetation

Community types can be broken into major groupings based on parent material (Figure 4).

Those found on till pockets include the Vaccinium/Snowbank, Pinus/Till Pocket Community Types and, less commonly, the Pinus/Sandstone Community Type. All of these types contain conifers, and can be expected to become forest stands relatively quickly. Pockets of till in bedrock depressions have older, deeper, acidic soils, increased snow accumulation resulting in moister conditions, lower ungulate grazing pressure and decreased insolation all factors which could encourage the rapid establishment of forest vegetation in this area (Ogilvie unpublished cited in Lea 1984).

Communities found on sandstone and shale substrates include the Pinus/Sandstone, Amelanchier/Penstemon, Penstemon/Polygonum, Lithospermum/Shrub, Balsamorhiza/Xeric Out-

crop, the Calamagrostis/Soil Pocket and the Balsamorhiza/-Pseudotsuga/Ridgetop Community Types. These are regarded as early successional types with the exception of the Balsamorhiza/Pseudotsuga Community Type, which may be climax on ridgetops (Lea 1984). Rates of successional change are extremely slow however, and in areas with fine textured soils such as the Calamagrostis/Pocket Community Type dense turf layers of herbaceous plant roots develop which may provide too much competition for tree and shrub seedlings. In the summer months the soil under this turf layer looked and felt dry, possibly presenting a barrier to tree establishment in all but the wettest years. Coarse textured rocky soils, with bedrock fracturing to allow tree roots to penetrate, such as in the Balsamorhiza/Pseudotsuga/Ridgetop Community Type, was associated with conifer establishment. A similar correlation between soil texture and conifer establishment has been noted in other grassland systems in B.C. (Jackoy 1981, Green and van Ryswyk 1982, Mitchel and Green 1981).

Three community types are restricted to shales where moisture regime and slope stability, as influenced by the shape of outcrop and perviousness, play a role in plant growth. The Arenaria/Balsamorhiza/Unstable Colluvium Community Type is restricted to steep unstable or windswept slopes. Two different and often adjacent types are

restricted to highly compacted impervious shale outcrops: the Eriogonum/Xeric Shale Community Type to the convex outcrops which shed water; and the Selaginella/Shale Depression Community Type to concavities which funnel water.

Three community types are found on the narrow band of glaciofluvial sands and gravels. The Amelanchier/Penstemon Community Type is restricted to moister draws while the Astragalus/Kame Terrace Community Type is found on coarse gravels and sands and is composed of drought and browse-resistant species. From early photographs and the presence of snags and stumps these slopes once had a stand of mixed conifers before logging and burning. Despite this, succession into forest is slow, with few conifers established on these slopes. Astragalus crassicarpus, A. drummondii and Penstemon eriantherus appear to be shade intolerant indicating that these community types have developed their unique floristic composition after forest removal. One would expect these species to be good colonizers of alkaline glaciofluvial deposits.

The Agropyron/Sand Deposit Community Type, restricted to a narrow band of sand and silt along the top of the kame terraces shares many species with the Astragalus/Kame Terrace Community Type. Continual erosion of the sand parent material, compounded by the burrowing activity of

Columbia ground squirrels has limited the species present on these sites to those capable of colonizing the exposed mineral soil or that tolerate burial.

In conclusion, while parent material provides the most obvious correlate with vegetation differences its role in influencing soil moisture status in these communities requires further investigation. Wind exposure, slope micro-position, organic matter accumulation and animal interactions such as disturbance and grazing may also significantly influence the vegetation on these slopes.

MANAGEMENT IMPLICATIONS

Wildlife Management

There are two main goals in managing these sites for ungulates: 1) to maintain large ungulate populations without severe range degradation and 2) to prevent succession into conifer stands too dense to provide suitable winter range.

With the exception of the Vaccinium/Snowbank and the Pinus/Till Pocket Community Types, all of the vegetation types described here form important winter range for elk and deer. The Amelanchier/Penstemon, Astragalus/Kame Terrace, Penstemon/Polygonum and Lithospermum/Shrub Community Types are especially heavily browsed and several shrub species such as Ceanothus velutinus, Salix scouleriana and Acer glabrum have died or are present as remnants only. The negative effects of range degradation however, may be partially offset by the effect on the rate of succession.

The hypothesis that browse pressure has resulted in a slowing of successional rates, maintaining and even expanding some community types that form useful areas of winter range, has received some preliminary testing on the Amelanchier/Penstemon Community Type (see Chapter 2). Further study is required on other community types to see if they react in a similar manner. A large reduction in numbers of ungulates may result in a loss in the area that

serves as useful winter range.

Establishment of scattered individual conifers, especially unpalatable species such as Picea engelmannii, Pinus contorta and P. albicaulis, indicates that eventually most of these sites will be forested in the absence of some other disturbance, such as fire. Fire can be a valuable tool for retarding succession on these sites. Since many of the lodgepole pines present on the sites are of conebearing age it is expected that large stands of this serotinous species would result from a single burn, and several burns may be required to retard succession.

Cutting and fire are two common tools used on aspen stands to slow rates of succession and increase browse production. Aspen stands occur in or adjacent to the Amelanchier/Penstemon, Astragalus/Kame Terrace, Penstemon/Polygonum, Balsamorhiza/Xeric Outcrop and the Calamagrostis/Soil Pocket Community Types. Since aspen clones on these meadow communities are no longer expanding this might be a useful tool in increasing browse production. Care is required however, as cutting all of an aspen stand will expose the entire clone to browse pressure and this may result in loss of the stand if browse pressure is too great.

Floristic changes may also alter the carrying capacity of a community type. For instance the discovery in 1982 of seeding stands of both species of knapweed (Centau-

rea maculosa and C. repens) in a disturbed area of the large open slopes of the Astragalus/Kame Terrace and Agropyron/Sand Deposit Community Types should be viewed with some concern. Knapweed has already removed from productivity much of the rangeland in southern British Columbia, and the hot dry slopes associated with these community types are prone to invasion by these two species. Management for high ungulate populations might require control of these species.

Since the vegetation on these slopes appears to be changing, periodic monitoring of the vegetation in permanent plots on heavily used areas of winter range, especially in the Amelanchier/Penstemon, Astragalus/Kame Terrace, Lithospermum/Shrub, Polygonum/Penstemon and the Agropyron/Sand Deposit Community Types would greatly assist the wildlife manager's interpretation of the vegetation dynamics in the Natal and Harmer Ridge winter ranges.

Mined Land Reclamation

The study area surrounds an area of open pit coal mining and a knowledge of the vegetation pattern present on these slopes can be applied to reclamation planning and practices. The major objectives in reclaiming an open-pit mine site include erosion control and sustained vegetative cover compatible with land use goals. The end land use goal for the proposed and active mine sites on Natal and Harmer Ridges emphasizes wildlife habitat (Fraser and Ryder

1984).

Current mining practises in mountainous terrain produces reclaimed sites with a wide variety of microsite conditions, and virtually all of the community types described here could be expected to develop in time. The heterogenous mixture of waste-rock in mine dumps is similar to the sandstone colluvium parent material of several community types such as the Amelanchier/Penstemon, Penstemon/Polygonum, Lithospermum/Shrub, and the Arenaria/Balsamorhiza/Unstable Colluvium Community Types. Stands of these types contain a wide variety of species that the reclaimer may draw upon, whether native species or ecologically analogous cultivated species are used. Many species present on these sites are already being used in the reclamation process, such as Phleum pratense, Poa compressa, and most of the native trees and shrubs.

Further it may be to the reclaimer's economic advantage when developing his seed mix to consider the range of potential communities that might develop under natural recolonization conditions on any site and adjust his seed mix accordingly. Reclaiming difficult sites such as gullies, bedrock outcrops and unstable areas might also be facilitated by using species appropriate to those sites as indicated in this study. For example, propagation trials of Astragalus crassicaarpus, A. drummondii, Penstemon

eriantherus and P. lyallii, species found in the Astragalus/Kame Terrace Community Type, indicate that these species have good potential as reclamation species for disturbances on steep dry gravel deposits (Environmental Services, Westar Mining, unpublished data, Sparwood, B.C.).

Reforestation of portions of mine sites is required whether a forestry or wildlife end land use goal is chosen, as cover is an important structural component of deer and elk habitat. Site conditions dictate largely which tree and shrub species should be used and patterns described in this study have been used in reclamation planning (Fraser and Ryder 1984). Establishing conifers on east and north-facing slopes is easy, however when cover is required on southerly aspects patterns observed in several communities described here should be emulated. For example, one should be able to successfully use Pinus albicaulis and Abies lasiocarpa on gently sloping acidic locations that collect snow (like the Vaccinium/Snowbank Community Type) and Pseudotsuga menziesii on fractured bedrock (as in the Balsamorhiza/Pseudotsuga/Ridgetop Community Type).

Rare Plant Species

Southeastern British Columbia is especially rich in plants that are considered rare in British Columbia (Straley et al. 1985). In most cases the species that are

classified as rare are found in Alberta or the Rockies of Montana with range extensions into the East Kootenays (op. cit.).

Avoiding unwarranted disturbance of populations of rare species is recommended for the following reasons, 1) preservation of genetic material, 2) avoidance of irreparable damage to populations which may be threatened or endangered, 3) preservation of habitats which may add to local, regional or provincial diversity. Natal and Harmer Ridges are prone to disturbance by open-pit mining and related activities that could affect the rare plant populations present there.

A total of 15 species of vascular plants on the rare plant list for British Columbia have been found on the study site (Table 4). Two species, Astragalus crassicarpus and Penstemon lyallii are classified as R1 which is defined as a species present in British Columbia as few individuals in a single or few populations. P. lyallii and P. eriantherus are considered rare in adjacent Alberta (Argus and White 1977) and Washington State (Washington State Natural History Heritage Program 1984). All three of these species are found on the Astragalus/Kame Terrace Community Type. In addition these slopes represent one of the few areas of winter range available to ungulates under conditions of heavy snow fall.

