CLASSIFICATION OF THE GRASSLANDS, SHRUBLANDS, WOODLANDS, FORESTS AND ALPINE VEGETATION ASSOCIATIONS OF THE CUSTER NATIONAL FOREST PORTION OF THE BEARTOOTH MOUNTAINS IN SOUTHCENTRAL MONTANA

by

Kristin Louise Williams

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Biological Sciences

MONTANA STATE UNIVERSITY
Bozeman, Montana

January 2012

©COPYRIGHT

by

Kristin Louise Williams

2012

All Rights Reserved

APPROVAL

of a thesis submitted by

Kristin Louise Williams

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citation, bibliographic style, and consistency and is ready for submission to The Graduate School.

David W. Roberts

Approved for the Department of Ecology

David W. Roberts

Approved for The Graduate School

Dr. Carl A. Fox

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the Library shall make it available to borrowers under rules of the Library.

If I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for permission for extended quotation from or reproduction of this thesis in whole or in parts may be granted only by the copyright holder.

Kristin Louise Williams

January 2012

ACKNOWLEDGEMENTS

First and foremost, I would like to thank Dr. David Roberts for the extreme patience, priceless assistance and thought-provoking ecological insights he provided throughout my program, without which my experience would neither have been as successful or rewarding. The time and efforts of Dr. Aaron Wells and Dr. Sabine Mellmann-Brown in designing and coordinating the study were similarly priceless. I am very appreciative for their help and support. Finally, it is impossible to conduct field surveys in remote and treacherous terrain without valiant, experienced and positive crew members. As such, I would also like to state my express appreciation to Lauren Healy, Micheal Jenson, Julia Pederson, Blake Hodgins, Garrett Dickman and Sabine Mellmann Brown for their hard work, good times and friendship.

TABLE OF CONTENTS

1. INTRODUCTION 1

Study Area 7
Introduction 7
Geology and Soils 10
Climate 13
Vegetation 14
Multivariate Analysis 16
Literature Cited 23

2. CLASSIFICATION OF SHRUBLAND ASSOCIATIONS OF THE BEARTOOTH MOUNTAINS STUDY AREA AND COMPARISON TO EXISTING GRASSLAND AND SHRUBLAND HABITAT TYPE CLASSIFICATIONS 28

Contribution of Authors and Co-Authors 28
Manuscript Information Page 29
Abstract 30
Introduction 30
Study Area 33
Methods 35
Study Design 35
Plot Selection 36
Vegetation Data 37
Plant Taxonomy Considerations 38
Soil Data Collection 38
Environmental Site Data 40
Statistical Analysis 42
Results 44
Vegetation Composition 44
Correlation of Environmental Variables 47
Cluster Analysis of Communities 49
NMDS Ordination and Evaluation of Environmental Variables 56
Grassland and Shrubland Association Descriptions 74
Cluster 1: *Alyssum alyssoides/Balsamorhiza sagittata* (ALAL3/BASA3) Association (n=2) 74
Vegetation 74
Enviornment 75
Other Classification 75

TABLE OF CONTENTS (CONTINUED)

Cluster 2: *Festuca idahoensis/Geranium viscosissimum* (FEID/GEVI2) Association (n=4) 77
Vegetation 77
Enviornment 77
Other Classification 78
Cluster 3: *Artemisia tridentata* var. *vaseyana/ Festuca idahoensis* (ARTRV/FEID) Association (n=3) 80
Vegetation 80
Enviornment 80
Other Classification 81
Cluster 4: *Festuca idahoensis-Elymus spicatus* (FEID-PSSP6) Association (n=11) 82
Vegetation 82
Enviornment 82
Other Classification 83
Cluster 5: *Elymus spicatus/Artemisia frigida* (PSSP6/ARFR4) Association (n=4) 83
Vegetation 83
Enviornment 84
Other Classification 84
Discussion 86
Conclusion 91
Literature Cited 93

3. CLASSIFICATION OF WOODLAND AND FORESTED VEGETATION ASSOCIATIONS OF THE BEARTOOTH MOUNTAINS STUDY AREA AND COMPARISON WITH EXISTING WOODLAND AND FORESTED HABITAT TYPE CLASSIFICATIONS 96

Contribution of Authors and Co-Authors 96
Manuscript Information Page 97
Abstract 98
Introduction 99
Study Area 102
Methods 104
Study Design 104
Plot Selection 106
Plot Size 107
Vegetation Data 107
Plant Taxonomy Considerations 108
Soil Data Collection 108

TABLE OF CONTENTS (CONTINUED)

Environmental Site Data 110
Statistical Analysis 112
Results 114
Vegetation Composition 114
Correlation of Environmental Variables 118
Cluster Analysis of Communities 121
NMDS Ordination and Evaluation of Environmental Variables 129
Woodland and Forested Association Descriptions 154
Cluster 1: *Pinus flexilis/Symphoricarpos albus* Association (n=2) 154
Vegetation 154
Enviornment 154
Other Classification 155
Cluster 2: *Pseudotsuga menziesii* var. *glauca*/*Arnica cordifolia* Association (n=9) 157
Vegetation 157
Enviornment 157
Other Classification 158
Cluster 3: *Pinus flexilis/Artemisia frigida* Association (n=3) 161
Vegetation 161
Enviornment 162
Other Classification 162
Cluster 4: *Pinus flexilis/Agoseris glauca* Association (n=3) 163
Vegetation 163
Enviornment 164
Other Classification 164
Cluster 5: *Pinus contorta* var. *latifolia/ Ceanothus velutinus* Association (n=6) 166
Vegetation 166
Enviornment 166
Other Classification 167
Cluster 6: *Pseudotsuga menziesii* var. *glauca*/mixed xeric shrub Association (n=7) 169
Vegetation 169
Enviornment 170
Other Classification 170

TABLE OF CONTENTS (CONTINUED)

Cluster 7: *Pinus contorta* var. *latifolia* / *Spiraea betulifolia* Association (n=25) 173
Vegetation 173
Enviornment 174
Other Classification 175
Cluster 8: *Pseudotsuga menziesii* var. *glauca* / *Juniperus communis* var. *depressa* Association (n=2) 175
Vegetation 175
Enviornment 176
Other Classification 177
Cluster 9: *Abies lasiocarpa/Arnica cordifolia* Association (n=12) 178
Vegetation 178
Enviornment 179
Other Classification 180
Cluster 10: *Picea engelmannii/Minuartia obtusiloba* Association (n=2) 182
Vegetation 182
Enviornment 182
Other Classification 183
Cluster 11: *Abies lasiocarpa-Pinus albicaulis/ Vaccinium scoparium* Association (n=32) 184
Vegetation 184
Enviornment 185
Other Classification 185
Cluster 12: *Pinus albicaulis/ Arctostaphylos uva-ursi* Association (n=2) 188
Vegetation 188
Enviornment 188
Other Classification 189
Discussion 190
Conclusion 196
Literature Cited 197

4. CLASSIFICATION OF ALPINE VEGETATION ASSOCIATIONS OF THE BEARTOOTH MOUNTAINS STUDY AREA 201

Contribution of Authors and Co-Authors 201
Manuscript Information Page 202
Abstract 203

TABLE OF CONTENTS (CONTINUED)

Introduction 204
Study Area 207
Methods 210
Study Design 210
Plot Selection 211
Vegetation Data 212
Plant Taxonomy Considerations 213
Soil Data Collection 214
Environmental Site Data 215
Statistical Analysis 217
Results 219
Vegetation Composition 219
Correlation of Environmental Variables 223
Cluster Analysis of Communities 226
NMDS Ordination and Evaluation of Environmental Variables 234
Alpine Association Descriptions 255
Cluster 1: *Dryas octopetala* var. *hookeriana* Association (n=2) 255
Vegetation 255
Enviornment 255
Other Classification (n=2) 256
Cluster 2: *Helianthela uniflora-Astragalus alpinus* Association (n=2) 256
Vegetation 256
Enviornment 257
Other Classification 257
Cluster 3: *Salix planifolia/Carex scopulorum* Association (n=4) 257
Vegetation 257
Enviornment 258
Other Classification 256
Cluster 4: *Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens* Association (n=11) 259
Vegetation 259
Enviornment 260
Other Classification 260
Cluster 5: *Carex phaeochephala/Sibbaldia procumbens* Association (n=5) 261
Vegetation 261
Enviornment 261

TABLE OF CONTENTS (CONTINUED)

Other Classification 262
Cluster 6: *Salix glauca* var. *villosa/ Geum rossii* var. *turbinatum* Association (n=3) 263
Vegetation 263
Enviornment 263
Other Classification 264
Cluster 7: *Salix reticulata* var. *nana*/ *Polygonum viviparum* Association (n=2) 264
Vegetation 264
Enviornment 265
Other Classification 263
Cluster 8: D*eschampsia cespitosa-Carex microptera-Carex macloviana* Association (n=3) 266
Vegetation 266
Enviornment 266
Other Classification 267
Cluster 9: *Antennaria lanata-Hieracium triste* var. *gracile* Association (n=7) 268
Vegetation 268
Enviornment 268
Other Classification 269
Cluster 10: *Picea engelmannii-Pinus albicaulis/ Carex nardina* Association (n=4) 270
Vegetation 270
Enviornment 271
Other Classification 271
Cluster 11: *Carex nigricans/Veronica wormskjoldii* Association (n=9) 272
Vegetation 272
Enviornment 273
Other Classification 273
Cluster 12: *Senecio triangularis-Mertensia ciliata* Association (n=2) 274
Vegetation 274
Enviornment 274
Other Classification 275
Cluster 13: *Senecio fremontii-Draba incerta* Association (n=2) 275
Vegetation 275
Enviornment 275
Other Classification 276

TABLE OF CONTENTS (CONTINUED)

Discussion 276
Conclusion 283
Literature Cited 284

5. CONCLUSION 288

LITURATURE CITED 296

APPENDICES 303

APPENDIX A: Key to Grassland and Shrubland Series and Habitat Types 304
APPENDIX B: Key to Grassland and Shrubland Associations 307
APPENDIX C: Cover and Constancy Table for Grassland/Shrubland Associations of the Beartooth Mountains Study Area 310
APPENDIX D: Key to Woodland and Forested Series and Habitat Types 316
APPENDIX E: Key to Woodland and Forested Associations 323
APPENDIX F: Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area 326
APPENDIX G: Key to Alpine Vegetation Associations 354
APPENDIX H: Cover/Constancy Table for Alpine Vegetation Associations 359

LIST OF TABLES

Table Page

2.1. 10 most abundant and 10 most frequent species. Mean % cover is rounded to the nearest whole number 46

2.2. Correlation coefficient (Pearson's) for joint distribution of continuous environmental variables. Absolute values > 0.5 are in bold 48

2.3. Indicator Species for each cluster with INDVAL and p-val for each indicator species 55

2.4. D^2 values of GAMs fit to continuous environmental variables, based on the three dimensional NMDS ordination. All models are Gaussian 69

2.5. P-values and chi-squared values from Kruskal-Wallis Rank Sum Test for each of the continuous environmental variables. P-values < 0.1 are bolded. d.f.=4 69

2.6. Ordtest p-values for topographic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level 71

2.7. Ordtest p-values for climatic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level 72

2.8. Ordtest p-values for geologic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level 73

2.9. Ordtest p-values for the categorical variable, disturbance and PNV classification, based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level 74

3.1. The 10 most abundant and 10 most frequent species. Mean % cover is rounded to the nearest whole number 117

LIST OF TABLES (CONTINUED)

Table Page

3.2. Correlation coefficient (Pearson's) for joint distribution of continuous environmental variables. Absolute values > 0.5 are in bold 120

3.3. Indicator Species for each of 13 identified clusters 128

3.4. D^2 values of GAMs fit to continuous environmental variables, based on the three dimensional NMDS ordination. All models are Gaussian. D^2 > 0.5 are in bold 143

3.5. P-values and chi-squared values from Kruskal-Wallis Rank Sum Test for each of the continuous environmental variables. P-values < 0.1 are bolded. d.f.=11 143

3.6. Ordtest p-values for topographic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the p < 0.1 level 146

3.7. Ordtest p-values for climatic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the p < 0.1 level 148

3.8. Ordtest p-values for geologic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the p <. 01 level. 150

3.9. Ortest p-values for the categorical variable, disturbance, based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the p < 0.1 level 152

4.1. The 10 most abundant and 10 most frequent species. Mean % cover is rounded to the nearest whole number 222

4.2. Correlation coefficient (Pearson's) for joint distribution of continuous environmental variables. Absolute values > 0.5 are in bold 225

LIST OF TABLES (CONTINUED)

Table Page

4.3. Indicator Species for each of 13 identified clusters 233

4.4. D^2 values of GAMs fit to continuous environmental variables, based on the three dimensional NMDS ordination. All models are Gaussian 247

4.5. P-values and chi-squared values from Kruskal-Wallis Rank Sum Test for each of the continuous environmental variables. P-values <.05 are bolded. d.f.=12 247

4.6. Ordtest p-values for topographic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level 249

4.7. Ordtest p-values for climatic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level 251

4.8. Ortest p-values for the categorical variable, disturbance, based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level 252

4.9. Ordtest p-values for geologic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level 253

LIST OF FIGURES

Figure Page

1.1. Location of the Beartooth Mountain Range in relation to state boundaries and adjacent mountain ranges and basins 8

1.2. Hillshade relief map with drainages and plateaus labeled 9

1.3. Map of the major geologic units and Snotel stations 11

2.1. Number of species per plot across all plots 45

2.2. Species occurrence on each plot, across all species 45

2.3. Mean species abundance versus number of plots in which the species occurred 46

2.4. Correlations of measured site environmental variables: elevation (m), slope percent (%); and modeled site environmental variables: relative effective annual precipitation (REAP), total precipitation (TOTPRCP), growing degree day (GRDEGDAY), annual solar exposure (SOLAR), daily average temperature (DAVTEMP) 49

2.5. STRIDE analysis plot showing the PARTANA ratio and average Silhouette width for models containing 2 to 20 clusters 50

2.6. Silhouette width plot, indicating within cluster plot similarity for each of 5 clusters. Reversal bars represent negative silhouette width values which indicate poor similarity of a plot to the cluster in which it belongs. Cluster size and average Silhouette value for each cluster are displayed on right of plot 52

2.7. Partana plot, displaying the similarity of each plot within a cluster to each other plot in other clusters. White indicates high similarity, yellow moderate to high similarity and red a lack of similarity 53

2.8. Partana plot, displaying the similarity of each cluster to every other cluster. White indicates high similarity, yellow moderate to high similarity and red a lack of similarity 54

LIST OF FIGURES (CONTINUED)

Figure Page

2.9. Correlation of three-dimensional NMDS ordination and computed distances of sample plots, giving an indication of the NMDS ordination quality (r=0.897) 57

2.10. First two axes of three-dimensional NMDS ordination with associations outlined and identified by unique symbols 58

2.11. First two axes of three-dimensional NMDS ordination where points are habitat types and associations identified in this analysis are outlined 59

2.12. Hillshade relief and broad geologic map of study area where membership of grassland/shrubland samples to grassland/shrubland association is indicated by differently colored points 59

2.13. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.3404$ for smooth of Northing coordinate on all three dimensions. 60

2.14. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.1999$ for smooth of Easting coordinate on all three dimensions. 61

2.15. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.1808$ for smooth of elevation on all three dimensions.. 62

2.16. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.1247$ for smooth of slope percent (%) on all three dimensions. 63

2.17. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.3699$ for smooth of relative effective annual precipitation (REAP) on all three dimensions 64

2.18. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.2251$ for smooth of total annual precipitation (TOTPRCP) on all three dimensions. 65

LIST OF FIGURES (CONTINUED)

Figure Page

2.19. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.251$ for smooth of growing degree day (GRDEGDAY) on all three dimensions. 66

2.20. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.1492$ for smooth of units annual solar exposure (SOLAR). 67

2.21. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.1851$ for smooth of average daily temperature (DAVTEMP) on all three dimensions. 68

2.22. Boxplots of continuous environmental variables: Northing coordinate, Easting coordinate, elevation (m), slope percent (%), relative effective annual precipitation (REAP), total annual precipitation (TOTPRCP), greatest daily degree (GRDEGDAY), annual solar exposure (SOLAR) and average daily temperature (DAVTEMP). 70

3.1. Species occurrence on each plot, across all species. 115

3.2. Number of species per plot, across all plots. 116

3.3. Mean species abundance versus number of plots in which the species occurred. 117

3.4. Correlations of environmental variables: Easting coordinate, Northing coordinate, elevation (m), slope percent (%), relative effective annual precipitation (REAP), total annual precipitation (TOTPRCP), growing degree days (GRDEGDAY), annual solar exposure (SOLAR), average daily temperature (DAVTEMP). 119

3.5. STRIDE analysis plot showing the PARTANA ratio and average Silhouette width for models containing 2 to 20 clusters. 122

LIST OF FIGURES (CONTINUED)

Figure Page

3.6. Silhouette width plot, indicating within cluster plot similarity for each of 12 clusters. Reversal bars represent negative silhouette width values which indicate poor similarity of a plot to the cluster in which it belongs. Cluster size and average Silhouette value for each cluster are displayed on right of plot. 123

3.7. PARTANA plot, displaying the similarity of each plot within a cluster to each other plot in other clusters. White indicates high similarity, yellow moderate to high similarity and red a lack of similarity. 124

3.8. Partana plot, displaying the similarity of each cluster to every other cluster. White indicates high similarity, yellow moderate to high similarity and red a lack of similarity. 125

3.9. Correlation of three-dimensional ordination and computed distances of sample plots, giving an indication of the NMDS ordination quality (r=0.84). 131

3.10. First two axes of three-dimensional NMDS ordination with associations outlined and identified by unique color-symbol combinations..... 132

3.11. First two axes of three-dimensional NMDS ordination with associations outlined and habitat types identified by unique color-symbol combinations. 132

3.12. Hillshade relief and broad geologic map of study area where membership of woodland/forested samples to woodland/forested association is indicated by differently colored points..... 133

3.13. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.149$ for smooth of Northing coordinate on all three dimensions. 134

3.14. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.399$ for smooth of Easting coordinate on all three dimensions. 135

LIST OF FIGURES (CONTINUED)

Figure Page

3.15. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.879$ for smooth of elevation (m) on all three dimensions. 136

3.16. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.254$ for smooth of slope percent (%) on all three dimensions. 137

3.17. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.692$ for smooth of relative effective annual precipitation (REAP) on all three dimensions. 138

3.18. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.739$ for smooth of total annual precipitation (TOTPRCP) on all three dimensions. 139

3.19. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.847$ for smooth of growing degree days (GRDEGDAY) on all three dimensions. 140

3.20. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.295$ for smooth of annual solar exposure (SOLAR) on all three dimensions..... 141

3.21. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.795$ for smooth of average daily temperature (DAVTEMP) on all three dimensions. 142

3.22. Boxplots of continuous environmental variables Northing coordinate, Eaasting coordinate, elevation (m), slope percent (%), aspect degree, relative effective annual precipitation (REAP), total annual precipitation (TOTPRCP), growing degree days (GRDEGDAY), units solar loading (SOLAR) and average daily temperature (DAVTEMP). 144

4.1. Number of species per plot across all plots. 220

LIST OF FIGURES (CONTINUED)

Figure Page

4.2. Pearson's Correlation Coefficient for joint distribution of continuous environmental variables. Absolute values > 0.5 are in bold. 221

4.3. Mean species abundance versus number of plots in which the species occurred. 222

4.4. Correlations of environmental variables: Easting coordinate, Northing coordinate, elevation (m), slope percent (%), relative effective annual precipitation (REAP), total annual precipitation (TOTPRCP), growing degree days (GRDEGDAY), annual solar exposure (SOLAR), average daily temperature (DAVTEMP). 224

4.5. STRIDE analysis plot showing the PARTANA ratio and average Silhouette width for models containing 2 to 20 clusters. 227

4.6. Silhouette width plot, indicating within cluster plot similarity for each of 13 clusters. Reversal bars represent negative Silhouette width values which indicate poor similarity of a plot to the cluster in which it belongs. Cluster size and average Silhouette value for each cluster are displayed on right of plot. 228

4.7. Partana plot, displaying the similarity of each plot within a cluster to each other plot in other clusters. White indicates high similarity, yellow moderate to high similarity and red a lack of similarity. 229

4.8. Partana plot, displaying the similarity of each cluster to every other cluster. White indicates high similarity, yellow moderate to high similarity and red a lack of similarity. 230

4.9. Correlation of three-dimensional ordination and computed distances of sample plots, giving an indication of the NMDS ordination quality (r=0.713). 236

4.10. First two axes of three-dimensional NMDS ordination with alpine associations outlined. 237

LIST OF FIGURES (CONTINUED)

Figure Page

4.11. Hillshade relief and broad geologic map of study area where membership of alpine samples to alpine association is indicated by differently colored points 237

4.12. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.281 for smooth of Northing coordinate on three dimensions. 238

4.13. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.408 for smooth of Easting coordinate on three dimensions. 239

4.14. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.421for smooth of elevation (m) on three dimensions. 240

4.15. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.202 for smooth of slope percent (%) on three dimensions. 241

4.16. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.64 for smooth of relative effective annual precipitation (REAP) on three dimensions. 242

4.17. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.752 for smooth of total annual precipitation (TOTPRCP) on three dimensions. 243

4.18. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.506 for smooth of growing degree days (GRDEGDAY) on three dimensions. 244

4.19. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.00459 for smooth of annual solar exposure (SOLAR) on three dimensions 245

LIST OF FIGURES (CONTINUED)

Figure Page

4.20. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.466 for smooth of average daily temperature (DAVTEMP) on three dimensions... 246

4.21. Boxplots of continuous environmental variables elevation, slope percent (%), relative effective annual precipitation (REAP), total annual precipitation (TOTPRCP), growing degree days (GRDEGDAY), annual solar exposure (SOLAR) and average daily temperature (DAVTEMP). 248

ABSTRACT

The purpose of this thesis was to classify and describe low-elevation grassland and shrubland vegetation, mid-elevation woodland and forested vegetation, and high elevation alpine vegetation associations of the Beartooth Mountains study area and to compare newly derived associations with existing habitat type and community type classifications of ecologically relevant environments in Montana, Wyoming and Idaho. Five grassland/shrubland associations, twelve woodland/forested associations and thirteen alpine associations were classified and described for the Beartooth Mountains study area. Prior to this thesis, no comprehensive vegetation association classification of the Beartooth Mountains, the highest, largest and easternmost alpine region in Montana, has been conducted.

CHAPTER 1

INTRODUCTION

Vegetation ecologists commonly seek to characterize plant species distributions across the landscape. The recurrence of similar plant assemblages wherever the net influence of climate, soil, animal, disturbance and time factors have provided roughly equivalent environments was recognized early in vegetation studies (Daubenmire, 1966). Due to changing climate regimes and increasing demands placed on natural resources, the documentation and classification of vegetation, as tools for organizing and interpreting ecological information and context, are integral to biological conservation, resource management and scientific research (Pfister and Arno, 1980; Jennings et al., 2009).

Classification is the art and science of grouping objects considered to be similar in some respect (Kaufman and Rousseeuw, 1990; Gordon, 1999). In vegetation studies, researchers generally classify samples based on some aspect of floristic composition. Habitat types and community type associations are the most commonly used basic hierarchical units of floristic composition analysis (Spribille et al., 2001) in the western United States. Habitat types seek to classify land based on the vegetation composition sites are capable of supporting in late succession (Daubenmire, 1952; Pfister and Arno, 1980). The late succession association of plants characteristic of a habitat is referred to as the potential natural vegetation (PNV). Community types seek to classify vegetation associations based on existing species composition, regardless of a sites potential to support a particular late seral or climax association. As such, a single community type

may include samples classified to multiple habitat types, depending on the nature, frequency and distribution of stand-altering disturbances in the landscape. The recent resurgence of interest in vegetation classification and adoption of U.S. National Vegetation Classification (NVC) standards for associations and alliances (Jennings et al., 2009) has renewed interest in the theory behind and relative ecological usefulness of both frameworks.

The habitat type classification system is based on plant succession theory, a basic tenet of which states that the most shade tolerant or "climax" species present in a stand will eventually dominate in the absence of disturbance. Samples are first divided into 'series' comprised of stands with the same indicated climax tree species (Daubenmire, 1952; Pfister and Arno, 1980; Steele et al., 1981). Even if the indicated climax tree species occurs in low abundance, its presence alone is indicative of the successional trajectory of the stand. Series represent major environmental differences reflected by the distributions of climax tree species. Habitat types are subdivisions of series that represent environmental differences represented by total vegetation composition (Pfister and Arno, 1980). While a given habitat type should reflect all land areas capable of supporting the same potential natural vegetation association in late succession, it is not necessarily a reflection of similarities in existing vegetation between samples (Pfister and Arno, 1980).

Classification by community type association uses the floristic characteristics of species assemblage and abundance to group samples with similar composition and physiognomy into clusters that are consistently recognizable using diagnostic features (Jennings et al., 2009). NVC defines plant associations as "a vegetation classification

unit defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions, and physiognomy (Jennings et al., 2009)." Alliances are conceptually similar to 'series' and are defined by NVC (Jennings et al., 2009) as "a vegetation classification unit containing one or more associations, and defined by a characteristic range of species composition, habitat conditions, physiognomy, and diagnostic species, typically at least one of which is found in the uppermost or dominant stratum of the vegetation."

The habitat type concept emphasizes the diagnostic potential of climax-dominant species and uses the presumed climax development to assign samples to series (and land to habitat types) regardless of existing vegetation. The association/alliance concept emphasizes the composition of existing vegetation (Jennings et al., 2009; Pfister and Arno, 1980). NVC associations and habitat types are likely similar in stands where the potential climax species have attained dominance. In stands where the climax species remains subordinate to a seral species, ecologically interesting discrepancies between NVC associations and habitat types are bound to emerge (Jennings et al., 2009).

Multivariate analysis techniques such as ordination and classification can be used, often in concert, to assess the way in which species assemble into recognizable patterns along and across environmental gradients (Gauch, 1982; Podani, 1989; Dufrêne and Legendre, 1997; Jongman et al., 1995, and others). Ordinations are graphical aids used to portray patterns of variability in composition data and summarize the informational content of a dataset (Kent and Coker, 1992; Mueller-Dombois and Ellenburg, 1974; Greig-Smith, 1983). Ordinations may be used to clarify the distinctiveness of clusters

derived from classification and to explore the arrangement of samples and clusters across environmental gradients (Everritt, 1970).

The vegetation of grassland, shrubland, woodland, forested, alpine and riparian ecosystems have been classified and described for much of Montana (Mueggler and Stewart, 1980; Pfister et al., 1977; Cooper et al., 1997; Hansen et al., 1995; Bamberg, 1961). Of these major ecological divisions, the vegetation of the alpine remains least classified. Montana occupies a large portion of what is generally considered the Northern Rocky Mountain floristic province and is home to twenty-seven mountain ranges supporting alpine terrain (Cooper et al., 1997). However, only the vegetation of the nine ranges located on the Beaverhead National Forest in south-western Montana have been inventoried and classified (Cooper et al., 1997). Other alpine vegetation studies have been conducted in Glacier National Park (Bamberg and Major, 1968; Choate and Habeck, 1967), the Big Snowy Mountains and Flint Creek Mountains (Bamberg and Major, 1968) and the Beartooth Plateau (Johnson and Billings, 1962) and Line Creek Plateau (Lesica, 1993) of the Beartooth Mountain Range. However, these studies had small sample sizes and were carried out on small spatial scales relevant to the ranges they represent.

The Beartooth Mountain Range of south-central Montana and north-central Wyoming contains the highest peaks and largest representation of alpine tundra in Montana and Region One of the US Forest Service. The Beartooth Mountain Range also sits further north and east than other alpine ranges in Montana, Region One and ranges of the Great Basin (Billings, 1978). The vegetation of the Beartooth Mountain Range, therefore, exhibits a mixture of Rocky Mountain and Great Basin floristics (Billings,

1978) and is more similar to the high ranges of Wyoming, Utah and Colorado (Lesica, 1993) than to other alpine regions of Montana. Also, of the Great Basin alpine ranges Billings (1978) compared, the Beartooth Plateau had the highest percentage of species also occurring in the Arctic (47% or 91 out of 194 species). Several of Montana's listed rare plant species are arctic species with disjunct populations in the Beartooth Mountains (Lesica, 1993). The unique flora represented in the Beartooth Mountain Range increases the necessity of a more complete inventory and classification of plant associations for the Beartooth Mountain Range than has been attempted in the past.

In the winter of 2007-2008 the U.S. Forest Service (USFS) Custer National Forest, Natural Resource Conservation Service (NRCS) and the Department of Ecology at Montana State University (MSU) entered into a cooperative agreement to complete a National Soil Survey (NSS) and Terrestrial Ecological Unit Inventory (TEUI) for the Custer National Forest portion of the Beartooth Mountain Range, which I will herein refer to as the Beartooth Mountains study area. Two hundred TEUI protocol vegetation samples with associated NSS protocol soil profile pits were collected during the 2008 and 2009 summer field seasons. The Beartooth Mountains study area is large and ecologically diverse, ranging from grassland and shrubland associations at low elevations to turf and cushion plant communities at high elevations with forested associations occurring on the steep slopes in between. In order to accurately characterize the diversity of ecosystems and vegetation present in the study area, I divided the data into the following three categories for analysis: low-elevation grassland/shrubland samples (<10% tree cover, < 2,500 m elevation), mid-elevation woodland and forested samples

(>10% tree cover, all elevations), high-elevation alpine samples (<10% tree cover, ≥2,500 m).

The primary objective of Chapter 2 was to classify the vegetation of low-elevation shrublands of the Beartooth Mountains study area into compositionally and ecologically distinct community type associations. Samples were also classified to habitat type using Mueggler and Stewart's (1980) Grassland and Shrubland Habitat Types of Western Montana. I then created an amended dichotomous key to represent habitat types sampled in the study area and an entirely new dichotomous key to the associations classified in this analysis. Finally, I described the vegetation composition, environmental attributes and range of habitat types characterizing each grassland/shrubland association.

In Chapter 3, the primary objective was to classify the vegetation of mid-elevation woodlands and forests of the Beartooth Mountains study area into compositionally and ecologically distinct community type associations. Samples were additionally classified to habitat type using Steele et al. (1983) Forest Habitat Types of Eastern Idaho-Western Wyoming and Pfister et al. (1977) Forest Habitat Types of Montana. I again created an amended dichotomous key to habitat types, a dichotomous key to newly classified associations and described the vegetation composition, environmental attributes and range of habitat types characteristic of each woodland and forested association.

The primary objective of Chapter 4 was to classify the vegetation of the alpine region of the Beartooth Mountains study area into compositionally and ecologically distinct community type associations. Due to the infrequent, if not absent, role of stand-altering disturbance in the alpine region, habitat types and associations can be presumed

to be synonymous. As such, the existing vegetation of alpine plant communities was classified only according to the association framework. I created a dichotomous key to associations and compared my results with the results from previous alpine vegetation classifications ecologically pertinent to the Beartooth Mountains.