TABLE 4
 RARE PLANT SPECIES FOUND IN MEADOW COMMUNITIES ON
 NATAL AND HARMER RIDGES

Rating	Status in British Columbia*
R1	single or low populations with few individuals
R2	several populations, locally common
R3	widespread, scattered, small populations
R4	restricted distribution, large populations

* (from Straley et al.)

Species	Rating	Community Type
Melica spectabilis.....	R3....	Calamagrostis/Soil Pocket
Lewisia pygmaea.....	R3....	single collection, roadside
Delphinium bicolor.....	R2....	Selaginella/Shale Depression
Perideridia gairdneri...	R4....	Selaginella/Shale Depression
Dodecatheon conjugens...	R4....	Pinus/Till Pocket
		Amelanchier/Penstemon
		Balsamorhiza/Pseudotsuga- /Ridgetop
		Balsamorhiza/Xeric Outcrop
Castilleja cervina.....	R2....	Selaginella/Shale Depression
		Amelanchier/Penstemon
		Balsamorhiza/Pseudotsuga- /Ridgetop
		Balsamorhiza/Xeric Outcrop
		Vaccinium/Snowbank
		Pinus/Sandstone
		Astragalus/Kame Terrace
		Penstemon/Polygonum
		Lithospermum/Shrub
		Arenaria/Balsamorhiza/Un- stable Colluvium
		Calamagrostis/Soil Pocket
		Agropyron/Sand Deposit
		Eriogonum/Xeric Shale
Epilobium glaberrimum...	R3....	Selaginella/Shale Depression
Penstemon lyallii.....	R1....	Astragalus/Kame Terrace, also rock outcrops, roadcuts
Mimulus floribundus.....	R3....	Selaginella/Shale Depression
Penstemon eriantherus...	R2....	Astragalus/Kame Terrace
		Agropyron/Sand Deposit
Astragalus crassicaarpus.	R1....	Astragalus/Kame Terrace
		Agropyron/Sand Deposit
		Penstemon/Polygonum
Osmorhiza occidentalis..	R2....	Amelanchier/Penstemon
		Balsamorhiza/Pseudotsuga- /Ridgetop
		Lithospermum/Shrub

These gravel deposits are a valuable resource and a sand and gravel pit is in operation on these slopes. Since there is less than 6 square km of the Astragalus/Kame Terrace Community Type in British Columbia, this type of activity on these slopes should be discouraged.

REFERENCES CITED

- Argus, G.W. and D.J. White. 1978. The rare vascular plants of Alberta. Syllogeus 17. National Museum of Canada. 108 pp.
- B.C. Research. 1977. Stage II Environmental Study of the Line Creek Project, Vol I. Prepared for Crowsnest Resources, Fernie, British Columbia. 5-24.
- B.C. Research. 1981. Greenhills Surface Coal Mining Project. Stage II: Environmental Assessment. Kaiser Resources Ltd. Coal Division. 128 pp.
- Buffo, J., L. Fritschen, and J. Murphy. 1981. Direct solar radiation on various slopes from 0 to 60 north latitude. USDA Forest Service Research Paper, PNW - 142. Portland, Oregon. 74 pp.
- Češka, A. and H. Roemer. 1971. A computer program for identifying species-releve groups in vegetation studies. Vegetatio 23: 255-277.
- Češka, A. 1976. Specifications: Ceska-Roemer program for identifying species-releve groups. Mimeo release, Victoria, British Columbia. 17 pp.
- Clague, J.J. 1975. Late Quaternary sediments and geomorphic history of the southern Rocky Mountain Trench. Canadian Journal of Earth Sciences. Vol 12:595-605.
- Cole, G.F. 1978. A naturally regulated elk population. in Bunnell, F.L., D.S. Eastman, and J.M. Peek (eds.) Symposium on natural regulation of wildlife populations. Published by the Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow Idaho. Proceedings no. 14. 62-81.
- Crowsnest Resources Ltd. unpublished data, Environmental Services Dept. Sparwood B.C.
- Daubenmire, R. 1942. An ecological study of the vegetation of southeastern Washington and adjacent Idaho. Ecol. Monographs 12:53 - 79.

- Daubenmire, R. 1975. Steppe vegetation of Washington. Washington Agriculture Experimental Station Technical Bulletin 62. Pullman, Washington. 161 pp.
- Dick, J. 1978. A plan for the reclamation of surface mine coal lands in the East Kootenays. Unpublished M.Sc. Thesis. University of British Columbia. 265 pp.
- Dobyns E., D.F. Fraser and M.A.M. Bell. unpublished data on file, Biology Dept., University of Victoria.
- Fraser, D.F. and D.E. Ryder. 1983. Coal mine reclamation for wildlife in the southern Rockies of British Columbia. Proceedings of the Northern Great Plains 13th Annual Symposium on Coal Mine Reclamation. Boise, Idaho. 5-27
- Green, A.J. and van Ryswyk. 1982. Chernozems: Their characterization and distribution. in Nicholson, A.C., A. McLean and T.E. Baker (eds). Grassland Ecology and Classification Proceedings. British Columbia Ministry of Forests. Victoria. 95-112.
- Gibson, C. in prep. Elk movements in and around an active mine site in the East Kootenays. M. Sc. thesis, Resource Management Dept., University of British Columbia.
- Hebda, R. J. 1982. Postglacial history of grasslands of southern British Columbia and adjacent regions. in Nicholson, A.C., A. McLean and T.E. Baker (eds). Grassland Ecology and Classification Proceedings. British Columbia Ministry of Forests. Victoria. 157-192.
- Hitchcock, C.L. and A. Cronquist. 1976. Flora of the Pacific Northwest - an illustrated manual. University of Washington Press. Seattle. 730 pp.
- Johnson, C. G. 1981. Synecological relationships in the Billy Meadows area, Wallowa-Whitman National Forest. U.S. Forest Service Special Report. Baker, Washington. cited in Tisdale, E. W. 1982. Grasslands of Western North America: The Pacific Northwest Bunchgrass Type. in Nicholson, A.C., A. McLean and T.E. Baker (eds) Grassland Ecology and Classification Proceedings. British Columbia Ministry of Forests. Victoria 223-246.

- Krajina, V. J. 1965. Biogeoclimatic zones and classification of British Columbia. Ecology of western North America. Vol 1. Department of Botany. University of British Columbia. 1 - 17.
- Krajina, V. J. 1969. Ecology of Forest trees in British Columbia. Ecology of western North America. Vol. 2. Department of Botany. University of British Columbia. 1- 146.
- Kufeld, R.C. 1973. Foods eaten by the Rocky Mountain elk. Journal of Range Management 26(2):106-113.
- Laycock. L. 1980. pers. comm. Supervisor of Nurseries, B.C. Coal Ltd. Box 2000. Sparwood, B.C.
- Lea, E.C. 1980. Legend for vegetation maps of the East Kootenay area. Province of British Columbia, Ministry of the Environment.
- Lea, E.C. 1984. Biophysical Resources of the East Kootenay Area: Vegetation. Vol 1. Ministry of the Environment Technical Report No. 5. Victoria, B.C. 75 pp.
- Looman, J. 1969. The Fescue Grasslands of western Canada. Vegetatio 19:128-145.
- Looman, J. 1982. Grasslands of Western North America: Fescue Grasslands. in Nicholson, A.C., A. McLean and T.E. Baker (eds). Grassland Ecology and Classification Proceedings. British Columbia Ministry of Forests. Victoria. 209-222.
- Looman, J, and K. F. Best. 1981. Budd's Flora of the Canadian Prairie Provinces. 2nd edition. Agriculture Canada Publication 1662. Ottawa. 862 pp.
- McLean, A. 1970. Plant communities of the Similkameen Valley, British Columbia, and their relationship to soils. Ecol. Monograph 40:403-424.
- McLean, A. and W.D. Holland. 1958. Vegetation zones and their relationship to the soils and climate of the upper Columbia Valley. Canadian Journal of Plant Science 38:328-345.
- McLean, A. and E. W. Tisdale. 1972. Recovery rate of depleted range sites under protection from grazing. Journal of Range Management 25:178-181.

- Mitchell, W.R. and R.E. Green. 1981. Identification and Interpretation of Ecosystems of the Western Kamloops Forest Regions: Volume I: Very Dry Climatic Region, First Approximation. Land Management Handbook 2. B.C. Ministry of Forests, Victoria, B.C.
- Mueggler, W.F. and W.L. Stewart. 1980. Grassland and Shrubland habitat types of western Montana. U.S. Forest Service General Technical Report INT-66. 135 pp.
- Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons. Toronto, Ontario. 547 pp.
- Nelson, J. R. and T. A. Leege. 1982. Nutritional requirements and food habits. in Thomas, J.W. and D. E. Toweill (eds). Elk of North America - ecology and management. Stackpole Books, Harrisburg, Pa. 323 - 368.
- Nicholson, A.C., J. Pojar and E.H. Hamilton. 1982. Introduction (to the Southern Interior Grasslands of British Columbia) in Nicholson, A.C., A. McLean and T.E. Baker (eds) Grassland Ecology and Classification Proceedings. British Columbia Ministry of Forests. Victoria, B.C. 1 - 17.
- Olgilvie, R.T. unpublished. The mountain forests and alpine zones of Alberta. 19 pp. cited in Lea, E.C. 1984. Biophysical Resources of the East Kootenay Area: Vegetation. Vol 1. Ministry of the Environment Technical Report No. 5. Victoria, B.C. 75 pp.
- Olmsted, C.E. 1977. The effect of large herbivores on aspen in Rocky Mountain National Park. Unpublished Ph.D. thesis, University of Colorado, Boulder, Colorado. 155 pp.
- Polster, D.F. 1977. Plant communities of the Alpine and Meadow Areas of Southeastern British Columbia. Unpublished M.Sc. thesis, Biology Dept. University of Victoria, British Columbia. 147 pp.
- Poulton, C.E. 1955. The ecology of non-forested vegetation of Umatilla and Morrow Counties, Oregon. unpublished Ph.D. Thesis. Washington State University 213 pp.
- Price, R.A. 1962. Fernie map-area, east half, Alberta and British Columbia. Geological Survey of Canada Paper 61-24, 64 pp.

- Ryder, J. M. 1981. Biophysical Resources of the East Kootenay Area: Terrain. British Columbia Ministry of the Environment. Victoria 152 pp.
- Straley, G.B., R.L. Taylor and G.W. Douglas. 1985. The rare vascular plants of British Columbia. Syllogeus 59. 165 pp.
- Taesco Consultants Ltd. 1982. Elk Valley Biophysical Inventory. Part 2. Vegetation and Wildlife. Prepared by Taesco Consultants for Crows Nest Resources Limited, Fernie, British Columbia. 265 pp.
- Taylor, L. G. 1978. Geology of the B.C. Coal's Sparwood Property. Unpublished Internal Report. Westar Mining Ltd. Sparwood, British Columbia. 15 pp.
- Taylor, T.M.C. 1974. The Pea Family (Leguminosae) of British Columbia. B.C. Provincial Museum Handbook 32, Victoria. 251 pp.
- Tisdale, E. W. 1947. The grasslands of the southern interior of British Columbia. Ecology 28:346-382.
- Tisdale, E. W. 1979. A preliminary classification of Snake River Canyon grasslands in Idaho. University of Idaho FWR Experimental Station Note no. 32, Moscow, Idaho. 37 pp.
- Tisdale, E. W. 1982. Grasslands of Western North America: The Pacific Northwest Bunchgrass Type. in Nicholson, A.C., A. McLean and T.E. Baker (eds.) Grassland Ecology and Classification Symposium Proceedings. British Columbia Ministry of Forests, Victoria. 223-246.
- Utzig, G, D. MacDonald, P. Comeau, G. Still, M. Ketcheson, and T. Braumandl. 1982. Ecological classification for the Nelson forest region, revised second approximation with management interpretations. British Columbia, Ministry of Forests, Victoria. 111 pp.
- van Ryswyk, A.L., A. McLean, and L. S. Marchand. 1966. The climate, native vegetation, and soils of some grasslands at different elevations in British Columbia. Canadian Journal of Plant Science 46:35-50.
- Walter, H. and H. Leith. 1967. Klimadiagram-Weltatlas. VEB Gustav Fischer Verlag, Jena.

Washington Natural History Heritage Program. 1984. Endangered, threatened and sensitive vascular plants of Washington. Department of Natural Resources, Olympia. pp 29.

Westar Mining, unpublished data, Box 2000 Sparwood, B.C.

CHAPTER TWO

UNGULATES AND WINTER RANGE IN THE
SOUTHEAST ROCKIES OF BRITISH COLUMBIA

CHAPTER SUMMARY

Ten exclosures erected on elk (Cervus elaphus) and mule deer (Odocoileus hemionus) winter range in southeastern British Columbia showed woody biomass levels about 50 times higher than equivalent grazed paired plots. Significant increases were seen in conifer establishment, litter accumulation and seed production of a major browse species, Amelanchier alnifolia. Three herbaceous species showed increased cover and surface soil pH was higher in grazed areas. Possible causes of increased conifer establishment and implications for winter range management are discussed.

INTRODUCTION

Ungulate winter range in the southern Canadian Rockies consists of sparsely forested to open slopes on southern exposures (Jacques 1976, see also Chapter One). In the Kootenays where winter range is generally regarded as the limiting factor for wild ungulate populations, such slopes are few, covering less than 5% of the land area (Leege 1968, 1969; R. Demarchi pers. comm. 1983, Wildlife Branch, Cranbrook, B.C.).

Evidence suggests that the abundance of big game in this area is a recent phenomenon. Early records of explorers in the 1800's indicate that there were few big game animals in the East Kootenays (R. Demarchi pers. comm. 1984, Wildlife Branch, Cranbrook, B.C.). Near Sparwood, in the Elk Valley, Hornaday (1906) chronicles a hunting trip taken in the autumn of 1905, where he remarks several times on the scarcity of elk (Cervus elaphus) and at one point says "...during my whole time here I saw sign of Elk only once." A casual pass today over Hornaday's route indicate that elk populations have increased remarkably since 1905. Actual counts at peak winter periods in 1984 indicated that over 800 elk occupy the 25 square km winter range on Natal and Harmer Ridges (C. Gibson, in prep. Dept. of Resource Management, University of British Columbia).

This increase in animal numbers has been attributed to a combination of fires, mild winters and recent management. Widespread fires in the 1930's in the Elk Valley and recent logging and mining activity greatly increased the amount of suitable range. More recently, a series of relatively mild winters and improved wildlife management techniques have further increased the size of the elk population in the East Kootenays (Courtenay 1977; R. Demarchi pers. comm. 1984, Wildlife Branch, Cranbrook, B.C.).

Where open meadow communities now exist on portions of south and west slopes in the Front Range of the B.C. Rockies, blackened stumps or dead and down rotten wood indicate earlier forests probably killed by logging and fire.

Traditional views (Lea 1980) on the vegetation dynamics of these slopes are that they are: 1) edaphically maintained as meadow communities because slope and aspect impede conifer forest establishment or 2) that they are pyro-edaphic climaxes, maintained at an early successional stage by successive fires.

Animals have been shown to play an important role in the vegetation dynamics of several systems. Olmsted (1977) and Krebill (1972) showed that decreases in aspen stands in Rocky Mountain National Park were correlated with periods of high elk numbers. Snyder and Janke (1976) found that moose (Alces

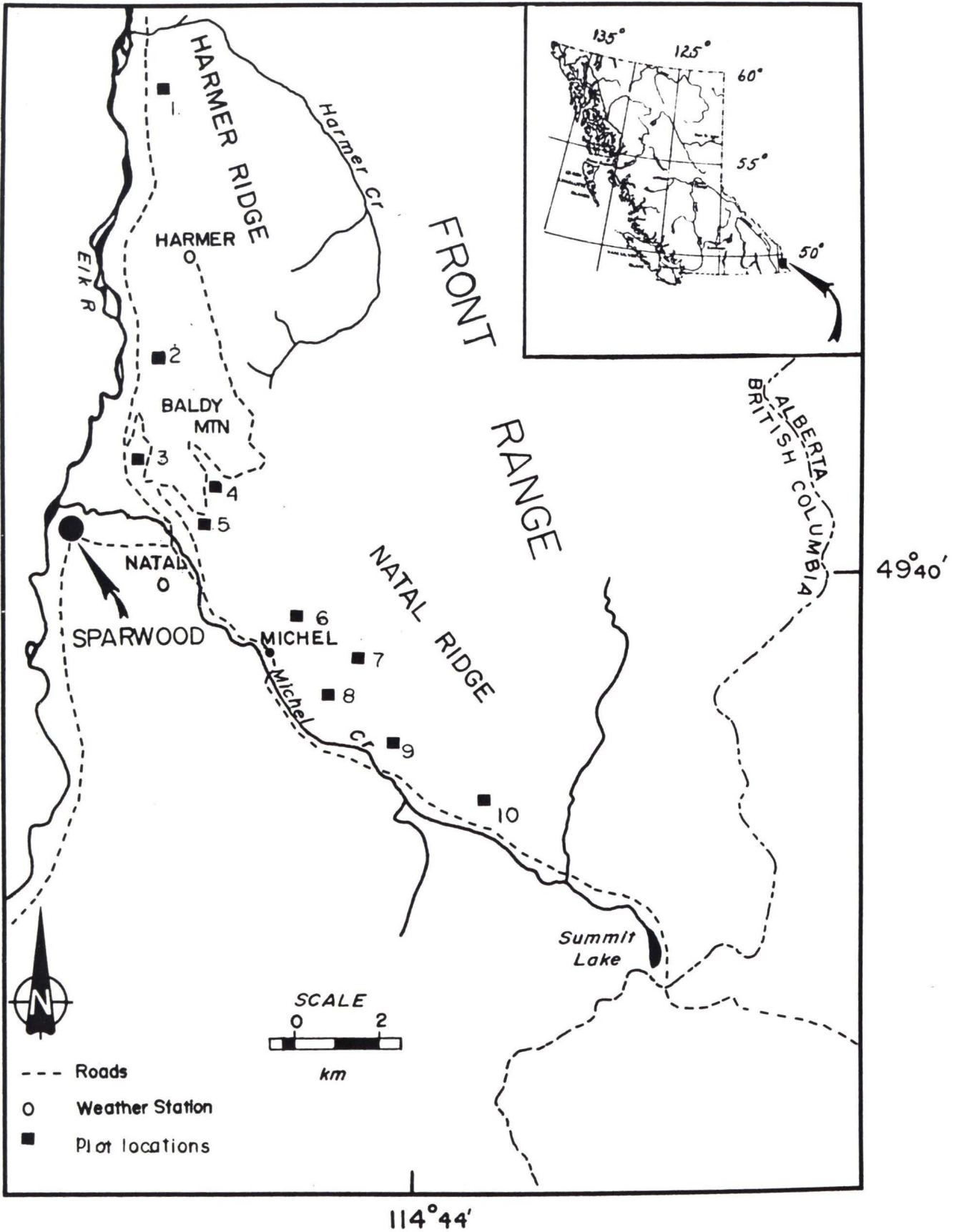
alces) browsing can open up mature spruce forest stands and produce dense stands of shrubby vegetation. Telfer and Cairns (1978) implicated the feeding activity of moose in the stabilization of forest margins in Elk Island Park.