Study Area

Introduction

The Beartooth Mountains study area is located in the Beartooth Mountain Range north of the Wyoming border in Montana (Figure 1.1) and is demarcated by the boundary of the Custer National Forest (Figure 1.2). Politically, the study area is bordered to the south, southwest and west by the Gallatin National Forest, to the far southwest by Yellowstone National Park and to the southeast by the Shoshone National Forest. Physiographically, the southern study area boundary is defined by the topographic divide that separates the East and West Rosebud and Rock Creek drainages to the north from the Lamar River and Clark's Fork Yellowstone River drainages to the south. The western study area boundary is defined by the topographic divide that separates the Sweetwater River drainage to the east from the Boulder River, Wounded Man Creek, and Pebble Creek drainages to the west. The Absaroka Mountain range borders the Beartooth Mountain Range along the southwestern and western borders of the Beartooth Mountain study area and also further south into Wyoming. The northwest portion of the study area is defined as that area to the south and southeast of the topographic divide that runs between Sugarloaf Mountain, Hicks Mountain, and Bear Trap Draw. The northeast and

eastern boundary of the study area is difficult to define physiographically, but is well defined by running an arbitrary line from northwest to southeast along the foothills of the Beartooth Mountains at approximately 1829 m (ca. 6000 ft.) elevation (Wells, 2008).

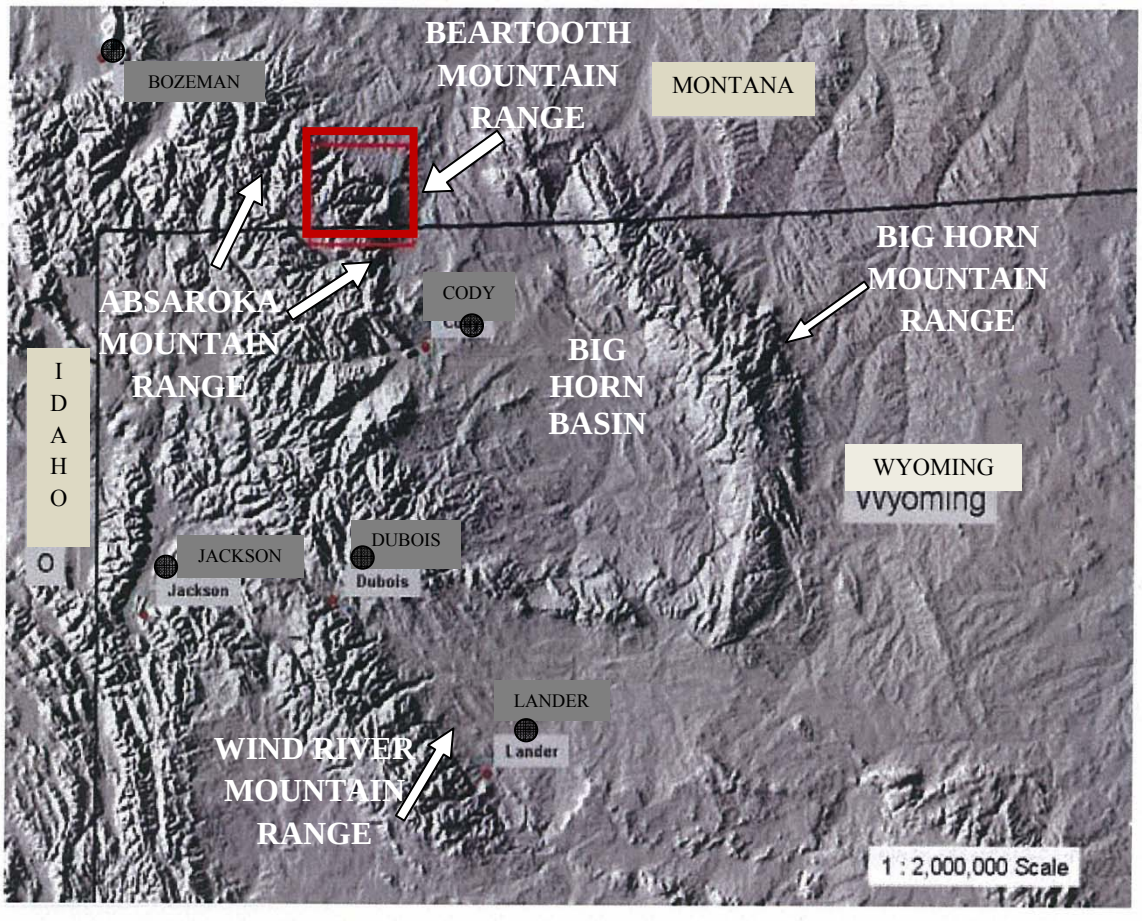


Figure 1.1. Location of Beartooth Mountain Range in relation to state boundaries and adjacent mountain ranges and basins. The Beartooth Mountains Study Area is outlined in red.

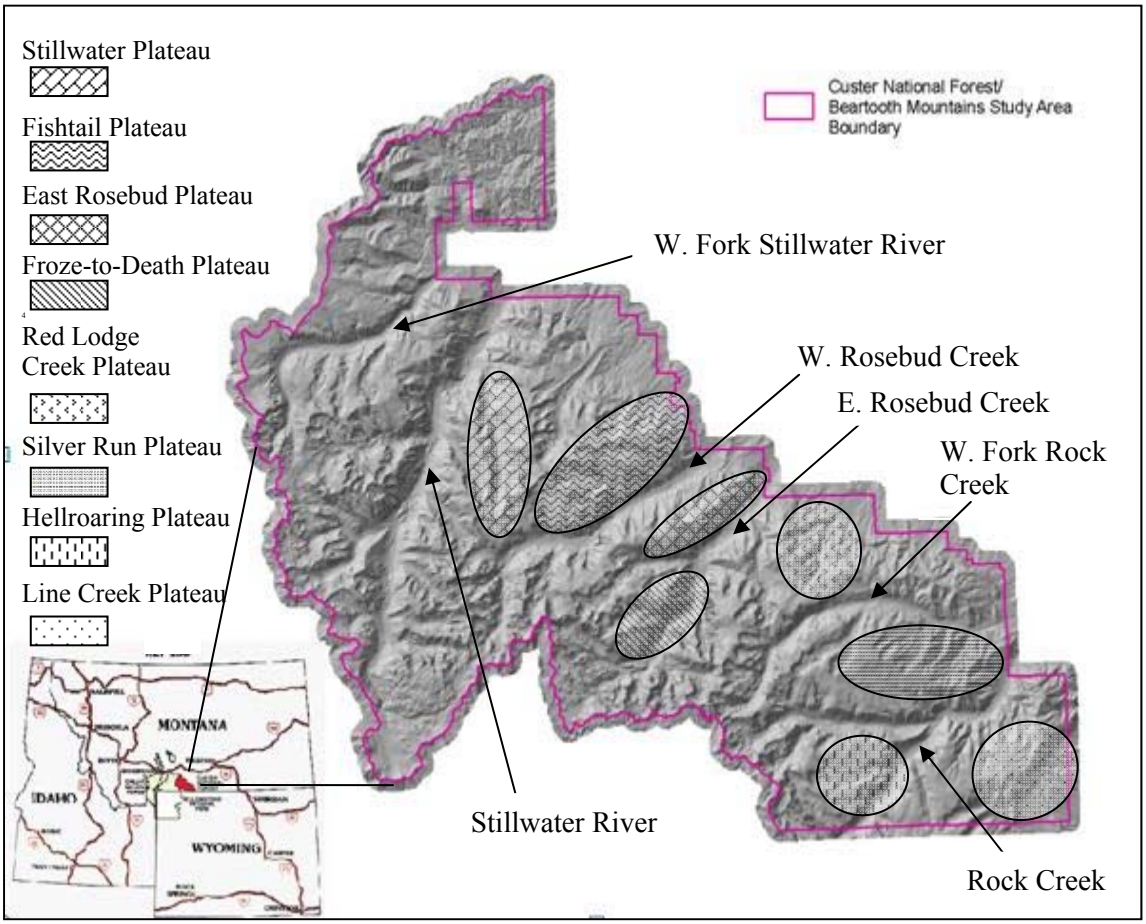


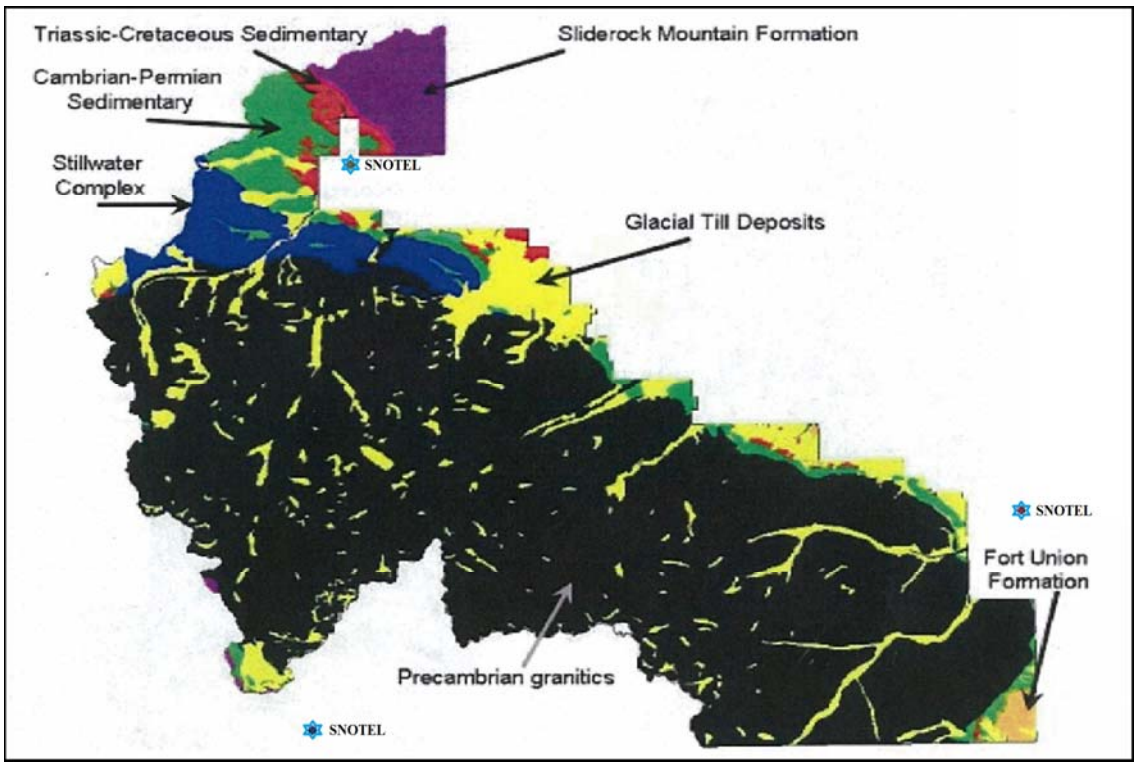
Figure 1.2. Hillshade relief map with major drainages and plateaus labeled.

The Beartooth Mountains study area is primarily comprised of the largest expanse of alpine plateau in the lower 48 states, which is dissected by six large, glacially-scoured waterways that drain from higher elevations in the south and southwest to lower elevations in the north and northeast. Drainages, listed from northwest to southeast, include: West Fork Stillwater River, Stillwater River, West and East Rosebud Creeks, West Fork Rock Creek and Rock Creek (Figure 1.2). Remnant plateaus along the same trajectory include: Stillwater Plateau, Fishtail Plateau, East Rosebud Plateau, Froze-to-Death Plateau, Red Lodge Creek Plateau, Silver Run Plateau, Hell Roaring Plateau and

Line Creek Plateau (Figure 1.2). Sidewalls of major drainages and slopes occurring along the northeastern and eastern margins of the massif are steep, generally forested and transitional between alpine turf communities of the plateau the woodland and shrubland communities of the sprawling, more temperate foothills below.

Geology and Soils

The Beartooth Mountain Range is a large uplifted fault block of Precambrian crystalline rock (Figure 1.3), primarily folded gneisses and migmatites, trending from northwest to southeast along the western margin of the Big Horn Basin (Johnson and Billings, 1962). Pegmatic, basaltic and acid –porphyry dikes are also frequent (Johnson and Billings, 1962; Alt and Hyndman, 1986). The entire massif is flanked to the north and northeast by a series of Cambrian to Cretaceous sedimentary rocks (Figure 1.3), including: limestone, dolomite, moderately hard green-gray shales and a basal deposit of sandstone, which were uplifted, tilted and displaced toward the north and northeast margins of the massif as it rose (Vaseth and Montangne, 1980). Metamorphic rocks of the Stillwater Complex later intruded along the northwest margin of the fault block (Figure 1.3). The Cretaceous volcanic rocks of the Slide Mountain Formation occupy the northwestern arm of the study area and the Lindley conglomerate member of the Paleocene Fort Union formation occurs in a small portion the southeastern portion of the study area (Figure 1.3).



Wells, 2008

Figure 1.3. Map of major geologic units and Snotel stations.

Sediments of the Paleozoic and younger were stripped from the highest elevations by prolonged erosion initiated with the original uplift of the range. The resultant exhumed peneplane of PreCambrian rocks is commonly referred to as the summit plateau and is evidenced by the flattish summits along the crest of the present range (Bevan, 1923). Following this original peneplanation, the range rose an additional 600 m (2,000 ft) and a second cycle of erosion, that which eventually formed the sub-summit plateau, was spurred. Later the range rose again, this time by several thousand feet, and the present day system of sharp valleys was carved by streams. In the Pleistocene Epoch, a piedmont ice cap developed in the valley of the Clarks Fork of the Yellowstone River on the southwestern flank of the Beartooth Mountain Range. This ice-cap, referred to as the

Beartooth ice-cap, covered the plateau occurring southwest of the summit divide. Outwash till from this piedmont ice cap has been found as far south as Jackson Hole, WY (Bevan, 1923). North and east of the summit divide ice accumulation was restricted to cirques and valley troughs. The recession of these smaller glaciers from the south and southwest to the north and northeast further dissected the alpine topography and once continuous erosional plain into smaller, distinct units of remnant plateau. Small glaciers still occur at the heads of several valleys on the northeast side of the main divide.

The now dissected plateau reaches approximately 3,050 (10,000 ft) altitude near the Boulder River in the northwestern portion of the range, rises to 3,350 m (11,000 ft) in the central portion and then descends several hundred feet in the southeastern portion of the Beartooth Mountain Range. The most extensive remnant of summit plateau, the Beartooth Plateau, occurs just north of the Wyoming border in the eastern portion of the Beartooth Mountain Range, ranges from 3,650 m (12,000 ft) to 3, 780 m (12,400 ft) and is bordered on almost all sides by steep slopes and/or sheer precipices dropping to the Big Horn Basin below.

Vaseth and Montagne (1980) used the Beartooth Mountains as a template to describe soils derived from glaciated hard coarse-grained metamorphic rocks. These soils are typically non-calcareous, coarse sandy or loamy and moderately high in coarse fragment content. Typic Cryoboralfs are found on forested sites at lower elevations and are one of the most developed soils of this landscape. Dystric Cryochrepts are typically found on forested, glacially scoured ridges and have low percent base saturation (<60%). Typic Cryochrepts are similar to Dystric Cryochrepts except that they have higher

percent base saturation and occur on valley sideslopes. Typic Cryumbrepts occur in frost-churned, glacially-scoured plateaus and ridges and are typically turf-dominated. Cryorthents may occur at high elevations in areas of steep glacial till. Permafrost is also reported for the Beartooth Mountains of Montana (Johnson and Billings, 1962; Alt and Hyndman, 1986). This typically arctic feature results in permanently saturated soils that have a tendency to slump and create solifluction terraces, frost boils, stone nets and stone stripes (Johnson and Billings, 1962). These features are caused by the action of frost heaving and are more common in wetter, high elevations of the range (Lesica, 1993).

Soils derived from limestone and dolomite with moderately hard green-gray shales were also described by Vaseth and Montage (1980). This geologic unit is generally exposed in ranges where the strata are steeply dipping, as is the case along the north and northeast margins of the uplifted gneiss fault block. In this complex, limestone is the most resistant to erosion, followed by dolomite and finally shales. The resulting landscape is one of intermittent limestone cliffs, dolomitic ridges and shale swales. Soils formed from limestone inherit high calcium carbonate content.