This paper explores the effect of elk on species composition and establishment of woody plants in heavily used low elevation (1120-1500 m ASL) winter range in the East Kootenays, and the implications these effects have on management.

MATERIALS AND METHODS

Ten pairs of 1.8 m squared paired plots were established on heavily used winter range on Natal and Harmer Ridges in southeastern British Columbia, September 1980 (Figure 1). One of each pair (subplot) was covered by a 0.75 m high enclosure covered in 2 in. square wire mesh. Each pair of subplots were subjectively placed to ensure that they had the same elevation, aspect, and species composition and were located on south-facing slopes at elevations between 1360 and 1600 m ASL in the Amelanchier/Penstemon Community Type described in Chapter 1 (Appendix IV). Vascular plant species composition with visual estimates of percent cover for each species was surveyed in July, 1984. At the same time the total number of flowers, stems and total number of flowering stems present of Amelanchier alnifolia was recorded from a 1 m square area in the center of each subplot. A. alnifolia is the dominant shrub on this community type, and the most important browse species. In August of 1983, changes in the potential reproductive output was examined by collecting all berries and extracting the seeds using Brinkman's methods (1974). In December 1984, before the area received heavy winter use by ungulates, paired plots were cleared of snow, and clipped of all above ground woody vegetation. The harvested material was separated into deciduous and coniferous components, oven dried at 25 degrees C for 7 days and each

FIGURE 1



LOCATION OF THE STUDY AREA, SHOWING PLOT LOCATIONS

component weighed. A 0.5 x 0.5 m area of leaf litter was hand collected from each subplot, and a composite soil sample from 5 locations in each subplot was taken from both the Ah and B soil horizons. Soil samples were tested for pH (1:1 in water) using a Good Digital pH meter and a glass electrode.

Percent cover for each species, oven dried woody biomass, pH's of Ah and B soil horizons, and fruiting and flowering of A. alnifolia were compared within the paired plots using a paired t-test (Zar 1974).

RESULTS

Nine out of 39 species found in the plots showed statistically significant differences in percent cover between grazed and ungrazed subplots after 3 years (Table 1). Six woody species increased inside and 3 herbaceous species increased outside the exclosures (Table 2).

Woody biomass was much higher inside than outside the exclosures (Table 2). Most of this biomass is from increased establishment of stems of suckering shrubs such as Amelanchier alnifolia, Spiraea betulifolia and Rosa acicularis. Conifer establishment occurred in all but one of the ten exclosures (Table 1). Three herbaceous species, Gentiana amarella, Chrysanthemum leucanthemum, and Medicago lupulina (Table 1), had higher cover outside the exclosure.

Litter accumulation averaged approximately twice as much inside as outside (Table 2). The average pH of the humus layer was lower inside than outside the exclosures, but no significant differences between subplots occurred in pH of the B horizon (Table 2). Significant increases were seen in flowering and fruiting of A. alnifolia in ungrazed subplots (Table 3).

TABLE 1

AVERAGE PERCENT COVER OF
SPECIES SHOWING SIGNIFICANT DIFFERENCES
FROM INSIDE AND OUTSIDE ENCLOSURES AFTER FOUR YEARS

The mean \pm S.E. refers to visual estimates and the t value refers to a paired t-test, P = probability value.

Species	% cover		# plots spp occurred in	Paired-t test	
	ungrazed plot	grazed plot		t	P
SPECIES WITH HIGHER % COVER WITHOUT GRAZING					
<u>Amelanchier</u> <u>alnifolia</u>	40 ± 10.5	7.6 ± 4.1	10	5.9	***
<u>Rosa</u> <u>acicularis</u>	19 ± 2.3	5.9 ± 1.9	10	6.1	***
<u>Salix</u> <u>scouleriana</u>	39 ± 18.3	17 ± 6.0	3	9.9	***
<u>Spiraea</u> <u>betulifolia</u>	13 ± 2.7	6.4 ± 1.5	8	4.2	*
<u>Pinus</u> <u>contorta</u>	1.0 ± 0	0.1 ± 0.9	9	8.0	***
<u>Pseudotsuga</u> <u>menziesii</u>	0.8 ± 0.1	-	4	3.9	*
SPECIES WITH HIGHER % COVER WITH GRAZING					
<u>Chrysanthemum</u> <u>leucanthemum</u>	0.2 ± 1.3	12 ± 3.4	7	- 3.7	**
<u>Gentiana</u> <u>amarella</u>	0.1 ± 0.1	1.6 ± 0.6	7	-3.4	**
<u>Medicago</u> <u>lupulina</u>	0.3 ± 0.2	10 ± 3.1	8	-2.1	*

* P 0.05; ** P 0.01; *** P 0.001

TABLE 2

MEAN LEAF LITTER, WOODY BIOMASS AND SOIL pH VALUES
FOR GRAZED AND UNGRAZED PLOTS

Means \pm S.E. of woody biomass, the LFH layer (both oven dried) and pH of Ah and B soil horizons. Significance values for the paired t-test compare the two treatments, $df = 9$.

	oven dried biomass		significance
	grazed	ungrazed	
oven dried biomass g/square m			
total woody	92 \pm 15.5	2192 \pm 654	2.77 *
conifer	0.2 \pm 0.2	29 \pm 9	3.27 **
litter layer	194 \pm 13.3	386 \pm 26	8.88 ***
total number of deciduous woody stems/square m	6.7 \pm 3.1	21.6 \pm 1.8	4.12 **
soil pH			
Ah layer	7.2 \pm 0.1	6.8 \pm 0.1	3.51 **
B layer	7.2 \pm 0.1	7.2 \pm 0.1	1.13 n.s.

n.s. P 0.05; *P 0.05 ; ** P 0.01 ; *** P 0.001

TABLE 3

FRUITING AND FLOWERING RESPONSE OF AMELANCHIER ALNIFOLIA
INSIDE AND OUTSIDE ENCLOSURES

Values represent means \pm S.E./square m. Significance values for a paired t-test compare the two treatments, $df = 9$, $P = 0.05$.

Amelanchier alnifolia

mean number/square m

	inside	outside	significance
number of stems	12.1 ± 1.2	5.0 ± 3.4	5.0 ***
number of flowering stems	4.0 ± 0.7	0.2 ± 0.1	4.8 ***
total number of flowers	15.2 ± 2.6	0.4 ± 0.3	5.7 ***
total number of fruits	8.8 ± 1.4	0.3 ± 0.2	5.8 ***
total number of seeds	29.3 ± 4.5	0.8 ± 0.5	6.6 ***

*** p 0.001

DISCUSSION

Woody plant biomass inside the enclosure averaged approximately 50 times the woody biomass on unexclosed (grazed) plots. Conifer establishment increased and the pH of the litter layer dropped on areas that were protected from browsing pressure.

Most of the increase in woody biomass inside the enclosure was due to increased stem establishment of shrub species such as Amelanchier alnifolia and Spiraea betulifolia. This increased production of stems was probably the result of vegetative increase in plants already present on the site. Some of the increase in stem numbers however, could be the result of increased seedling recruitment associated with the increased flowering, fruiting and seed production on these sites (Table 4). The increase in flowering and subsequent seed production of A.alnifolia inside the enclosures was probably due to increased leaf area (and therefore increased photosynthates) available to the unbrowsed plants and reduced rates of herbivory on flower primordia. It is possible however, that this is strictly a response to the competition for light and space present in the dense stands that developed. Increased effort in sexual reproduction allows the establishment of seedlings with a wider range of genotypes, some of which may cope better with increased competition in an ungrazed environment.

Conifer establishment occurred in 9 of the 10 the ungrazed subplots. They included Douglas-fir (Pseudotsuga menziesii), Engelmann spruce (Picea engelmannii) and lodgepole pine (Pinus contorta). The only conifer to establish outside of an exclosure was a single lodgepole pine.

Whether the increased conifer establishment was due to the change in microsite soil conditions, microclimatic changes or through a more indirect effect requires further investigation. Increased litter accumulation inside the exclosure coupled with increased plant cover could result in cooler microsite conditions and decreased soil pH, factors which could encourage conifer establishment.

Rodents may also play a role. Abbot and Quink (1970) have shown that rodents such as Peromyscus and Clethrionomys bury seeds in caches between the litter layer and the surface horizons. Increased conifer establishment in the exclosure may simply reflect the fact that inside the exclosures represented better seed cache sites than outside and subsequent germination of cached seeds is responsible for the high rate of conifer establishment.

The second change in species composition was the presence of three herbaceous plants that were found in higher percentages outside the exclosures. Medicago lupulina and Chrysanthemum leucanthemum are well known "increaser" species under conditions of heavy grazing pressure (Jones 1933). Both

are aggressive weed species that are common components of grazed agricultural pastures. The third species is a native perennial, Gentiana amarella, and is not commonly regarded as an "increaser" species. However, it has not been known to form a part of the diet of elk (Nelson and Leege 1982), and it may not be grazed along with other species of native herbaceous plants on these sites, allowing it to increase. The occurrence of this species on these dry slopes is unusual as it generally occurs in "moist places" (Hitchcock and Cronquist 1976).

The role that herbivores play in the dynamics of plant communities can be quite variable and difficult to predict. Tansley and Adamson (1925) found that exclusion of herbivores from chalk downs in Britain caused a decrease in the total number of species found in a stand and over a longer period Hope-Simpson (1940) found exclusion allowed the encroachment of woody vegetation. It seems likely that grazing and browsing by native ungulates have slowed down rates of successional change in this community type and have stabilized this as an open scrub community.