Climate

Billings (1978) considered the Beartooth Mountain Range to be the northeastern-most occurrence of Great Basin alpine areas in North America (Figure 1.1). Great Basin alpine areas are annually drier than alpine regions of the Rocky Mountains or the Cascades-Sierra Nevada, with the exception of the Ruby Mountains and nearby ranges (Billings, 1978). Winter snow and summer rain generally increase from southwest to northeast across the ranges of the Great Basin (Billings, 1978). The alpine regions of

both the Great Basin ranges and Rocky Mountain ranges experience considerably moister and cooler conditions in both the winter and summer than the desert valleys below. The Beartooth Mountain Range experiences a continental climate regime characterized by hot, dry summers and cold, wet winters (Johnson and Billings, 1962). Winds are predominantly from the west, resulting in both large and fine-scale precipitation gradients (Johnson and Billings, 1962; Lesica, 1993). On a large scale, the western portion of the study area receives more precipitation than the eastern portion due to orographic effects (Johnson and Bilings, 1962). On a smaller scale, windward west-facing slopes in the alpine are often blown free of snow while lee east-facing slopes receive additional snow accumulation (Johnson and Billings, 1962; Lesica, 1993). This dynamic of moisture distribution plays a critical role in structuring the mosaic of plant communities in the alpine zone. The timing and form in which precipitation is received also changes along a gradient trending from north to south. The northern portion of the study receives the majority of annual precipitation during the months of March, April, May and June in the forms of snow and rain, while the southern portion of the study area receives precipitation during the months of November, December, and January primarily in the form of snow (Wells, 2008).

Vegetation

The vegetation of the Beartooth Mountains study area is quite diverse, typically most similar to alpine floristic composition of the Rocky Mountains but also representing Great Basin species and large expanses of alpine tundra flora (Billings, 1978). Johnson and Billings (1962) found that almost half the alpine species (91 out of 194 species)

found on the Beartooth Plateau also occur in the arctic. Holmgren (1972) noted, and Billings (1978) agreed, that the variation in floristic composition from one peak to another in the alpine zone across the Great Basin is much greater than in other zones.

The low elevation foothills of the study area are dominated by *Pinus flexilis* woodlands, *Artemisia tridentata* var. *vaseyana*- dominated shrublands and *Festuca idahoensis-Elymus spicatus* grasslands. When fires occur in this landscape, both *Pinus flexilis* and *Artemisia tridentata* var. *vaseyana* components are temporarily destroyed. The resultant *Festuca idahoensis- Elymus spicatus* grasslands are then reinvaded by *Artemisia tridentata* var. *vaseyana* and eventually *Pinus flexilis*, creating a dynamic mosaic dependant on fire frequency (Lesica, 1993). Lesica (1993) proposed that the entire area might become *Pinus flexilis* woodland under atypically long fire-free intervals. *Pseudotsuga menziesii* forests occur on more sheltered slopes at low elevation. *Pinus flexilis* can occur at high elevations on limestone parent material.

Forests with an abundance of *Pinus contorta* are common between lower and upper timberline, with abundance generally decreasing as elevation and exposure increase. At mid and upper elevations, *Abies lasiocarpa* is often the indicated climax species. *Picea engelmannii* can become the indicated climax in extremely cold and/or wet forested sites. Near upper timberline, *Pinus albicaulis* becomes dominant and *Abies lasiocarpa* and *Picea engelmannii* become stunted and/or subdominant. These forest types are all prone to fire (Fischer and Clayton, 1983) and experienced frequent fires prior to the commencement of fire suppression (Lesica, 1993). The dominance of *Pinus contorta* and *Pseudotsuga menziesii* at all but the highest elevations is evidence that

stands are in seral stages of succession (Lesica, 1993). *Pinus ponderosa* occurred in only one sample and occurred with *Pinus flexilis* and *Abies lasiocarpa*.

Above timberline lies the alpine zone. Alpine vegetation occurs in a mosaic of turf, cushion, grassland, snowbed and wetland sites (Johnson and Billings, 1962; Cooper et al., 1997). Wind exposure, moisture and timing of snow release are considered to be the most important environmental factors determining the mosaic of vegetation above treeline (Billings 1988; Bliss 1963; Johnson and Billings 1962).

Multivariate Analysis

Multivariate analysis techniques such as ordination and classification can be used, often in concert, to assess the way in which species assemble into recognizable patterns along and across environmental gradients (Gauch, 1982; Podani, 1989; Dufrêne and Legendre, 1997; Legendre and Legendre, 1998; Jongmann et al., 1995, and others). Classification is the art and science of giving names to groups of individuals which are thought to be similar in some respect (Gordon, 1999; Kaufman and Rousseeuw, 1990). Ordinations are graphical aids used to portray patterns of variability in composition data and summarize the informational content of a dataset (Kent and Coker, 1992, Mueller-Dombois and Ellenburg, 1974; Greig-Smith, 1983). Ordinations may be used to clarify the distinctiveness of clusters derived from classification and to explore the arrangement of samples and clusters across environmental gradients (Everritt, 1993).

Both cluster analysis and nonmetric multidimensional scaling (NMDS) multivariate analyses require the creation of a dissimilarity matrix which characterizes

the distance/dissimilarity of sample composition in vegetation space (Faith et al., 1987; Everritt, 1993). Dissimilarity indices are not identical in their ecological interpretations (Gauch, 1982; Faith et al., 1987). This makes it extremely important to use a dissimilarity index that accurately represents, to the extent possible, the ecological signal present in the original data (Faith et al., 1987). The Bray-Curtis index (Bray and Curtis, 1957) is able to handle data sets with relatively high Beta diversity and generally produces ordinations with less distortion than other resemblance indices. It is therefore considered an effective index for ecological research (Gauch, 1973). However, Bray-Curtis will not perform optimally when Beta diversity is excessively high (over several half-changes) (Gauch, 1973). In these situations, it is advantageous to divide the original data into meaningful subsets as was done here with the vegetation data from the Beartooth Mountains study area (Gauch, 1973). The Bray-Curtis index (Bray and Curtis, 1957) is calculated as follows:

$$d_{BC}(i,j) = \frac{\sum_{k=1}^{n}|y_{i,k} - y_{j,k}|}{\sum_{k=1}^{n}(y_{i,k} + y_{j,k})}$$

$$S_{BC} = 1 - d_{BC}$$

Where i and j are samples, k are species, n=total number of species and y is the abundance of species k in sample i.

Clusters can either be determined using agglomerative hierarchical, hierarchical divisive or fixed-cluster algoriFthms. Hierarchical cluster methods can be represented by dendrograms illustrating sample partitioning (Everitt, 1993). Hierarchical agglomerative methods join samples in order of greatest similarity, beginning with the two most similar

samples. Agglomerative algorithms differ in their methods of considering plots for merger with clusters containing more than one plot. Divisive methods separate samples into progressively more nested groupings, until only individuals samples remain (Everitt, 1993). In fixed-cluster algorithms, the number of clusters to be considered is specified by the researcher. Fixed-cluster algorithms consider plots for cluster membership by attempting to maximize an internal geometric evaluator criterion (Aho et al., 2008, Everitt, 1979).

Unless the underlying structure of the data is obvious, different clustering algorithms often yield different cluster partitions for the same number of clusters (Podani, 1989; Noy-Meir and van der Maarel, 1987). Since the optimal number of clusters is generally not known prior to analysis, geometric evaluators are used to evaluate each classification's ability to maximize within-cluster homogeneity and between-cluster heterogeneity. The geometric evaluator PARTANA (optpart package for R; Roberts, 2011) measures the ratio of within-cluster similarity to between-cluster similarity. PARTANA is comparable to the W/B (within/between) algorithm of McClain & Rao (1975), but employs similarities rather than dissimilarities or distances to calculate ratios (Aho et al., 2008). Silhouette width (ASW, Rousseeuw, 1987) evaluates cluster suitability by calculating the average dissimilarity of a sample to other samples in the same cluster and comparing that with average dissimilarity of the same plot to the average dissimilarity of the nearest neighbor cluster. Silhouette width is measured as follows (Kauffman and Rousseeuw, 1990):

$$s_i := (b_i - a_i) / \max(a_i, b_i)$$

Where a_i is the average dissimilarity between a sample and all other samples in that cluster, and b_i is the smallest of the average dissimilarities between a sample and all samples in the most similar cluster (i.e. nearest neighbor cluster) (cluster package; Maechler et al., 2005). Higher average silhouette values across clusters, and across the entire cluster solution, are indicative of cluster distinctness (Kauffman and Rousseeuw, 1990).

Optimization algorithms can be used to optimize individual geometric criteria by reallocating samples to more suitable clusters (Everitt, 1979; Everitt, 1993). BESTOPT (optpart package for R; Roberts, 2008) is a reallocation algorithm designed to maximize within versus between cluster dissimilarity as calculated by the PARTANA index (Aho et al., 2008). BESTOPT can perform replicate runs using random initial cluster memberships to ensure optimal cluster geometry is achieved, as advocated by Everitt (1979). Similarly, OPTSIL (optpart package for R; Roberts, 2011) maximizes the average silhouette width of each cluster for a given cluster solution. Although there is no way of ensuring that the geometric criterion value obtained is a global optimum, well-structured data will usually produce the same or very similar final clusters (Everitt, 1979).

Stride analysis (optpart package for R; Roberts, 2011) allows the researcher to plot PARTANA ratios and average silhouette widths across a range of cluster number solutions for each algorithm. Stride plots are used to indicate the number of clusters that optimize geometric criteria.

Non-geometric evaluators measure how effectively a classification represents species distribution and provides insight to the ecological significance of clustering solutions (Dufrêne and Legendre, 1997; Aho et al., 2008). Cluster solutions in which species occur predominantly in one cluster and are generally absent from other clusters indicate a meaningful cluster structure from the perspective of those species (Aho et al., 2008). Indicator species can be calculated for each cluster in a cluster solution in order to characterize cluster composition. Dufrêne and Legendre (1997) define an indicator species as "the most characteristic species of each group, found mostly in a single group of the typology and present in the majority of the sites belonging to that group." Indicator value can be calculated as follows (Dufrêne and Legendre, 1997):

$$INDVAL_{ij} = A_{ij} \times B_{ij} \times 100$$

Where $INDVAL_{ij}$ is the indicator value of species *i* in sites of cluster *j,* A_{ij} is the relative mean abundance of species *i* in sites of cluster *j*, and B_{ij} is the relative frequency of occurrence of species *i* in sites of cluster *j*. The mean, as opposed to sum, abundance is used to derive A_{ij} to remove potential bias resulting from different numbers of samples per cluster and differences of abundance among sites in a cluster (Dufrêne and Legendre, 1997). The p-values for significant indicator species can also be calculated for each cluster and these probabilities summed for the entire data set using INDVAL (labdsv package for R; Roberts, 2011).

Aho et al. (2008) noted that classification comparisons using multiple internal evaluators are important because: 1) scientists working with non-synthetic data must rely on internal strategies for objective classification assessment and, 2) one can verify that a

classification has the desirable characteristics of cluster compactness along with high fidelity of species to clusters.

Ordination seeks to represent sample dissimilarity in a low dimensional space (Kent and Coker, 1992; Mueller-Dombois and Ellenberg, 1974). Ordinations are commonly used to identify and interpret ecological signals in the data by allowing factor revelation and arrangement of stands and clusters along environmental gradients (Kent and Coker, 1992; Kenkel and Orlóci, 1986; Mueller-Dombois and Ellenberg, 1974; Dale, 1975; Everitt, 1979). Nonmetric multidimensional scaling (NMDS) (Kruskal, 1964) is an ordination technique that maximizes rank-order agreement of inter-point distances in the mapping and compositional resemblance (similarities or dissimilarities) of samples (Kent and Coker, 1992; Minchin, 1987; Kenkel and Orlóci, 1986; Kruskal and Wish, 1978; Mueller-Dombois and Ellenber, 1974). 'Non-metric' denotes that inter-point distances are derived from the rank order of dissimilarities (Minchin, 1987), whereas, metric scaling techniques (PCA, PCO, correspondence analysis) derive inter-point distances from proportional dissimilarities (Minchin, 1987). NMDS ordinations based on the Bray-Curtis dissimilarity matrix are considered to be one of the more robust ordination techniques for ecological studies (Minchin, 1987; Faith et al., 1987).

NMDS ordinations are useful in indirect gradient analysis when the relative position of samples in the ordination match, or approach monotonicity with, the relative locations of those samples in environmental space (Kent and Coker, 1992; Minchin, 1987; Kenkel and Orloci, 1986). Kruskal (1964) developed an algorithm with an objective optimization criterion that can be used in a method of successive approximation

to minimize stress. Stress measures the degree to which the rank correlations of inter-point distances and dissimilarities deviate from montonicity (Kruskal, 1964; Kenkel and Orloci, 1986). Stress is calculated as the square root of a normalized "residual sum of squares" (Kruskal, 1964). Smaller stress values indicate better ordinations (Kruskal, 1964). The number of dimensions utilized in a NMDS ordination is specified by the researcher (Kruskal, 1964). Using additional dimensions will further reduce stress, but 2 and 3 dimension ordinations are generally recommended due to the increasing potential of distortion and difficulty of interpretation found with greater dimensions (Shepard, 1974; Kenkel and Orloci, 1986). When selecting an NMDS solution, multiple iterations with independent starting configurations can be used to ensure a global, as opposed to local, stress minimum is selected (Kruskal and Wish, 1978). The ability of NMDS to recover underlying data structure decreases as the proportion of zeros in the data increases (Kenkel and Orloci, 1986), which can provide incentive to split data into meaningful subsets.

Literature Cited

Aho, K., Roberts, D.W., and Weaver, T. 2008. Using Geometric and Non- Geometric Internal Evaluators to Compare Eight Vegetation Classification Methods. Journal of Vegetation Scientist 19(4): 549-562.

Alt, D.D. and Hyndman, D.W. 1986. Roadside Geology of Montana. Mountain Press Pub. Co. Missoula, MT. 427 p.

Bamberg, S.A. 1961. Ecology of the vegetation and soils associated with calcareous parent materials in three alpine regions of Montana. Ecological Monographs, 1968.

Bamberg, S.A. and Major, J. 1968. Ecology of the vegetation and soils associated with calcareous parent materials in three alpine regions of Montana. Ecological Monographs 38: 127-167.

Bevan, A. 1923. Summary of the Geology of the Beartooth Mountains, Montana. The Journal of Ecology. 31 (6): pp. 441-465.

Billings, W. 1978. Alpine phytogeography across the Great Basin. Great Basin Naturalist Memoirs, North America.

Billings, W.D. 1988. Alpine vegetation. In Barbour, M.C. and Billings, W.D., eds. *North American terrestrial vegetation*. Second edition. Cambridge, UK: Cambridge University Press: 391-420.

Bliss, L.C. 1963. Alpine plant communities of the Presidential Range, New Hampshire. Ecology 44:678-697.

Bray, J.R. and Curtis J.T. 1957. An ordination of the upland forest communities of Southern Wisconsin. Ecological Monographs. 27:325-349.

Choate, C.M. and Habeck, J.R. 1967. Alpine plant communities at Logan Pass, Glacier National Park, Montana. Proceedings of the Montana Academy of Sciences. 27: 36-54.

Cooper , S.V., Lesica, P., Page-Dumroese, D. 1997. Plant community classification for alpine vegetation on the Beaverhead National Forest, Montana. Gen. Tech. Rep. INT-GTR-362. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Dale, M.B. 1975. On objectives of methods of ordination. Vegetation 30:15-32.

Daubenmire, R. F. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecological Monographs 22: 301-330.

Daubenmire, R. 1966. Vegetation: identification of typal communities. Science 151(3708): 291-298.