IMPLICATIONS FOR MANAGEMENT

In this study, rapid changes in species composition and stand structure resulted from the exclosure of ungulates on a selected community type. Succession to a mixed conifer stand would be expected should ungulate numbers be reduced to the point where they were no longer controlling the growth of shrubs and the establishment of conifer species. Other plant communities may react differently because of different species composition. If this study had been carried out a decade earlier when large stands of Ceanothus velutinus dominated these sites (see Chapter 1) it seems likely that the rate, and possibly the route of succession of scrubby vegetation could be strongly influenced through this species' ability to fix nitrogen and increase soil fertility coupled with prostrate, twiggy growth which traps litter and hinders erosion. At this time the presence of suckering shrubs, including important browse species such as Amelanchier alnifolia, is probably responsible for the observed changes in the ungrazed vegetation through their effect on the stand microclimate, enabling conifer establishment. In the absence of fire, or some other forest reducing factor, the end result could be the loss of winter range. If open scrub vegetation, suitable for ungulate forage is to be maintained, management through overgrazing or fire (or a combination) appears necessary.

REFERENCES CITED

- Abbot, H.G. and T.F. Quink. 1970. Ecology of eastern white pine seed caches made by small forest mammals. *Ecology* 51:271-278.
- Brinkman, K.A. 1974. Rosaceae -Rose family. Amelanchier Med. Serviceberry. in Shopenmeyer. C.S. (ed.) Seeds of woody plants in the United States. Forest Service, U.S.D.A., Washington, D.C. 212-215.
- Cairns, A.L. and E.S. Telfer. 1980. Habitat use by four sympatric ungulates in a boreal mixed hardwood forest. *Journal of Wildlife Management* 44(4):849-857.
- Courtenay, J. 1977. Elk and mule deer use of partially disturbed winter range during a mild East Kootenay winter. Kaiser Resources Ltd. Env. Services Dept. 117 pp.
- Demarchi, R. (pers. comm.) 1983. Wildlife Branch, Cranbrook, B.C.
- Gibson, C. (in prep.) Elk movements in and around an active coal mine in southeastern British Columbia. M.Sc. thesis. Dept. of Resource Management. University of British Columbia.
- Hornaday, W. 1906. Campfires in the Canadian Rockies. Scribner and Sons. New York. 176 pp.
- Hitchcock, C.L. and A. Cronquist. 1976. Flora of the Pacific Northwest - an illustrated manual. University of Washington Press, Seattle. 730 pp.
- Hope-Simpson, J. 1940. Studies of the vegetation of the English chalk. VI. Late stages in succession leading to chalk grassland. *Journal of Ecology* 28:386-402
- Jacques, D. R. 1976. Alpine-subalpine winter wildlife habitat for large ungulate in the southern Rocky Mountains of Alberta. in Luttermerding, H.A. and J.A. Shields (eds.). Proceedings of the workshop on alpine and subalpine environments. Victoria, British Columbia, April 28-30, 1976. Proceedings published by the B.C. Ministry of the Environment 134 - 146.

- Jones, M. G. 1933. Grassland management and its influence on the sward. *Emp. Journal of Experimental Agriculture*. 1:43-45.
- Krebill, R.G. 1972. Mortality of aspen on the Gros Ventre elk winter range. Intermountain Forest and Range Experimental Station Research Paper INT - 129. U.S. Department of Agriculture, Ogden, Utah. 16 pp.
- Lea, E.C. 1984. Biophysical Resources of the East Kootenay Area: Vegetation. Vol. 1/ Ministry of the Environment Technical Report No. 5. Victoria. B.C. 75 pp.
- Leege, T. A. 1968. Prescribed burning for elk in northern Idaho. Tall Timbers Fire Ecology Conference Proceedings 8:235-254.
- Leege, T. A. 1969. Burning seral brush ranges for big game in northern Idaho. *Trans. North America Wildlife and Natural Resource Conference* 34:429-437.
- Leege, T. A. 1975. Question: timber or elk in northern Idaho. *Idaho Wildlife Review* 27(4):3-17.
- Nelson, J. R. and T.A. Leege. 1982. Nutritional requirements and food habits. in Thomas, J.W. and D.E. Towell (eds.). *Elk of North America - ecology and management*. Stackpole Books, Harrisburg, Pa. 323-368.
- Olmsted, C.E. 1977. The effect of large herbivores on aspen in Rocky Mountain National Park. Unpublished Ph.D. thesis, University of Colorado, Boulder, Colorado. 155 pp.
- Snyder, J.D. and R.A. Janke. 1976. Impact of moose browsing on boreal-type forest of Isle Royale National Park. *American Midland Naturalist*. 95:79-82.
- Tansley, A. G. and R. S. Adamson. 1925. Studies in the vegetation of the English chalk. III. The chalk grasslands of the Hampshire-Sussex border. *Journal of Ecology* 13:177-223.
- Telfer, E.S. and A.L. Cairns. 1978. Stem breakage by moose. *Journal of Wildlife Management*. 42:639-642.
- Zar, J. H. 1979. *Biostatistical Analysis*. Prentice-Hall of Canada Inc., Toronto. 620 pp.

APPENDIX I
SITE DESCRIPTION DATA

plot #	slope (%)	elevation (m)	aspect (degrees)	% cover			rock
				mineral soil	dead wood	plant cover	
001	46	1570	208	10	10	75	05
002	40	1578	208	00	00	100	00
003	35	1578	208	10	10	88	02
004	38	1490	201	00	02	96	02
005	40	1490	201	05	02	93	00
006	37	1490	201	00	00	100	00
007	10	1555	203	00	00	100	00
008	37	1604	208	05	05	90	00
009	66	1923	218	20	05	60	15
010	55	1899	203	00	00	100	00
011	68	1889	201	15	10	40	35
012	76	1853	201	05	05	85	05
013	78	1848	220	00	00	100	00
014	82	1884	217	05	00	90	05
015	78	1896	198	05	00	90	05
016	22	1729	222	60	05	35	00
017	28	1739	222	45	05	50	00
018	32	1756	218	20	20	60	00
019	52	1737	210	40	00	60	00
020	48	1804	222	10	15	65	10
021	85	1798	220	10	20	70	00
022	55	1832	218	15	00	85	00
023	52	1558	180	05	20	70	05
024	49	1579	180	25	05	55	15
025	56	1588	183	10	15	65	10
026	62	1609	182	25	10	60	05
027	55	1622	220	30	05	30	50
028	64	1615	230	20	05	30	45
029	72	1676	272	15	20	50	05
030	64	1677	260	10	15	70	05
031	72	1673	260	40	10	35	05
032	72	1497	290	20	20	50	10
033	70	1494	203	05	10	75	10
034	75	1677	225	05	15	60	20
035	70	1670	210	15	00	80	05
036	28	1585	183	05	05	20	70

SITE DESCRIPTION DATA (cont.)

plot #	slope (%)	elevation (m)	aspect (degrees)	% cover			
				mineral soil	dead wood	plant cover	rock
037	23	1585	180	05	05	80	10
039	28	1579	235	15	10	65	10
040	78	1597	230	25	05	70	00
041	25	1591	223	70	05	05	25
042	16	1615	272	10	20	65	05
043	05	1619	265	15	15	70	00
044	23	1745	200	00	10	85	05
045	15	1668	268	10	15	65	05
046	35	1867	262	00	00	100	00
047	45	1863	262	00	05	90	05
048	55	1866	280	10	05	80	05
049	45	1887	240	00	10	85	05
050	85	1890	238	05	15	80	00
051	34	2012	202	20	05	70	05
052	68	2043	250	05	05	85	05
053	55	2043	-	20	05	60	15
054	48	1880	238	70	10	15	05
055	36	1909	238	60	02	36	02
056	34	1920	283	50	10	35	05
057	59	1928	275	05	20	73	02
058	45	1928	228	20	05	65	10
059	45	1762	247	00	02	98	00
060	44	1787	228	15	05	80	00
061	54	1670	213	00	15	85	00
062	62	1671	180	35	10	40	15
063	46	1683	180	05	15	50	20
064	47	1701	248	00	10	90	00
065	45	1713	218	20	05	20	55
066	42	1726	224	00	00	100	00
067	45	1737	238	00	05	95	00
068	59	1670	220	15	10	70	05
069	25	1679	220	30	20	35	15
070	32	1671	220	35	10	50	05
071	44	1958	200	05	05	90	00
072	05	1942	218	05	00	95	00
073	20	1900	220	10	00	85	05
074	45	1925	248	20	05	75	00
075	45	1930	180	70	00	25	05
076	21	1760	200	10	20	65	05
077	30	1695	200	05	03	82	10
078	30	1695	245	15	05	80	00
079	45	1725	140	07	03	90	00

SITE DESCRIPTION DATA (cont.)

plot #	slope (%)	elevation (m)	aspect (degrees)	% cover			
				mineral soil	dead wood	plant cover	rock
080	46	1735	180	20	05	65	15
081	60	1729	178	00	05	95	00
082	58	1712	178	10	02	88	00
083	48	1095	219	20	10	45	25
084	46	1695	180	25	02	78	05
085	41	1580	185	00	00	100	00
086	35	1580	197	30	00	60	10
087	37	1575	208	10	05	70	15
088	45	1010	208	25	00	70	05
089	47	1620	218	20	05	40	35
090	78	1380	270	10	05	70	15
091	82	1450	274	15	10	70	05
092	40	1478	270	05	07	88	00
093	68	1550	270	30	10	35	25
094	37	1535	270	20	15	60	05
095	22	1545	270	10	20	68	02
096	42	1680	160	20	00	75	05
097	49	1680	184	05	07	83	05
098	55	1660	85	20	00	80	00
099	63	4670	85	10	05	83	02
100	68	1662	104	05	15	80	00
101	68	1652	142	20	03	77	00
102	76	1640	138	05	05	85	05
103	72	1630	162	20	05	55	20
104	72	1630	161	10	05	80	05
105	67	1640	158	05	02	03	95
106	45	1625	188	75	00	25	00
107	67	1630	164	02	03	95	00
108	18	1770	208	00	05	95	00
109	18	1780	180	00	10	90	00
110	32	1770	192	05	00	95	00
111	37	1762	124	00	00	100	00
112	55	1282	180	20	05	65	10
113	55	1300	170	20	00	75	05
114	60	1300	188	10	05	80	05
115	67	1325	190	30	00	45	25
116	60	1315	190	10	00	80	10
117	52	1300	215	05	05	80	10
118	50	1280	174	05	00	90	05
119	65	1280	174	05	03	90	02
120	63	1290	180	30	05	35	30
121	65	1695	223	10	10	70	10

SITE DESCRIPTION DATA (cont.)

% cover

plot #	slope (%)	elevation (m)	aspect (degrees)	% cover			rock
				mineral soil	dead wood	plant cover	
122	65	1350	170	10	05	75	10
123	50	1380	170	05	10	85	00
124	10	1360	200	05	15	75	05
125	50	1405	200	10	15	65	10
126	08	1420	210	05	20	75	00
127	67	1340	215	40	10	50	00
128	65	1290	230	25	10	60	05
129	65	1300	235	30	10	55	05
130	23	1570	220	05	05	90	00
131	27	1583	140	10	10	40	40
132	25	1570	180	30	10	50	10
133	35	1555	210	15	10	70	05
134	27	1460	170	05	10	75	10
135	56	1315	210	20	10	70	00
136	65	1290	230	10	10	80	00
137	55	1288	210	05	05	90	00
138	55	1300	215	10	05	80	05
139	60	1300	230	00	10	90	00
140	45	1305	205	25	10	65	00
141	52	1300	170	15	00	80	05
142	52	1300	170	25	15	50	10
143	45	1310	180	30	05	60	05
144	50	1315	200	05	00	95	00
145	62	1320	205	10	05	75	10
146	18	1580	160	20	05	70	05
147	22	1575	180	15	05	75	05
148	18	1570	195	65	05	25	05
149	20	1560	165	05	00	90	05
150	25	1570	160	15	05	80	00
151	22	1570	180	10	00	90	00
152	88	1412	220	05	15	75	05
153	40	1385	225	10	10	75	05
154	30	1380	225	15	10	70	05
155	15	1480	225	10	05	55	30
156	25	1390	215	10	00	90	00
157	25	1430	240	05	00	95	00
158	40	1460	235	05	05	90	00
159	35	1490	230	10	05	85	00
160	80	1280	230	05	05	90	00
161	55	1250	210	05	00	90	05
162	43	1300	200	15	05	75	05
163	24	1388	234	00	05	95	00

SITE DESCRIPTION DATA (cont.)

plot #	slope (%)	elevation (m)	aspect (degrees)	% cover			
				mineral soil	dead wood	plant cover	rock
164	35	1360	220	30	00	20	50
165	90	1212	240	15	00	85	00
166	70	1240	236	10	00	65	25
167	50	1260	240	10	00	85	05
168	60	1380	260	05	05	85	05
169	37	1435	228	15	05	70	10
170	25	1572	176	05	15	70	10
171	15	1610	245	10	15	65	10
172	55	1295	200	10	00	80	10
173	50	1275	175	05	00	90	05
174	30	1200	205	10	00	85	05
175	45	1215	180	10	00	85	05
176	-	-	-	-	-	-	-
177	67	1280	160	15	00	80	05
178	40	1345	190	10	00	85	05

APPENDIX II

PLANT SPECIES FOUND IN THE STUDY AREA

Nomenclature for vascular plant species follows Hitchcock C.L. and A. Cronquist. 1974. Flora of the Pacific Northwest - an illustrated manual. University of Washington Press, Seattle, Wa. 730 pp.

Nomenclature for bryophytes largely follows that of Lawton, E. 1971. Moss flora of the Pacific Northwest. The Hattori Botanical Library, Nichinin, Miyazaki, Japan. 362 pp.

LYCOPODIACEAE

Lycopodium selago L.

SELAGINELLACEAE

Selaginella densa Rydb.

EQUISETACEAE

Equisetum arvense L.

Equisetum hymale L.

Equisetum palustre L.

Equisetum pratense Ehrb.

Equisetum scirpoides Michx.

OPHIOGLOSSACEAE

Botrychium boreale Midle

POLYPODIACEAE

Cryptogramma crispa (L) Bernh.

CUPRESSACEAE

Juniperus communis L.

Juniperus scopulorum Sarg.

Thuja plicata Donn

PINACEAE

- Abies lasiocarpa (Hook.) Nutt.
Tsuga heterophylla (Raf.) Sarg.
Larix lyallii Parl.
Larix occidentalis Nutt.
Piceae engelmannii Parry
Piceae glauca (Moench) Voss
Pinus albicaulis Engelm.
Pinus contorta Dougl.
Psuedotsuga menziesii (Mirbel) Franco.

SALICACEAE

- Populus tremuloides Michx.
Populus trichocarpa T. & G.
Salix spp.
Salix scouleriana Barratt
Salix planifolia Barratt
Salix glauca L.

BETULACEAE

- Alnus incana (L.) Moench.
Alnus sinuata (Regel) Rydb.
Betula papyifera Marsh.

URTICACEAE

- Urtica dioica L.

SANTALACEAE

- Comandra umbellata (L.) Nutt.

ARISTOLOCHIACEAE

- Asarum caudatum Lindl.

POLYGONACEAE

- Eriogonum umbellatum Torr.
Polygonum convolvulus L.
Polygonum douglassii Greene
Polygonum anchoreum Blake

CHENOPODIACEAE

- Chenopodium capitatum (L.) Asch.
Chenopodium album L.
Chenopodium rubrum L.
Salsola kali L.

PORTULACACEAE

- Claytonia lanceolata Poir.
Lewisia pygmaea (Gray) Robins.

CARYOPHYLLACEAE

Arenaria capillaris Poir.
Arenaria lateriflora L.
Cerastium arvense L.
Cerastium vulgatum L.
Gypsophila paniculata L.
Silene menziesii Hook
Silene cucubalis Wibel.
Silene douglassii Hook
Silene parryi (Wats.) Hitchc. & Mag.
Stellaria media (L.) Cyrill.
Stellaria longipes Goldie

RANUNUCLACEAE

Actaea rubra (Ait.) Willd.
Anemone multifida Pior.
Anemone occidentalis Wats.
Aquilegia formosa Fisch.
Aquilegia flavescens Wats.
Clematis columbiana (Nutt.) T. & G.
Delphinium bicolor Nutt.
Ranunculus acris L.
Ranunculus eschscholtzii Schlecht.
Thalictrum occidentale Gray
Trollius laxus Salisb.

BERBERIDACEAE

Berberis repens Lindl.

FUMARIACEAE

Corydalis aurea Willdl.

CRUCIFERAE

Arabis glabra (L.) Bernh.
Arabis holboellii Hornem.
Brassica kaber L.
Capsella bursa-pastoris (L.) Medic.
Descurainia sophia (L.) Schinz. & Thell.
Thlaspi arvense L.

CRASSULACEAE

Sedum lanceolatum Torr

SAXIFRAGACEAE

Heuchera cylindrica Dougl.
Lithophragma parviflora (Hook.) Nutt
Mitella nuda L.
Parnassia fimbriata Konig.
Saxifraga bronchialis L.

Saxifraga rhomboidea Greene

GROSSULACEAE

- Ribes lacustre (Pers.) Poir.
Ribes Inerme Rydb.
Ribes irriguum Dougl.
Ribes viscosissimum Pursh

ROSACEAE

- Amelanchier alnifolia Nutt.
Craetagus douglasii Lindl.
Fragaria virginiana Dushesne
Geum macrophyllum Willd.
Geum triflorum Pursh.
Potentilla arguta Pursh.
Potentilla fruticosa L.
Potentilla pensylvanica L.
Prunus virginiana L.
Prunus emarginata (Dougl.) Walp.
Rosa acicularis Lindl.
Rosa woodsii Lindl.
Rubus idaeus L.
Sorbus scopulina Greene
Sorbus aucuparia L.
Sorbus sitchensis Roemer
Spiraea betulifolia Pall.

FABACEAE

- Astragalus americanus (Hook.) Jones
Astragalus crassicaarpus Nutt.
Astragalus drummondii Hook.
Astragalus robbinsii (Oakes) Gray
Hedysarum sulphurescens Rydb.
Lathryus ochroleucus Rydb.
Lotus corniculatus L.
Lupinus sericeus Pursh.
Medicago lupulina L.
Medicago sativa L.
Melilotus alba Desr.
Melilotus officinalis (L.) Lam.
Oxytropis campestris (L.) DC
Trifolium pratense L.
Trifolium hybridum L.
Trifolium repens L.
Vicia americana Muhl.

GERANIACEAE

Geranium richardsonii Fisch. & Trautv.
Geranium viscosissimum F. & M.

LINACEAE

Linum perenne L.

ACERACEAE

Acer glabrum Torr.
Acer negundo L.

CELASTRACEAE

Pachistima myrsinites (Pursh) Raf.

RHAMNACEAE

Ceanothus velutinus Dougl.
Rhamnus alnifolia L'Her.