Dufrêne, M., and Legendre, P.1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67: 345-366.

Everitt, B.S. 1979. Unresolved problems in cluster analysis. Biometrics. 35:169-181

Everitt, B.S. 1993. Cluster Analysis. Oxford University Press, London.

Faith, D.P., Minchin, P.R. and Belbin, L. Compositional dissimilarity as a robust measure .of ecological distance. Plant Ecology 69 (1-3): 57-68.

Fischer, W.C. and Clayton, B.D. 1983. Fire ecology of Montana forest habitat types east of the Continental Divide. USDA Intermountain Forest and Range Experiment Station General Technical Report INT-141, Ogden, UT.

Gauch, H.G. 1973. A quantitative evaluation of the Bray-Curtis ordination. Ecology 54: 829-836.

Gauch, H. G. 1982. *Multivariate analysis in community ecology*. Cambridge University Press, London, UK.

Gordon, A.D. 1999. Classification. 2nd Edition. Chapman & Hall/CRC, Boca Raton, FL.

Greig-Smith, P. 1983. *Quantitative Plant Ecology*. 3rd Edition. Oxford, Blackwell Scientific.

Hanson, P.L., Pfister, R.D., Boggs, K., Cook, B.J., Joy, J. and Hinckley, D.K. 1995. Classification and Management of Montana's Riparian and Wetland Sites. Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana, Missoula, MT. Miscellaneous Publication No. 54.

Holmgren, N.H. 1972. Plant geography of the Intermountain Region. pp. 77-161. *In*: A. Cronquist, A.H. Holmgren, N.H. Holmgren, and J.L. Reveal (eds.), Intermountain flora. Vol. 1. Hafner Publ. Co., New York.

Jennings, Michael D., Faber-Langendoen, D., Loucks, O.L., Peet, R.K., Roberts, D. 2009. Standards for associations and alliances of the U.S. National Vegetation Classification. Ecological Monographs, 79(2): 173-199.

Johnson, P.L. and Billings, W.D. 1962. The alpine vegetation of the Beartooth Plateau in relation to Cryopedogenic processes and patterns. Ecological Monographs 32: 105-135.

Jongmann, R.H.G., ter Braak, C.J.G. and van Tongeren, O.F.R.. 1995. Data analysis in community and landscape ecology. Cambridge University Press, Cambridge, UK.

Kaufman, L. and Rousseeuw, P.J. 1990. Finding groups in data: an introduction to cluster analysis. John Wiley & Sons, Inc., NY.

Kenkel, N.C. and Orloci, L. 1986. Applying metric and nonmetric multidimensional scaling to ecological studies: some new results. Ecology 67:919-928.

Kent, M., and Coker, P. 1992. Vegetation description and analysis: a practical approach. Belhaven Press, London, UK.

Kruskal, J.B. 1964. Nonmetric multidimensional scaling: a numerical method. Psychometrika. 29: 115-129.

Kruskal, J.B. and Wish, M. 1978. Multidimensional Scaling. Sage University Paper series on Quantitative Applications in the Social Sciences, number 07-011. Sage Publications, Newbury Park, CA.

Legendre, P. and Legendre, L. 1998. Numerical ecology. 2nd English edition. Elsevier Science BV, Amsterdam.xv+853 p.

Lesica, P. 1993. Vegetation and flora of the Line Creek Plateau Area, Carbon County, Montana. Unpublished report to U.S. Forest Service. Montana Natural Heritage Program. Helena. 30 pp.

Maechler, M., Rousseeuw, P., Struyf, A. and Hubert, M. 2005. cluster: Cluster Analysis Basics and Extensions. R package version 2.11.1.

McClain, J.O. and Rao, V.R. 1975. CLUSTISZ: A program to test for the quality of cluttering of a set of objects. Journal of Marketing Research. 12:456-460.

Minchin, P.R. 1987. An evaluation of the relative robustness of techniques for ecological ordination. Plant Ecology. 69 (1-3):89-107.

Mueller-Dombois, D. and Ellenburg, H. 1974. Aims and methods of vegetation ecology. John Wiley, New York, New York, USA.

Mueggler, W.F. and W.L. Steward. 1980. Grassland and Shrubland Habitat Types of Western Montana. USDA Forest Service General Technical Report INT-66, Ogden, Utah.

Noy-Meir, I. and van der Maarel, E. 1987. Relations between community theory and community analysis in vegetation science: some historical perspectives. Vegetation. 69: 5-15.

Pfister, R.D., Kovalchik, B.L., Arno, S.F. and Presby, R.C.. 1977. Forest Habitat Types of Montana. USDA Forest Service General Technical Report INT-34, Ogden, Utah.

Pfister, R.D., and Arno, S.F. 1980. Classifying forest habitat types based on potential climax vegetation. Forest Science 26: 52-70

Podani, J. 1989. Comparison of Ordinations and Classifications of Vegetation Data. Vegetation 83:111-128.

Roberts, D.W. 2007. labdsv: Ordination and Multivariate Analysis for Ecology. R package version 2.11.1.

Roberts, D.W. 2011. optpart: Optimal partitioning of similarity relations. R package version 2.11.1.

Rousseeauw, P.J. 1987. Silhoueetes: A graphical aid to the interpretation and validation of cluster analysis. Journal of Computational and Applied Mathematics. 20:53-65.

Shepard, R.N. 1974. Representation of structure in similarity data: problems and prospects. Psychometricka 39: 373-421.

Spribille, T., Stroh, H.G. & Triepke, F.J. 2001. Are habitat types compatible with floristically-derived associations? Journal of Vegetation Science. 12: 791-796.

Steele, R., Pfister, R.D., Ryker, R.A. & Kittams, J.A. 1981. Forest Habitat Types of Central Idaho. USDA Forest Service Intermountain Forest and Range Experimental Station General Technical Report. INT-114, Ogden, UT.

Steele, R., Cooper, S.V., Ondov, D.M., Roberts, D.W. & Pfister, R.D. 1983. Forest Habitat Types of Eastern Idaho-and Western Wyoming. USDA Forest Service Intermountain Research Station General Technical Report INT-144, Ogden, UT.

Vaseth, R. and C. Montagne. 1980. *Geologic parent materials of Montana Soils*. Montana Agricultural Experiment Station Bulletin 721, Bozeman, MT.

Wells, A. 1998. Custer National Forest National Cooperative Soil Survey and Terrestrial Ecological Unit Inventory: Pre-Mapping, Preliminary Data Analysis, and Study Design Development. Unpublished document.

CHAPTER 2

CLASSIFICATION OF SHRUBLAND ASSOCIATIONS OF THE BEARTOOTH MOUNTAINS STUDY AREA AND COMPARISON TO EXISTING GRASSLAND AND SHRUBLAND HABITAT TYPE CLASSIFICATIONS

Contribution of Authors and Co-Authors

Manuscripts in Chapters 2, 3, 4

Chapter 2:

Author: Kristin L. Williams

Contributions: Supervised and conducted field data collection activities, managed and analyzed data and wrote the manuscript.

Co-author: Dave W. Roberts

Contributions: Obtained funding, supervised project, provided statistical consultation and edited text at all stages of manuscript development.
Journal to be submitted to: *Western North American Naturalist*

Manuscript Information Page

- Kristin L. Williams and Dave W. Roberts
- *Western North American Naturalist*
- Status of manuscript (check one)
  _x_Prepared for submission to peer-reviewed journal
  ___Officially submitted to peer-reviewed journal
  ___Accepted by a peer-reviewed journal
  ___Published in a peer-reviewed journal

Abstract

The purpose of this chapter was to classify and describe low-elevation grassland and shrubland vegetation associations of the Beartooth Mountains study area. A total of five associations, primarily dominated by *Artemisia tridetanata* var. *vaseyana, Festuca idahoensis and Elymus spicatus,* were classified and described. Newly classified associations were then compared to grassland and shrubland habitat types previously classified and described for western Montana (Mueggler and Stewart, 1980) and to community types previously described for low elevations of Line Creek Plateau in the Beartooth Mountains (Lesica, 1993). Additionally, I created a dichotomous key to grassland and shrubland associations for use in the field and thoroughly described the vegetation, environment and characteristic habitat types of each association.

Introduction

Vegetation ecologists commonly seek to characterize plant species distributions across the landscape. The recurrence of similar plant assemblages wherever the net influence of climate, soil, animal, disturbance and time factors have provided roughly equivalent environments was recognized early in vegetation studies (Daubenmire, 1966). Due to changing climate regimes and increasing demands placed on natural resources, the documentation and classification of vegetation, as tools for organizing and interpreting ecological information and context, are integral to biological conservation, resource management and scientific research (Pfister and Arno, 1980; Jennings et al., 2009).

Classification is the art and science of grouping objects considered to be similar in some respect (Kaufman and Rousseeuw, 1990; Gordon, 1999). In vegetation studies, researchers generally classify samples based on some aspect of floristic composition. Habitat types and community type associations are the most commonly used basic hierarchical units of floristic composition analysis (Spribille et al., 2001) in the western United States. Habitat types seek to classify land based on the vegetation composition sites are capable of supporting in late succession (Daubenmire, 1952; Pfister and Arno, 1980). The late succession association of plants characteristic of a habitat is referred to as the potential natural vegetation (PNV). Community types seek to classify vegetation associations based on existing species composition, regardless of a sites potential to support a particular late seral or climax association. As such, a single community type may include samples classified to multiple habitat types, depending on the nature, frequency and distribution of stand-altering disturbances in the landscape. The recent resurgence of interest in vegetation classification and adoption of U.S. National Vegetation Classification (NVC) standards for associations and alliances (Jennings et al., 2009) has renewed interest in the theory behind and relative ecological usefulness of both frameworks.

The habitat type classification system is based on plant succession theory, a basic tenet of which states that the most shade tolerant or “climax” species present in a stand will eventually dominate in the absence of disturbance. Samples are first divided into ‘series’ comprised of stands with the same indicated climax tree species (Daubenmire, 1952; Pfister and Arno, 1980; Steele et al., 1983). Even if the indicated climax tree

species occurs in low abundance, its presence alone is indicative of the successional trajectory of the stand. Series represent major environmental differences reflected by the distributions of climax tree species. Habitat types are subdivisions of series that represent environmental differences represented by total vegetation composition (Pfister and Arno, 1980). While a given habitat type should reflect all land areas capable of supporting the same potential natural vegetation association in late succession, it is not necessarily a reflection of similarities in existing vegetation between samples (Pfister and Arno, 1980).

Classification by community type association uses the floristic characteristics of species assemblage and abundance to group samples with similar composition and physiognomy into clusters that are consistently recognizable using diagnostic features (Jennings et al., 2009). NVC defines plant associations as "a vegetation classification unit defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions, and physiognomy (Jennings et al., 2009)." Alliances are conceptually similar to 'series' and are defined by NVC (Jennings et al., 2009) as

> "a vegetation classification unit containing one or more associations, and defined by a characteristic range of species composition, habitat conditions, physiognomy, and diagnostic species, typically at least one of which is found in the uppermost or dominant stratum of the vegetation."

The habitat type concept emphasizes the diagnostic potential of climax-dominant species and uses the presumed climax development to assign samples to series (and land to habitat types) regardless of existing vegetation. The association/alliance concept emphasizes the composition of existing vegetation (Jennings et al., 2009; Pfister and Arno, 1980). NVC associations and habitat types are likely similar in stands where the

potential climax species have attained dominance. In stands where the climax species remains subordinate to a seral species, ecologically interesting discrepancies between NVC associations and habitat types are bound to emerge (Jennings et al., 2009).

The primary objective of this chapter was to classify the vegetation of low-elevation shrublands of the Beartooth Mountains study area into compositionally and ecologically distinct associations using cluster analysis. Samples were also classified to habitat type using Mueggler and Stewart's (1980) Grassland and Shrubland Habitat Types of Western Montana. In order to use and compare both classifications in the field, I created an amended dichotomous key to habitat types, including only those types observed in the Beartooth Mountains study area, as well as, a dichotomous key to the grassland and shrubland associations identified in this chapter. I provide descriptions of the characteristic vegetation composition and environmental variability found in each association and compared my association descriptions with the descriptions of grassland/shrubland habitat types described by Mueggler and Stewart (1980) and the community types identified for lower elevations of the Line Creek Plateau in the Beartooth Mountains (Lesica, 1993).

Study Area

Shrubland vegetation occurs at low elevations on the north and northeastern margins of the Beartooth Mountains study area. This portion of the study area is characterized by moderate to steeply dipping sedimentary strata of varying erosivity (limestone = most resistant, dolomite = moderately resistant, shales = least resistant) that form a landscape of intermittent limestone cliffs, dolomitic ridges and shale swales

(Chapter One, Figure 1.3). Soils formed in limestone soils inherit particularly high calcium carbonate content (Vaseth and Montage, 1980).

The Beartooth Mountains experience a continental climate regime that is characterized by hot, dry summers and cold, wet winters (Johnson and Billings, 1962; Wells, 2008). Winds are predominantly from the west, resulting in a dominant, orographically-driven west to east moisture gradient, where the western portion receives more precipitation than the eastern portion (Johnson and Billing, 1962; Lesica, 1993). The northern and northeastern margins of the study area, the areas of the study area where shrublands occur, receive the majority of annual precipitation during the months of March, April, May, and June in the forms of snow and rain (Wells, 2008).

The vegetation of the Beartooth Mountains study area is quite diverse. It includes a mixture of Central Rocky Mountain flora and species more typical of the Great Plains. The low elevation foothills, occurring along the northeastern and eastern margin of the study area, are dominated by an intergrading mosaic of *Pinus flexilis* woodlands, *Artemisia tridentata* var. *vaseyana* shrublands and *Festuca idahoensis-Elymus spicatus* grasslands. When fires occur in this landscape, both *Pinus flexilis* and *Artemisia tridentata* var. *vaseyana* components are temporarily destroyed (Lesica, 1993). The resultant *Festuca-Agropyron* grasslands are then reinvaded by *Artemisia tridentata* var. *vaseyana* and eventually *Pinus flexilis*, creating a dynamic mosaic dependant on both fire frequency (Lesica, 1993) and environmental variables. Lesica (1993) proposed that the entire area might become *Pinus flexilis* woodland under atypically long fire-free intervals.

Methods

Study Design

The data were collected for the purposes of a United States Forest Service (USFS) and Natural Resource Conservation Service (NRCS) collaborative inventory/mapping project called a Terrestrial Ecological Unit Inventory (TEUI). TEUI's are an attempt to produce large scale, consistent and integrated ecosystem inventory, classification and mapping management tools for all public lands nationwide. The TEUI approach to land classification and mapping is based on a National Hierarchy of Ecological Units, a hierarchical land unit classification system within which soil and vegetation map units are nested (Cleland, 1997). The National Hierarchy classification system begins by grouping land areas into broad classes based on large-scale climatic and physiographic factors. More detailed, nested categories are then classified based on systematically smaller-scale climatic, geological, geomorphic, vegetative, and topographic factors (Winters et al., 2005). The lowest nested category is called an 'ecological unit'. Each ecological unit represents a unique combination of geologic, climatic, geomorphologic and topographic characteristics.

Field seasons were restricted to the weeks between mid June and late August due to persistent spring snowpack and early snowfall in the late summer/early fall. The study area was pre-stratified into ecological units using TEUI protocol, vegetation data were collected according to TEUI protocol and soil samples were collected according to NRCS standards and protocol.

Plot locations were selected to reflect all dominant and characteristic vegetation types of each ecological unit prior to sampling. Dominant associations within each unit were estimated using aerial photos, satellite imagery and topographic maps. Plots were distributed within each ecological unit to represent the diversity of slopes, elevations, aspects and dominant plant associations in each ecological unit. Special attention was also paid to the distribution of sample plots across larger environmental gradients, such as the prevalent west to east moisture gradient, within each ecological unit.