MALVACEAE

Iliamna rivularis (Dougl.) Greene

VIOLACEAE

Viola adunca Sm.
Viola canadensis L.
Viola orbiculata Geyer

ELAEAGNACEAE

Elaeagnus commutata Bernh.

ONAGRACEAE

Epilobium angustifolium L.
Epilobium glaberrimum Barbey
Epilobium latifolium L.
Epilobium paniculatum Nutt.
Oenothera spp.

ARALIACEAE

Aralia nudicaulis L.

UMBELLIFERAE

Angelica arguta Nutt.
Daucus carota L.
Heracleum lantaum Michx.
Lomatium dissectum (Nutt.) Math. & Const.
Lomatium macrocarpum (Nutt.) Coult. & Rose
Lomatium triternatum (Pursh.) Coult. & Rose
Osmorhiza chilensis H. & A.
Osmorhiza depauperata Phil.
Osmorhiza occidentalis (Nutt.) Torr
Perideridia gairdneri (H. & A.) Math.

CORNACEAE

Cornus canadensis L.
Cornus stolonifera Michx.

ERICACEAE

Arctostaphylos uva-ursi (L.) Spreng.
himaphila umbellata (L.) Bart.
Menziesia ferruginea Smith.
Monotropa uniflora L.
Pyrola asarifolia Michx.
Pyrola chlorantha SW.
Pyrola secunda L.
Pyrola uniflora L.
Rhododendron albiflorum Hook.
Vaccinium myrtillus L.
Vaccinium caespitosum Michx.
Vaccinium scoparium Leiberg.

PRIMULACEAE

Androsace septentrionalis L.
Dodecatheon conjugens Greene

GENTIANACEAE

Gentiana amarella L.

APOYNACEAE

Apocynum androsaemifolium L.

POLEMONIACEAE

Collomia linearis Nutt.
Linanthus spetentrionalis Mason
Polemonium pulcherrimum Hook.

HYDROPHYLLACEAE

Hydrophyllum capitatum Dougl.
Phacelia hastata Dougl.
Phacelia linearis (Pursh) Holz.
Phacelia sericea (Grah.) Rydb.

BORAGINACEAE

Cryptantha torreyana(Gray)Greene
Hackelia micrantha (Easwt.) J.L. Gentry
Lappula echinata Gilib.
Lithospermum ruderale Dougl.
Mertensia paniculata (Ait.) G. Don
Myosotis sylvatica Hoff.

LABIATAE

Ajuga reptans L. Bugle
Mentha arvensis L.
Stachys palustris L.

SCROPHULARIACEAE

Castilleja occidentalis ?
Castilleja rhexifolia Rydb.
Castilleja cervina Greenm.
Castilleja miniata Dougl.
Castilleja lutescens (Greenm.) Rydb.
Castilleja sulphurea Rydb.
Collinsia parviflora Lindl.
Linaria vulgaris Hill
Mimulus guttatus DC
Mimulus floribundus Lindl.
Pedicularis racemosa Dougl.
Pedicularis bracteosa Benth.
Pedicularis groenlandica Retz.
Penstemon fruticosus (Pursh) Greene
Penstemon procerus Dougl.
Penstemon eriantherus Pursh.
Penstemon confertus Dougl.
Verbascum thapsus L.
Veronica wormskjoldii Roem & Schult.
Veronica americana Schwein.

OROBANCHACEAE

Orobanche uniflora L.

PLANTAGINACEAE

Plantago lanceolata L.
Plantago eriopoda Torr.
Plantago elongata Pursh

RUBIACEAE

Galium aparine L.
Galium boreale L.

CAPRIFOLACEAE

Linnaea borealis L.
Lonicera involucrata (Rich.) Banks
Lonicera utahensis Wats.
Sambucus racemosa L.
Symphoricarpos albus (L.) Blake
Viburnum edule (Michx.) Raf.

VALERIANACEAE

Valeriana sitchensis Bong.

CAMPANULACEAE

Campanula rotundifolia L.

ASTERACEAE

Achillea millefolium L.
Agoseris glauca (Pursh) Raf.
Agoseris aurantiaca (Hook.) Greene
Anaphalis margaritacea (L.) B. & H.
Antennaria racemosa Hook.
Antennaria alpina (L.) Gaertn.
Antennaria umbrinella Rydb.
Antennaria microphylla Rydb.
Antennaria luzuloides T. & G.
Antennaria lanata (Hook.) Greene
Arnica chamissonis Less.
Arnica latifolia D.C. Eat.
Arnica cordifolia Hook.
Arnica sororia Greene
Arnica rydbergii Greene
Artemisia frigida Willd.
Artemisia michauxiana Bess.
Artemisia dranunculus L.
Aster conspicuus Lindl.
Aster foliaceus Lindl.
Aster subspicatus Nees.
Aster engelmannii (Eat.) Gray
Balsamorhiza sagittata Pursh.
Centaureae maculosa Lam.
Centaureae repens L.
Chrysanthemum leucanthemum L.
Cirsium arvense (L.) Scop.
Cirsium vulgare (Savi.) Tenore
Cirsium hookerianum Nutt.
Conyza canadensis (L.) Cronq.
Crepis nana Rich.
Erigeron compositus Pursh
Erigeron perigrinus (Pursh) Greene
Erigeron philadelphicus L.
Erigeron speciosus (Lindl.) DC
Filago arvensis L.
Gaillardia aristata Pursh
Grindelia squarrosa (Pursh) Dunal
Hieracium canadense Michx.
Hieracium cynoglossoides Arv. Touv.
Hieracium albiflorum Hook.
Matricaria maritima L.
Microceris nutans (Geyer) Schulz Bip.

Petasites sagittatus (Banks) Gray
Senecio triangularis Hook.
Senecio vulgaris L.
Senecio streptanthifolius Greene
Senecio indecorus Greene
Senecio integerrimus Nutt.
Senecio canus Hook.
Solidago missouriensis Nutt.
Solidago occidentalis (Nutt.) T. & G.
Solidago multiradiata Ait.
Solidago spathulata DC
Solidago canadensis L.
Tanacetum vulgare L.
Taraxacum officinale Weber
Tragopogon dubius Scop.

JUNCACEAE

Juncus spp.
Juncus bufonius L.
Juncus confusus Cov.
Juncus parviflora (Ehrh.) Desv.

CYPERACEAE

Carex spp.
Carex brevicaulis Mack.
Carex rostrata Stokes
Carex concinna R. Br.
Carex concinnoides Mack.
Carex rossii Boott
Carex capillaris L.
Carex aurea Nutt.
Carex aquatilis Wahl.
Carex prae-gracilis W. Boott
Carex praticola Piper
Scirpus spp.

POACEAE

Agropyron cristatum (L.) Gaertn.
Agropyron intermedium (Host) Beauv.
Agropyron spicatum (Pursh) Scribn. & Scribn.
Agropyron caninum (L.) Beauv.
Agropyron intermedium (Host) Beauv.
Agropyron repens (L.) Beauv.
Agropyron dasystachyum (Hook) Scribn.
Agropyron smithii Rydb.
Agrostis alba L.
Agrostis scabra Willd.
Alopecurus alpinus Smith
Alopecurus pratensis L.
Avena sativa L.

Beckmannia syzigachne (Steud.) Fern
Bromus tectorum L.
Bromus mollis L.
Bromus carinatus H. & A.
Bromus inermis Leys.
Bromus pumpellianus Scribn.
Bromus anomolus Rupr.
Calamagrostis rubescens Buckl.
Calamagrostis montanensis (Scribn.) Scribn.
Calamagrostis canadensis (Michx.) Beauv.
Cinna latifolia (Trevir.) Griseb
Dactylis glomerata L.
Danthonia unispicata (Thurb.) Munro
Danthonia parryi Scribn.
Deschampsia atropurpurea (Wahl.) Scribn.
Deschampsia elongata (Hook.) Munro
Deschampsia cespitosa (L.) Beauv.
Distichlis stricta (Torr.) Rydb.
Elymus cinereus Scribn. & Merr.
Elymus canadensis L.
Elymus glaucus Buckl.
Elymus ambiguus Vasey and Scribn.
Festuca scabrella Torr.
Festuca idahoensis Elmer
Festuca ovina ?
Festuca rubra L.
Glyceria grandis Wats.
Hierochloa odorata (L.) Beauv.
Hordeum jubatum L.
Koeleria cristata Pers.
Lolium perenne L.
Melica spectabilis Scribn.
Oryzopsis micrantha (Trin. & Rupr.) Thurb.
Phalaris arundinaceae L.
Phleum pratense L.
Phleum alpinum L.
Poa spp.
Poa fendleriana ?
Poa nervosa (Hook.) Vasey
Poa compressa L.
Poa grayana ?
Poa bulbosa L.
Poa trivialis L.
Poa cusickii Vasey
Poa leptocoma Trin.
Poa nemoralis L.
Poa interior Rydb.
Poa palustris L.
Poa pratensis L.
Poa alpina L.

Poa cusickii Vasey
Poa sandbergii Vasey
Poa scabrella (Thurb.) Benth.
Puccinellia sp
Sitanion hystrix (Nutt.) Smith.
Stipa occidentalis Thurb.
Trisetum spicatum (L) Richter

LILIACEAE

Allium schoenoprasum L.
Allium cernuum Roth.
Calochortus apiculatus Baker
Clintonia uniflora (Schult.) Kunth.
Disporum hookeri (Torr.) Nicholson
Erythronium grandiflorum Pursh
Lilium columbianum Hansom
Smilacina racemosa (L.) Desf.
Smilacina stellata (L.) Desf.
Stenanthium occidentale Gray.
Streptopus amplexifolius (L.) DC
Tofieldia glutinosa (Michx.) Pers.
Veratrum viride Ait.
Zigadenus venosus Wats.