This extensive stratification process reflects the ongoing efforts of ecologists to standardize protocol and satisfy the principles and procedures of classical sampling theory. While many of the fundamental principles (e.g. randomization) underlie all sampling decisions, it is also important to recognize that the objectives of an ecological study may differ considerably from objectives studied using classical theory (Kenkel et al., 1989). Specifically, classical theory is concerned with the estimation of population parameters of discrete, recognizable units while vegetation ecology is concerned with the recognition of patterns in community assemblage and distribution where the sampling unit (i.e. a plot) is arbitrarily defined (Kenkel et al., 1989).

Plot Selection

Once arriving at the target plot coordinates, field researchers confirmed that the plot position represented uniformity of environment, was large enough to include normal species composition and had homogenous vegetation throughout. Obvious ecotones were not sampled. Within the stratified sampling protocol, characteristics were identified for each target sample plot, including: desired slope percent, aspect and vegetation

association. If the site was not representative of the dominant association, slope percent and/or aspect value specified, sample plots were moved to the closest plot center reflecting target parameters. If a plot reflecting the target parameters could not be found, the sample plot was either not collected or an alternate plot was chosen to reflect the dominant vegetation observed at or close to the target sample plot position.

Vegetation Data

Vegetation data of grassland/shrubland samples were collected using circular fixed-radius macroplots with a radius of 11.35 m, resulting in a 405 m^2 ($1/10^{th}$ of an acre) area plot. All species occurring within the perimeter of the community macroplot were recorded and their abundance estimated. Since plants show huge plasticity between individuals and it is often impossible to define an individual, abundance of each species can be effectively and efficiently characterized using aboveground canopy cover estimates (Wilson, 1991). Canopy cover is defined as the percentage of ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage of plants where small openings within the canopy are included in the cover estimate (Winthers et al., 2005). Cover was estimated according to the following classes:

- 0.1 = "trace" = species with less than 1 percent cover (1% = 1.1m radius).
- The nearest 1 percent for species with cover between 1 and 10 percent.
- The nearest 5 percent for species with cover between 10 and 30 percent cover.
- The nearest 10 percent for species with cover exceeding 30 percent cover.

Using the same cover classes, cover was recorded separately for each lifeform category. Lifeform categories include: graminoid (GR), forb (FB), shrub (SH), and tree

(TR and TO). Tree layer subcategories were defined by height (TR: <=2.0 m, TO: >2.0 m). The possibility of overlap between tree sublayers requires that overstory and regeneration cover for each tree species be estimated or measured directly, not calculated by summing the sublayer cover values.

Plant Taxonomy Considerations

Plants were primarily identified using Plants of Wyoming (Dorn, 1977). Where the collected species could not be identified using Plants of Wyoming (Dorn, 1977), Plants of Montana (Dorn, 1984) was used. For particularly difficult identifications, several floras were consulted, including: Flora of the Pacific Northwest (Hitchcock and Cronquist, 1963), The Intermountain Flora (various authors, various years) and Grasses of Montana (Lavin and Seibert, 2011). NRCS species codes were recorded according to Dorn's taxonomy where possible. Where no NRCS code was available for Dorn's taxonomy, the NRCS synonym code was used. When referencing species belonging to associations, community types or habitat types described by other authors, the taxonomy used in the original publication was retained.

Soil Data Collection

Soil pedon data were collected according to NRCS standards using codes and procedures outlined in the NRCS publication Field Book for Describing and Sampling Soils (Shoeneberger et al., 2002). Geologic information was collected according to the standards in Forest Service Manual 2881. Surficial geology, origin and kind were identified using the terms and definitions listed in the FRIS Terra data dictionary.

Geomorphic information was collected to the standards in A Geomorphic Classification System (Haskins et al. 1998).

A soil pit was dug near the center of each macroplot in an area that appeared to be representative of the soils supporting the target vegetation. All soil pits were dug to a depth of 1m where possible. If lithic contact was made prior to reaching 1m, the type of lithic layer contacted and depth to contact was recorded.

Soil horizons were identified and the depth, texture, color (either wet or dry but must be indicated) and pH were recorded for each. Texture modifiers, such as: percent gravel, percent cobble, percent stone, and percent boulder were also recorded for each horizon. Additionally, root pore percentage, clay film percentage, calcium carbonate accumulation and redoximorphic features were estimated within each horizon. Where redoximorphic and/or calcium carbonate features were observed, the beginning depth and end depth of that feature were recorded along with color classes specific to the feature. Finally, soil was classified using the NRCS soil classification system.

A soil sample was collected from each soil horizon and the organic horizon. Samples were chosen to be representative of the horizon they were taken from and included samples of gravel or cobble, calcium carbonate accumulations or redoximorphic features that were encountered. Soil horizon samples were organized into soil profile boxes in order of horizon. A total of ten representative samples was sent to the lab for analysis. These samples were used as quality control to confirm the textures, colors, pHs and soil classifications determined by soil technicians in the field.

Environmental Site Data

There are no NRCS Snotel stations within the boundaries of the study area. In order to evaluate the distribution of plant community associations with respect to climatic gradients occurring within the study area, climate variables were modeled using climate data from nearby Snotel sites, including: Beartooth Lake, WY, Burnt Mtn., MT and Cole Creek, MT. The Snotel station at Beartooth Lake provides a good approximation of the climate at high elevations and the stations at Burnt Mtn. and Cole Creek provide a good approximation of the climate at lower elevations (Chapter One, Figure 1.2). Modeled variables include: relative effective annual precipitation (REAP), total precipitation (TOTPRCP), growing degree days (GRDEGDAY), average daily temperature (DAVTEMP) and annual solar exposure (SOLAR).

Relative effective annual precipitation (REAP) uses precipitation, slope, aspect and soil properties to indicate the amount of moisture available at a given location. As such, two sites receiving the exact same annual precipitation may have very different effective precipitation due to other site factors. Total annual precipitation (TOTPRCP) is calculated by summing the inches of precipitation received, either as snow or rain, in a year. Growing degree days (GRDEGDAY) are calculated by subtracting a base temperature (usually 10°C) from the average of the daily maximum and minimum temperatures of a location. The minimum temperature is bounded by the base temperature and the maximum temperature is generally bounded by 30°C, as most plants grow in this range. The annual GRDEGDAY is calculated by summing daily GRDEGDAY. Growing degree days (GRDEGDAY) is an indicator of both the length

and warmth of the growing season of a location. Annual average daily temperature (DAVTEMP) is calculated by summing the monthly averages and dividing by 12. Monthly average daily temperatures are calculated by summing the daily maximum temperatures with the daily minimum temperatures and dividing by two. Annual average daily (DAVTEMP) is a rough estimate of the overall annual temperature of a location. The solar loading (SOLAR) variable estimates incoming solar electromagnetic radiation given latitude, slope and aspect information for the summer solstice in watt hours/m².

Measured and modeled environmental variables are identified as continuous and categorical variables and listed below.

Continuous:

- Northing Coordinate (UTM's)
- Easting Coordinate (UTM's)
- Elevation (m)
- Slope Percent (%)
- Aspect (°)
- Relative Effective Annual Precipitation (REAP)
- Total Precipitation (TOTPRCP)
- Growing Daily Degree (GRDEGDAY)
- Annual Solar Exposure (SOLAR)
- Average Daily Temperature (DAVTEMP)

Categorical:

- Topographic Position
- Primary Landform
- Vertical Slope Shape
- Horizontal Slope Shape
- Slope Complexity
- Geologic Parent Material
- Parent Material Kind
- Soil Depth
- Soil Particle Size
- Soil Temperature Regime
- Soil Moisture Regime
- Soil Moisture Sub-Class

- NRCS Soil Classification
- Disturbance History
- Potential Natural Vegetation Classification

Statistical Analysis

Two hundred vegetation community plots with associated soil profile pits were collected during the 2008 and 2009 summer field seasons. These two hundred sample plots were then divided into the following three groups based on physiognomy and elevation: low-elevation grassland/shrubland samples (<10% tree cover, < 2,500 m elevation), mid-elevation woodland and forested samples (>10% tree cover, all elevations), high-elevation alpine samples (<10% tree cover, >2,500 m). The following is the analysis of the 24 samples identified as 'grassland/shrubland'. The vegetation data were analyzed using several multivariate techniques, including: cluster analysis, nonmetric multidimensional scaling ordinations (NMDS) and summaries of environmental variables and plant species cover and constancy by identified cluster. Multivariate statistics were performed in R (R Development Core Team, 2011).

The Bray-Curtix index (Bray and Curtis, 1957) was used to create a dissimilarity matrix of vegetation composition data for the shrubland/grassland samples. Vegetation data were not transformed or standardized. Distance analysis (DISANA, labdsv package for R; Roberts, 2010) was used to identify structure in the dissimilarity matrix and to identify plots that were highly dissimilar from all other plots (i.e. outliers).

Cluster analysis was performed using partitioning around medoids (PAM), a fixed cluster algorithm (cluster library for R; Kaufman and Rousseeuw, 1990) and OPTSIL (optpart package for R; Roberts, 2010), a silhouette width-maximizing reallocation

algorithm. STRIDE (optpart package for R; Roberts, 2010) plots were used to identify cluster number solutions likely to result in the maximization of geometric criteria (PARTANA ratio and silhouette width).

Dufrêne and Legendre's (1997) indicator value algorithm was used to assess the ecological significance of various clustering solutions. The algorithm determines indicator species by identifying those species exhibiting the highest constancy and fidelity in each cluster. Indicator values were calculated for each species as follows:

$$INDVAL_{ij} = A_{ij} \times B_{ij}$$

Where $INDVAL_{ij}$ is the indicator value of species *i* in sites of *j*, A_{ij} is the relative mean abundance of species *i* in sites of cluster *j*, and B_{ij} is the frequency of occurrence of species *i* in sites of cluster *j*.

Final classifications were chosen based on the characteristics of: 1) high PARTANA ratios, 2) high silhouette width averages, both within cluster and across clusters, and 3) high ecological significance as determined by species indicator values. Communities were named using the two most abundant significant indicator species in each cluster. If only one species was identified as an indicator species, only that species name was used in the cluster name.

The unconstrained ordination technique NMDS (Non-Metric Multidimensional Scaling; Kruskal and Wish, 1978) was applied to a Bray-Curtis dissimilarity matrix of vegetation community abundance data (labdsv package; Roberts, 2010, MASS package; Venables and Ripley, 2002). Environmental variables were evaluated for explanatory value using the D^2 values (defined below) of GAMs (generalized additive models, mgcv

package for R; Wood, 2004) fit to the ordination in combination with the p- and chi-squared values obtained from a Kruskal-Wallis rank sum test (Kruskal and Wallis, 1952). The D^2 value of deviance was defined as:

D^2 = (null deviance – residual deviance) / null deviance.

Results

Vegetation Composition

A total of 218 species was recorded from 24 sample plots. Trees were stunted and occurred only in the tree regeneration (TR) category. Species richness per plot (based on the 218 species/strata) ranges from 13 species to 60 species, with a mean of 38 (Figure 2.1). Of the 218 total species, 79 are found only in one plot (Figure 2.2). *Festuca idahoensis* and *Elymus spicatus* have the highest frequency, both occurring in 23 of 24 plots (Figure 2.3, Table 2.1). The shrub species *Artemisia tridentata* var. *wyomingensis*, *Symphoricarpos albus* and *Artemisia tridentata* var. *vaseyana* have the highest abundance (Figure 2.3, Table 2.1). The 10 species with the greatest frequency and abundance are listed in Table 2.1.

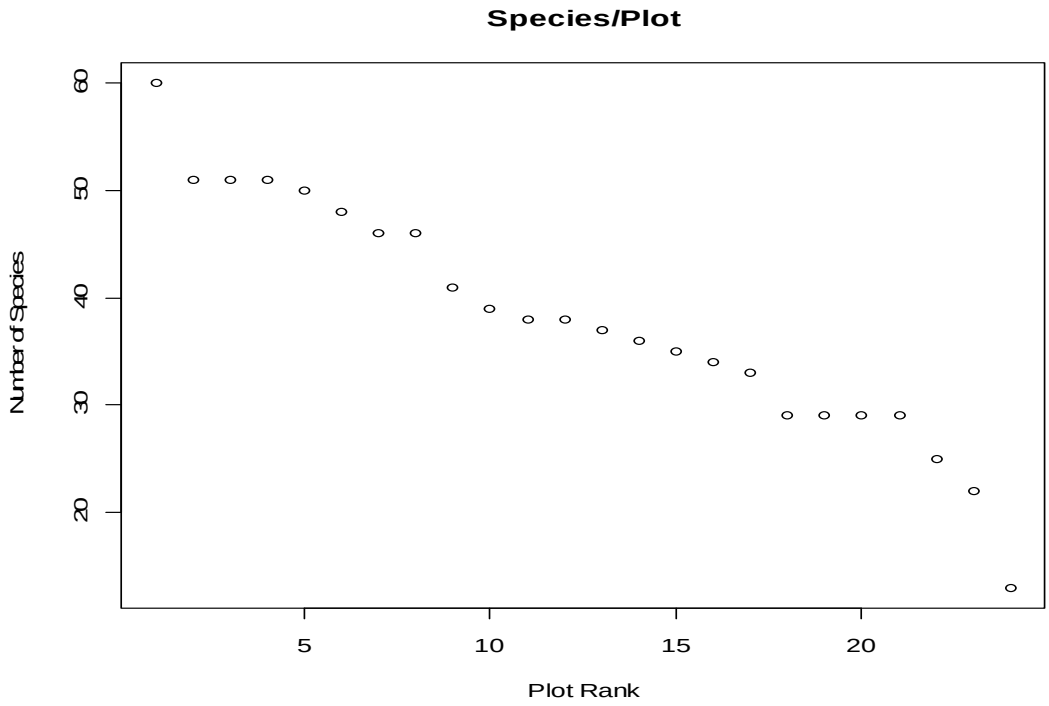


Figure 2.1. Number of species per plot across all plots.

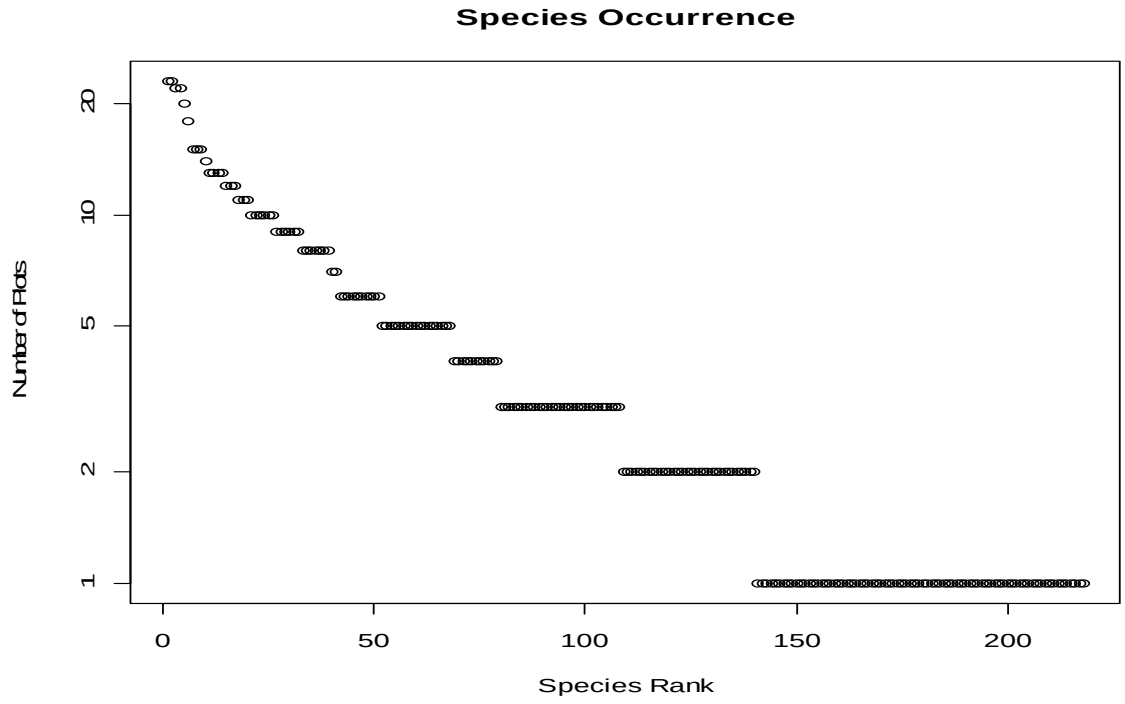


Figure 2.2. Species occurrence on each plot, across all species.