IRIDACEAE

Sisyrinchium angustifolium Mill.

ORCHIDACEAE

Corallorhiza trifida Chat.
Corallorhiza maculata Raf.
Goodyera oblongifolia Raf.
Habenaria sp.
Habenaria unalascensis (Spreng.) Wats.
Habenaria viridis (L.) R. Br.
Habenaria dilatata (Pursh.) Hook
Habenaria hyperborea (L.) R. Br.
Listera sp.
Spiranthes romansoffiana Cham.

BRYOPHYTES AND LIVERWORTS

Aulacomnium palustre (Hedw.) Schwaegr.
Brachythecium spp
Brachythecium pseudotriquetrum (Hedw.) Gaertn., Meyer &
 Anderson
Bryum sp.
Bryum argenteum
Bryum caespiticium (Hedw.) L.

Ceratodon purpureus (Hedw.) Brid.
Desmatodon latifolius (Hedw.) Brid.
Encalypta vulgaris Hedw.
Eurhynchium pulchellum (Hedw.) Jenn.
Polytrichum juniperinum Hedw.
Polytrichum piliferum Hedw.
Rhacomitrium canescens
Tortula sp.
Tortula ruralis (Hedw.) Goertn.

LICHENS

Cladonia sp
Cladonia chlorophaea (Flk.) Spreng.
Cladonia fimbriata (L.) Fr.
Peltigera sp.
Peltigera apthosa (L.) Willd.
Peltigera canina (L.) Willd.
Peltigera piliferum Hedw.
Peltigera rufescens (Wiess) Humb.

APPENDIX III

FULL TABLE INCLUDING DIFFERENTIAL SPECIES GROUPS

Symbol	Actual Cover
5	75- 100 % cover
4	50 - 75 % cover
3	25 - 50 % cover
2	5 - 25 % cover
1	numerous or scattered, 5% cover
+	few, 5% cover rating
-	rare, one or two plants, with negligible cover rating

COMMUNITY TYPES

Number	Name
I	Vaccinium/Snowbank
II	Pinus/Sandstone
III	Pinus/Till Pocket
IV	Amelanchier/Penstemon
V	Astragalus/Kame Terrace
VI	Penstemon/Polygonum
VII	Lithospermum/Shrub
VIII	Arenaria/Balsamorhiza/Unstable Colluvium
IX	Balsamorhiza/Xeric Outcrop
X	Calamagrostis/Soil Pocket
XI	Balsamorhiza/Pseudotsuga/Ridgetop
XII	Agropyron/Sand Deposit
XIII	Eriogononum/Xeric Shale
XIV	Selaginella/Shale Depression
XV	Transitional Plots

APPEDIX IV
RAW DATA FOR THE EXCLOSURE STUDY

Exclosure #	1	2	3	4	5	6	7	8	9	10
aspect (in compass degrees)	1 8 3	1 8 0	2 2 0	1 7 5	2 0 0	1 8 5	2 1 0	2 0 8	2 7 2	2 5 0
elevation (m ASL)	1 6 0 0	1 5 7 8	1 5 4 2	1 5 8 6	1 4 7 0	1 5 9 5	1 3 8 0	1 4 8 7	1 4 8 0	1 5 9 0
Slope (%)	4 8	3 7	2 4	7 3	6 0	2 7	2 3	3 8	4 4	2 0

SPECIES LIST	VISUAL ESTIMATE OF COVER $\left(\begin{array}{l} \% \text{inside} \\ \% \text{outside} \end{array} \right)$									
	1	2	3	4	5	6	7	8	9	10
Exclosure #	1	2	3	4	5	6	7	8	9	10
Amelanchier alnifolia	40 05	30 01	40 10	30 10	60 10	30 10	30 15	50 05	40 05	50 05
Berberis repens	10 10	00 00	01 01	01 01	01 05	00 00	01 01	01 05	00 00	00 00
Rosa acicularis	30 10	10 01	15 05	14 05	30 05	30 20	00 00	20 01	05 01	05 05
Ceanothus velutinus	00 00	00 00	30 00	00 00	00 00	00 00	05 01	00 00	00 00	00 00
Salix scouleriana	00 00	00 00	90 15	00 00	00 00	00 00	40 00	00 00	30 15	20 10
Spireae betulifolia	20 10	15 05	15 05	30 05	10 15	10 05	05 01	00 00	00 00	10 05
Shepherdia canadensis	00 00	00 00	15 05	00 00	00 00	10 10	00 00	25 20	00 00	00 00
Chrysanthemum leucanthemum	00 10	00 15	00 05	01 30	00 00	00 05	01 15	00 05	00 00	00 00
Medicago lupulina	00 01	00 20	00 01	01 40	00 00	01 05	00 00	01 05	00 05	00 05

Raw Data for exclosure study (cont)

Exclosure #	1	2	3	4	5	6	7	8	9	10
<i>Festuca idahoensis</i>	$\frac{05}{05}$	$\frac{10}{05}$	$\frac{05}{01}$	$\frac{10}{01}$	$\frac{10}{10}$	$\frac{05}{05}$	$\frac{10}{15}$	$\frac{15}{05}$	$\frac{10}{05}$	$\frac{10}{15}$
<i>Gientiana amarella</i>	$\frac{00}{01}$	$\frac{00}{01}$	$\frac{00}{01}$	$\frac{00}{01}$	$\frac{00}{01}$	$\frac{00}{01}$	$\frac{00}{01}$	$\frac{01}{01}$	$\frac{00}{05}$	$\frac{00}{01}$
<i>Picea engelmanni</i>	$\frac{00}{00}$	$\frac{01}{00}$	$\frac{00}{00}$	$\frac{00}{00}$	$\frac{00}{00}$	$\frac{00}{00}$	$\frac{00}{00}$	$\frac{00}{00}$	$\frac{00}{00}$	$\frac{00}{00}$
<i>Pseudotsuga menziesii</i>	$\frac{01}{00}$	$\frac{00}{00}$	$\frac{01}{00}$	$\frac{05}{00}$	$\frac{00}{00}$	$\frac{01}{00}$	$\frac{00}{00}$	$\frac{05}{00}$	$\frac{00}{00}$	$\frac{00}{00}$
<i>Pinus contorta</i>	$\frac{01}{00}$	$\frac{01}{01}$	$\frac{01}{00}$	$\frac{01}{00}$	$\frac{00}{00}$	$\frac{01}{00}$	$\frac{01}{00}$	$\frac{01}{00}$	$\frac{01}{00}$	$\frac{01}{00}$

The following species showed the same cover abundance inside and outside each exclosure %.

Raw Data for exclosure study (cont)

Exclosure #	1	2	3	4	5	6	7	8	9	10
<i>Penstemon confertus</i>	10	05	10	01	01	05	01	01	01	05
<i>Lupinus sericeus</i>	05	05	01	01	10	05	20	25	10	20
<i>Smilacina stellata</i>	05									01
<i>Penstemon attenuatus</i>	01		01		01					
<i>Calamagrostis rubescens</i>	15	05	10				10	10		05
<i>Polygonum douglassi</i>	01	01	01		01		01		01	01
<i>Heuchera cylindrica</i>	05		01	01	01			01		01
<i>Arnica cordifolia</i>	01		01				01			01

Raw Data for exclosure study (cont)

Exclosure #	1	2	3	4	5	6	7	8	9	10
<i>Collinsia parviflorus</i>	01	01	01	01		01	01	01	01	
<i>Selaginella densa</i>	01		01	05	10		01		01	
<i>Cladonia</i> spp	01	01	01	01		01			01	
<i>Aster conspicuus</i>			01				01	05	05	01
<i>Rubus parviflorus</i>			05							
<i>Thalictrum occidentale</i>			05							
<i>Arenaria lateriflora</i>			01							
<i>Epilobium angustifolium</i>			01	01		01			01	01
<i>Poa palustris?</i>			05				01			01
<i>Erigeron speciosus</i>					01		05		01	01
<i>Agoseris nutans</i>				01		01		01		
<i>Carex brevicaulis</i>							01			
<i>Fragaria virginiana</i>	01		01	01						01
<i>Deschampsia cespitosa</i>		15			10	01		15		
<i>Arctostaphylos uva-ursi</i>			01							

VITA

Surname: Fraser

Given Names: David Frank

Place of Birth: Vancouver, British Columbia.

Date of Birth: December 11, 1956.

Educational Institutions Attended:

University of Victoria, B.C.

1975-1980

University of Victoria, B.C.

1980-1986

Degrees, Diplomas, Etc. Awarded with Dates and Name of Institutions:

B. Sc. (Biology) 1980 University of Victoria 1980

Honours and Awards:

Rotary International Exchange Student Scholarship 1974

Freeman King Bursary 1979

British Columbia Reclamation Research and Technical Advisory Committee Student Bursary for outstanding contribution to the field of Reclamation Research. 1984.

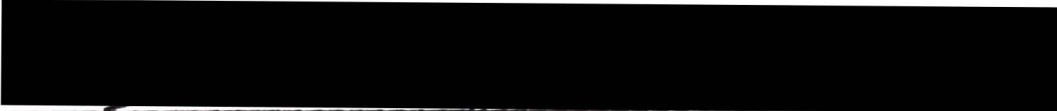
PARTIAL COPYRIGHT LICENSE

I hereby grant the right to lend my thesis or dissertation (the title of which is shown below) to users of the University of Victoria Library or in response to a request from the Library of any other university, or similar institution, on its behalf or for one of its users. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by me or a member of the University designated by me. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Title of Thesis:

Ecology of meadow communities in southeastern British Columbia.

Author


DAVID F. FRASER

December 16, 1985