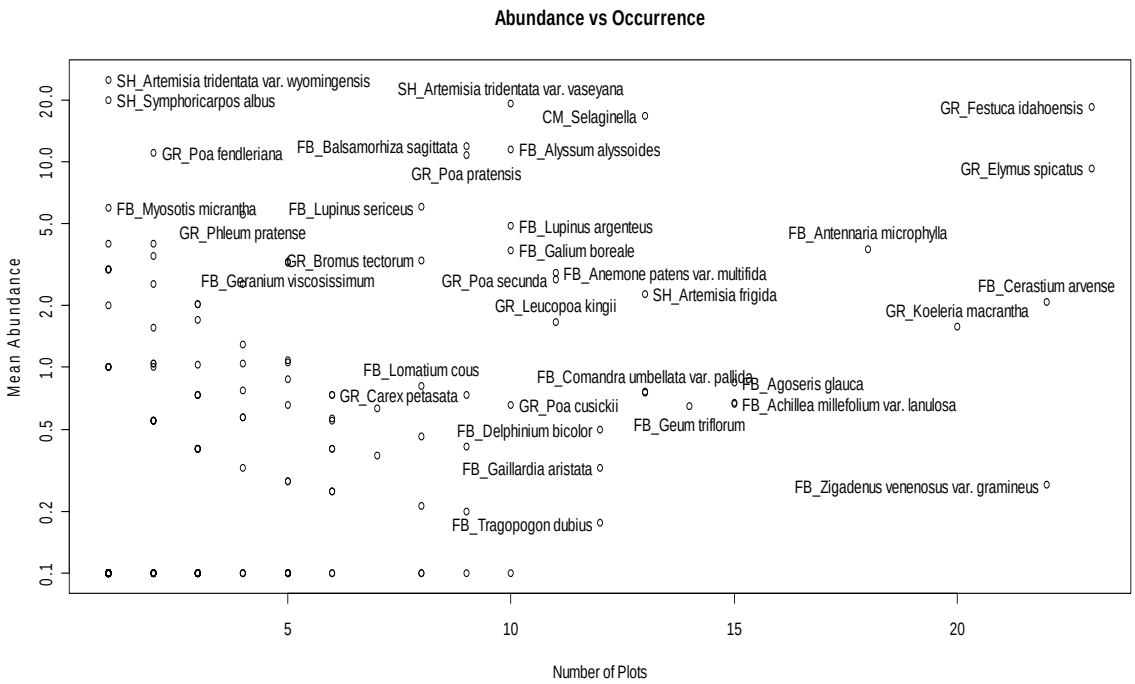


Figure 2.3. Mean species abundance versus number of plots in which the species occurred.

Table 2.1. 10 most abundant and 10 most frequent species. Mean % cover is rounded to the nearest whole number.

10 Most Abundant Species	**Mean % Cover**	**10 Most Frequent Species**	**Number of Occurrences**
SH_*Artemisia tridentata var. wyomingensis*	25	GR_*Festuca idahoensis*	23
SH_*Symphoricarpos albus*	20	GR_*Elymus spicatus*	23
SH_*Artemisia tridentata var. vaseyana*	19	FB_*Zigadenus venenosus var. gramineus*	22
GR_*Festuca idahoensis*	19	FB_*Cerastium arvense*	22
CM_*Selaginella spp. (densa or watsonii)*	17	GR_*Koeleria macrantha*	20
FB_*Balsamorhiza sagittata*	12	FB_*Antennaria microphylla*	18
FB_*Alyssum alyssoides*	12	FB_*Phlox hoodii*	15
GR_*Poa fendleriana*	11	FB_*Agoseris glauca*	15
GR_*Poa pratensis*	11	FB_*Achillea millefolium var. lanulosa*	15
GR_*Elymus spicatus*	9	FB_*Geum triflorum*	14

Correlation of Environmental Variables

Correlation between continuous environmental variables was tested using Pearson's correlation coefficient. Values closer to 1 and -1 indicate positive and negative correlations respectively, while values closer to 0 indicate a lack of correlation. Correlations between modeled variables and elevation are generally strongly negative or positive (Table 2.2). Average daily temperature (DAVTEMP) and growing degree days (GRDEGDAY) have the strongest positive correlation (0.938) and both are negatively correlated with elevation (-0.759 and -0.758 respectively). Total precipitation (TOTPRCP) and Easting coordinate are strongly negatively correlated (-0.737). Average daily temperature (DAVTEMP) and Northing coordinate are moderately positively correlated. Relative effective annual precipitation (REAP) and total precipitation (TOTPRCP) are only moderately positively correlated (0.765). The correlation between Northing coordinate and elevation is somewhat disjointed. Low elevation samples occur at higher Northing coordinate values and higher elevation samples occur at lower Northing coordinate values, but there are relatively few plots in between. Northing coordinate and elevation are moderately negatively correlated (-0.673). All other correlations are relatively weak. The plotted correlations of elevation, slope percent, relative effective annual precipitation (REAP), total precipitation (TOTPRCP), growing degree days, (GRDEGDAY), annual solar exposure (SOLAR) and average daily temperature (DAVTEMP) are shown in Figure 2.4.

Table 2.2. Correlation coefficient (Pearson's) for joint distribution of continuous environmental variables. Absolute values > 0.5 are in bold.

	Easting	Northing	Elevation	Slope Percent	REAP	TOTPRCP	GRDEGDAY	SOLAR	DAVTEMP
Easting	1	**-0.766**	0.318	-0.04	-0.419	**-0.737**	-0.055	0.358	-0.232
Northing		1	**-0.673**	-0.05	0.011	0.23	**0.556**	-0.214	**0.634**
Elevation			1	0.379	0.36	0.247	**-0.759**	0.452	**-0.759**
Slope Percent				1	0.135	0.26	-0.193	-0.417	-0.166
REAP					1	**0.765**	-0.0533	-0.429	-0.429
TOTPRCP						1	**-0.577**	-0.364	-0.396
GRDEGDAY							1	0.02	**0.938**
SOLAR								1	-0.044
DAVTEMP									1

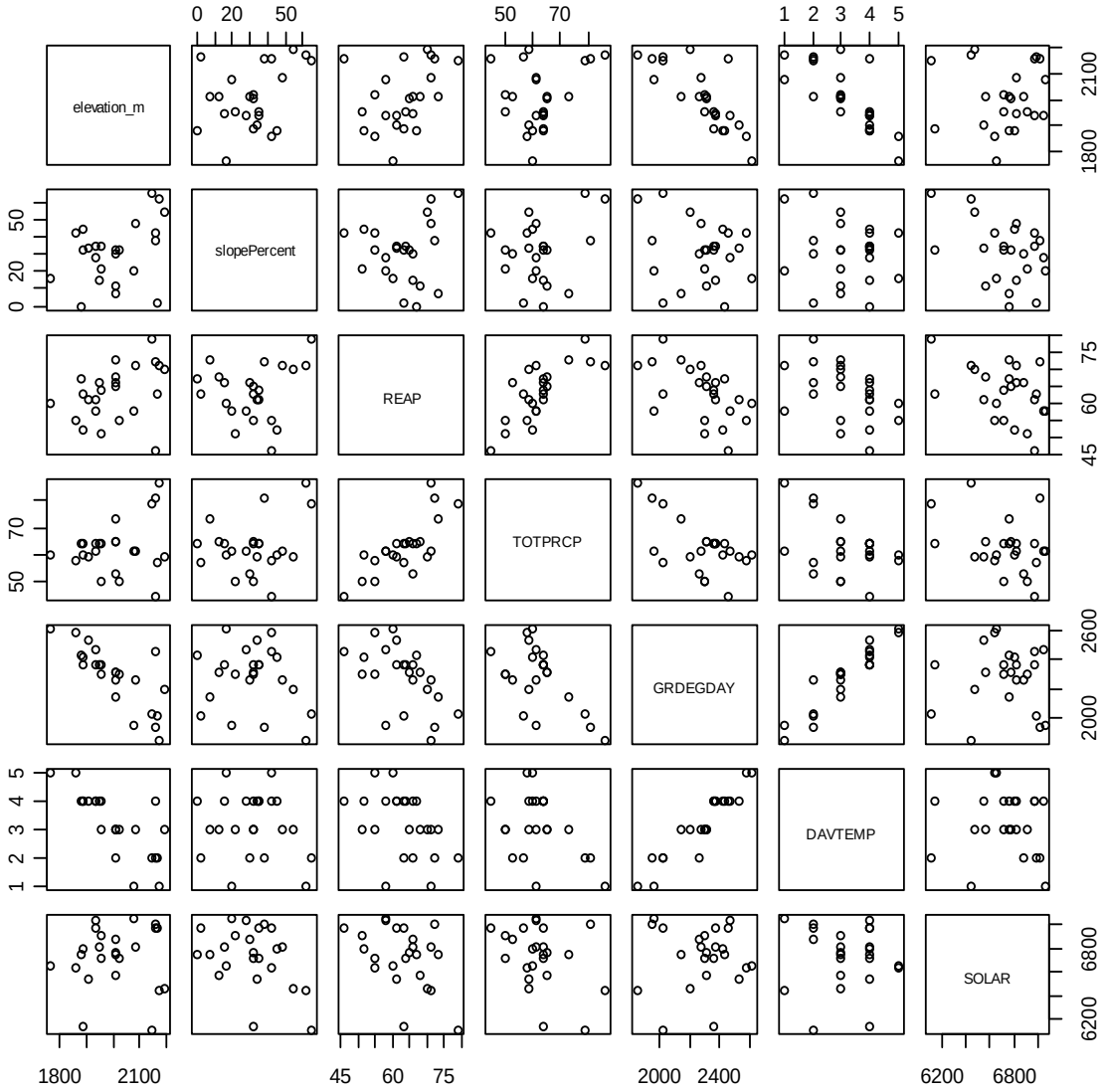


Figure 2.4. Correlations of measured site environmental variables: elevation (m), slope percent (%); and modeled site environmental variables: relative effective annual precipitation (REAP), total precipitation (TOTPRCP), growing degree day (GRDEGDAY), annual solar exposure (SOLAR), daily average temperature (DAVTEMP).

Cluster Analysis of Communities

According to the STRIDE analysis plot (Figure 2.5), models with 5 clusters produced optimal PARTANA ratios and average silhouette widths (Figure 2.6). I

analyzed 2,3,4,5, 6 and 7 cluster models using BESTOPT and OPTSIL run on original BESTOPT models and 4,5,6,7 and 8 cluster models using PAM and OPTSIL run on original PAM models. All cluster numbers of BESTOPT models and models derived from running OPTSIL on original BESTOPT models collapsed into two clusters models. However, membership to clusters was not consistent. The 3 cluster PAM model also returned a two cluster solution following OPTSIL analysis. PAM models specifying 6, 7 and 8 cluster solutions all returned five clusters solutions following OPSTIL analysis.

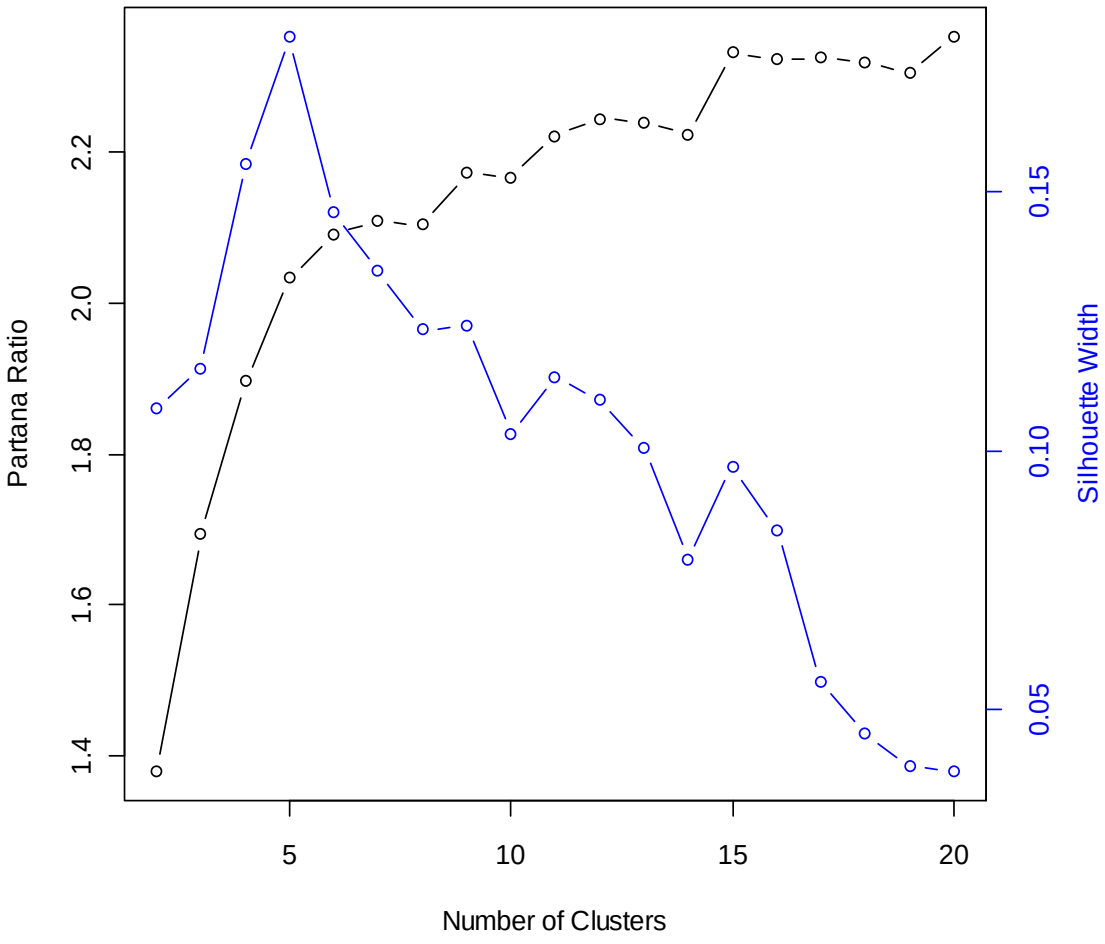


Figure 2.5. STRIDE analysis plot showing the PARTANA ratio and average Silhouette width for models containing 2 to 20 clusters.

The 4 and 5 cluster OPTSIL models run on original 4 and 5- cluster PAM models returned higher Silhouette widths and PARTANA ratios than their original PAM counterparts. The 5-cluster OPTSIL PAM model also had a higher average Silhouette width (0.21, Figure 2.6) than the 4-cluster OPTSIL PAM model (0.18). The 5- cluster solution had 1 reversal (Figure 2.6) while the 4-cluster solution had no reversals. Reversals represent negative silhouette values and occur when a plot is more similar to another cluster than the cluster to which it belongs. The PARTANA ratio of the 5-cluster model is slightly higher than that of the 4-cluster models (2.1 and 1.97, respectively), though PARTANA plots (Figure 2.7 and Figure 2.8) still indicate some similarities between plots in separate clusters, as well as similarities between entire clusters. The average diameter of the 5-cluster model (0.7299) is lower than the average diameter of the 4-cluster model (0.8232). Lower average diameters indicate that samples are less dispersed from the center of the cluster to which they belong. Both the 4 and 5-cluster OPTSIL PAM models had 23 significant indicator species derived from INDVAL analysis, but the distribution of indicator species between clusters was more proportionate under the 5-cluster model. I selected the 5-cluster OPTSIL PAM model to define communities.

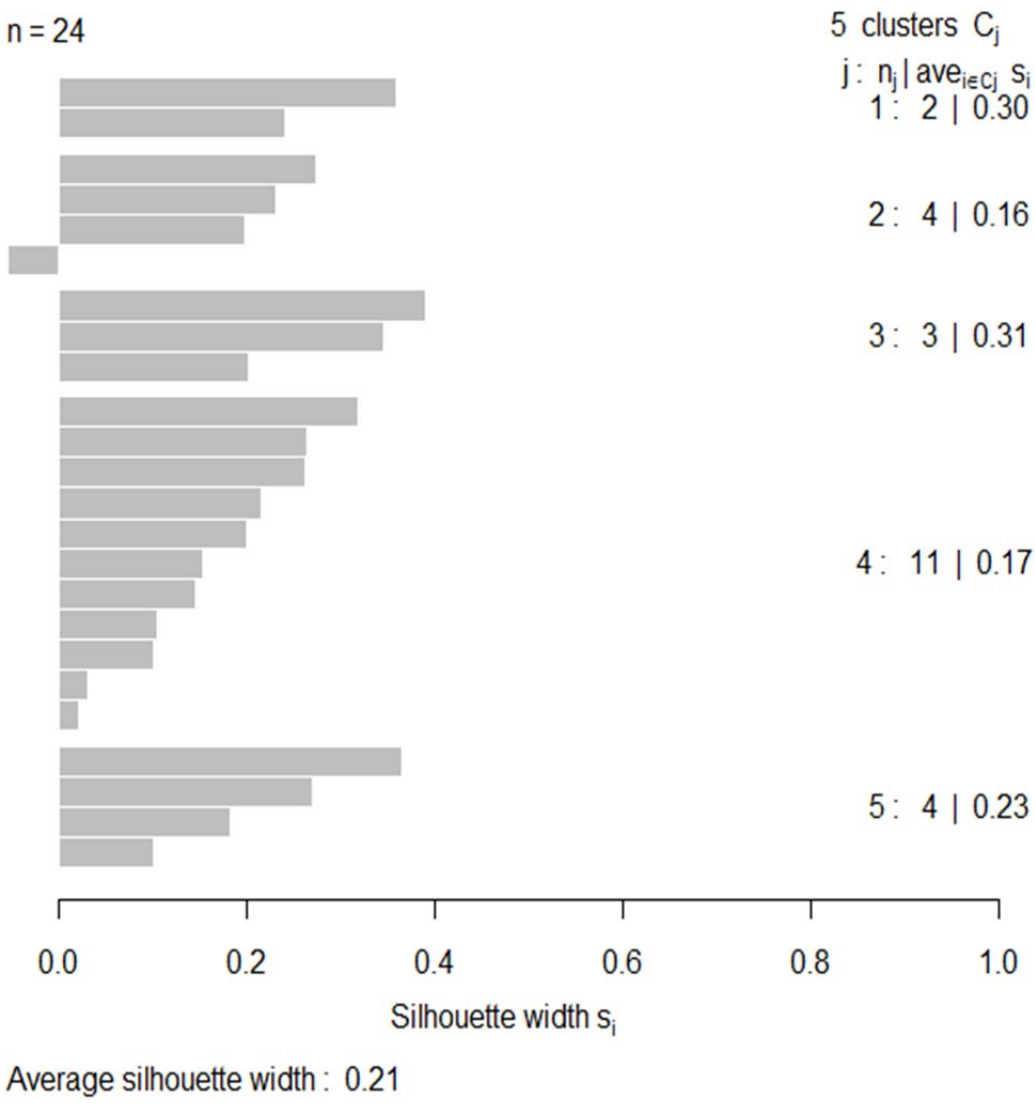


Figure 2.6. Silhouette width plot, indicating within cluster plot similarity for each of 5 clusters. Reversal bars represent negative silhouette width values which indicate poor similarity of a plot to the cluster in which it belongs. Cluster size and average Silhouette value for each cluster are displayed on right of plot.

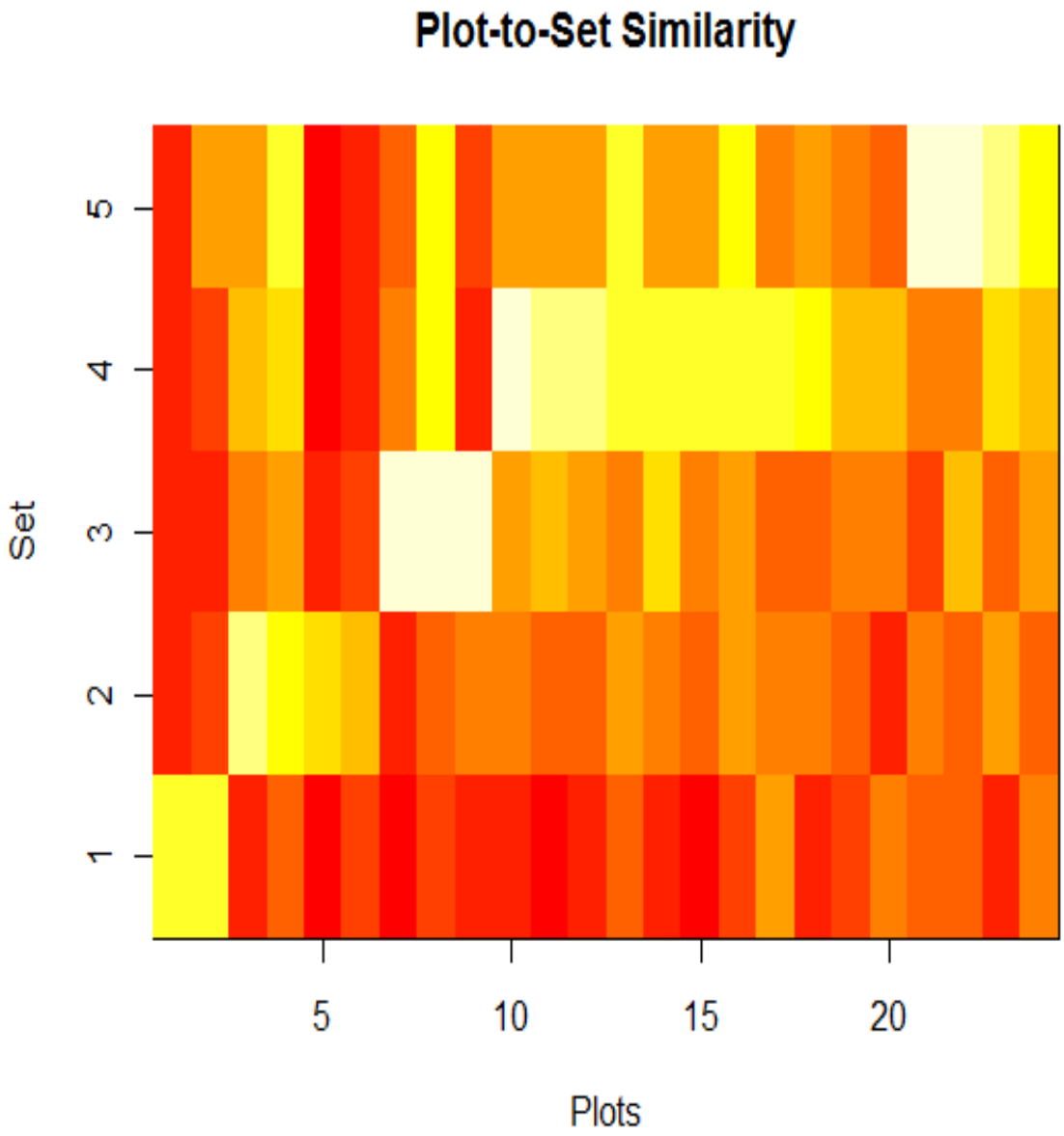


Figure 2.7. Partana plot, displaying the similarity of each plot within a cluster to each other plot in other clusters. White indicates high similarity, yellow moderate to high similarity and red a lack of similarity.

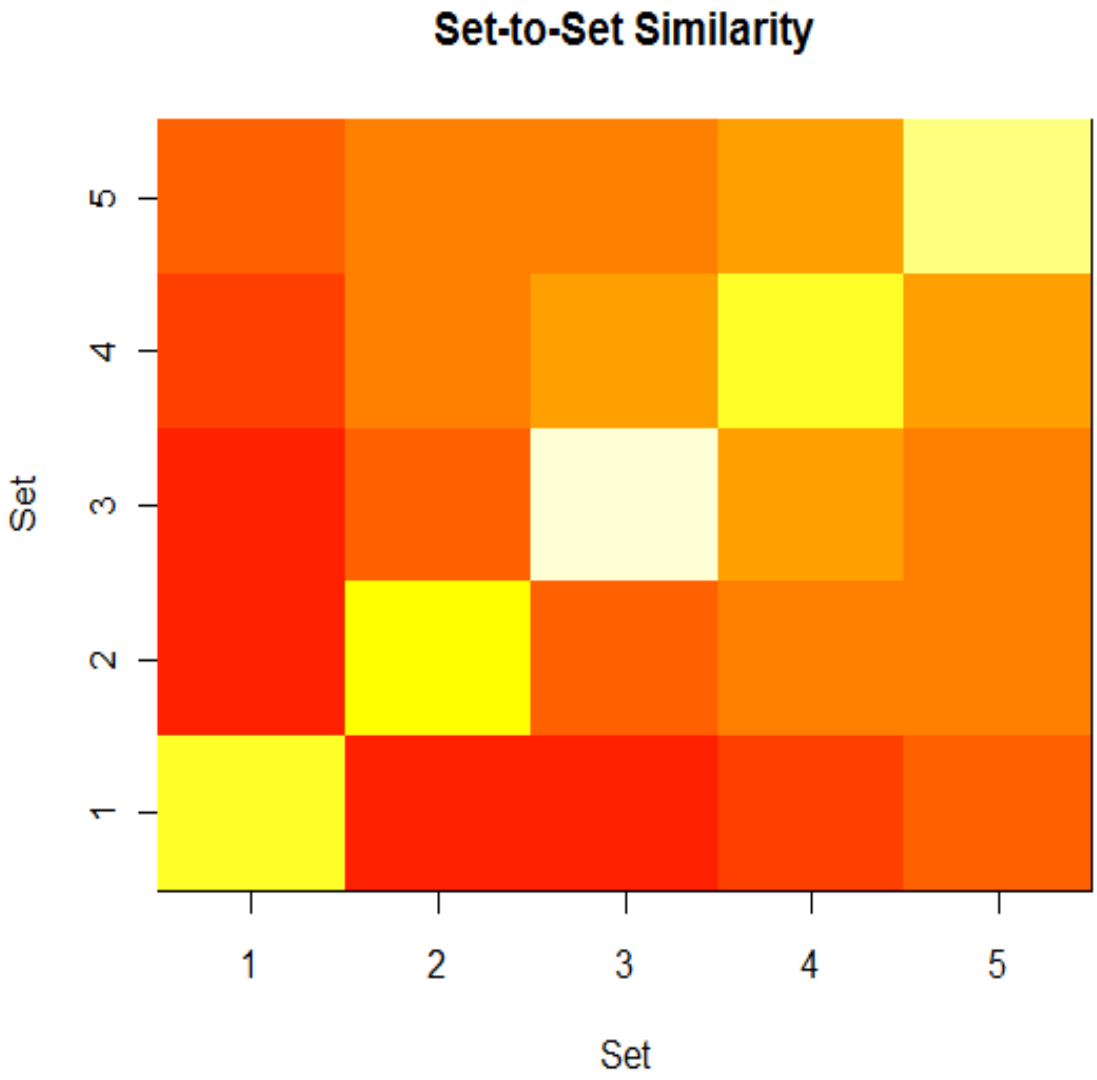


Figure 2.8. Partana plot, displaying the similarity of each cluster to every other cluster. White indicates high similarity, yellow moderate to high similarity and red a lack of similarity.

Based on the cluster analysis, 5 grassland/shrubland associations were identified. Cluster 1, the *Alyssum alyssoides-Balsamorhiza sagittata* association, was named for the two most abundant indicator species (Table 2.3). Cluster 2 was called the *Festuca idahoensis/Geranium viscosissimum* association. *Festuca idahoensis* was present in all samples of cluster 2 (Appendix C) and was used in the dichotomous classification key to

association, but was not identified as an indicator species (Table 2.3). I used *Festuca idahoensis* in the association name because it was consistently present in samples of the association. Cluster 3, the *Artemisia tridentata* var. *vaseyana*/*Festuca idahoensis* association, is the only shrub-dominated association. *Artemisia tridentata* var. *vaseyana* was identified as an indicator species for this cluster (Table 2.3). *Festuca idahoensis* was not identified as an indicator species but was included in the association name due to its constancy and abundance in samples of this cluster (Appendix C). Cluster 4 is the *Festuca idahoensis-Elymus spicatus* association. *Festuca idahoensis* was the only indicator species (Table 2.3) identified for cluster 4. *Elymus spicatus* occurred with enough consistency and abundance to include it in the association name (Appendix C). Cluster 5 is the *Elymus spicatus/Artemisia frigida* association. Both *Elymus spicatus* and *Artemisia frigida* are indicator species (Table 2.3) for cluster 5.

Table 2.3. Indicator Species for each cluster with INDVAL and p-val for each indicator species.

	cluster	indicator	value probability
FB_Alyssum alyssoides	1	0.9320	0.006
GR_Bromus tectorum	1	0.9097	0.025
FB_Balsamorhiza sagittata	1	0.7793	0.005
FB_Lupinus argenteus	1	0.7523	0.011
FB_Lomatium triternatum	1	0.7500	0.009
FB_Vicia Americana	1	0.6286	0.031
FB_Geranium viscosissimum	2	0.9977	0.001
GR_Carex petasata	2	0.9055	0.005
FB_Campanula rotundifolia	2	0.8642	0.009
GR_Poa pratensis	2	0.7680	0.006
FB_Arnica sororia	2	0.7500	0.016
FB_Silene latifolia	2	0.7500	0.012
GR_Achnatherum occidentale	2	0.7500	0.007
FB_Galium boreale	2	0.7447	0.040

Table 2.3. Indicator Species for each cluster with INDVAL and p-val for each indicator species (continued)

	cluster	indicator	value probability
GR_Bromus carinatus var. linearis	2	0.7217	0.022
FB_Potentilla gracilis var. flabelliformis	2	0.7174	0.022
FB_Taraxacum officinale	2	0.5714	0.036
SH_Artemisia tridentata var. vaseyana	3	0.9100	0.001
TR_Pinus flexilis	3	0.6667	0.018
FB_Erigeron caespitosus	3	0.6182	0.038
GR_Festuca idahoensis	4	0.4561	0.003
SH_Artemisia frigida	5	0.7901	0.006
GR_Hesperostipa comata	5	0.7397	0.025
GR_Elymus spicatus	5	0.4485	0.030

NMDS Ordination and Evaluation of Environmental Variables

While the 2-dimensional NMDS ordination of sample plots has a relatively high r-value (0.827), a third dimension increases the r-value to r= 0.897, reflecting an improvement in the representation of underlying dissimilarities (Figure 2.9). Although the NMDS ordination and the cluster analysis are both based on a Bray-Curtis dissimilarity index derived from the same sample presence and abundance information, the results are independent and can be used in conjunction to determine the efficacy and ecological interpretation of clustering solutions. Reasonable separation of clusters on the NMDS ordination suggests that communities are distinct and classifiable groupings (Figure 2.10 and Figure 11).

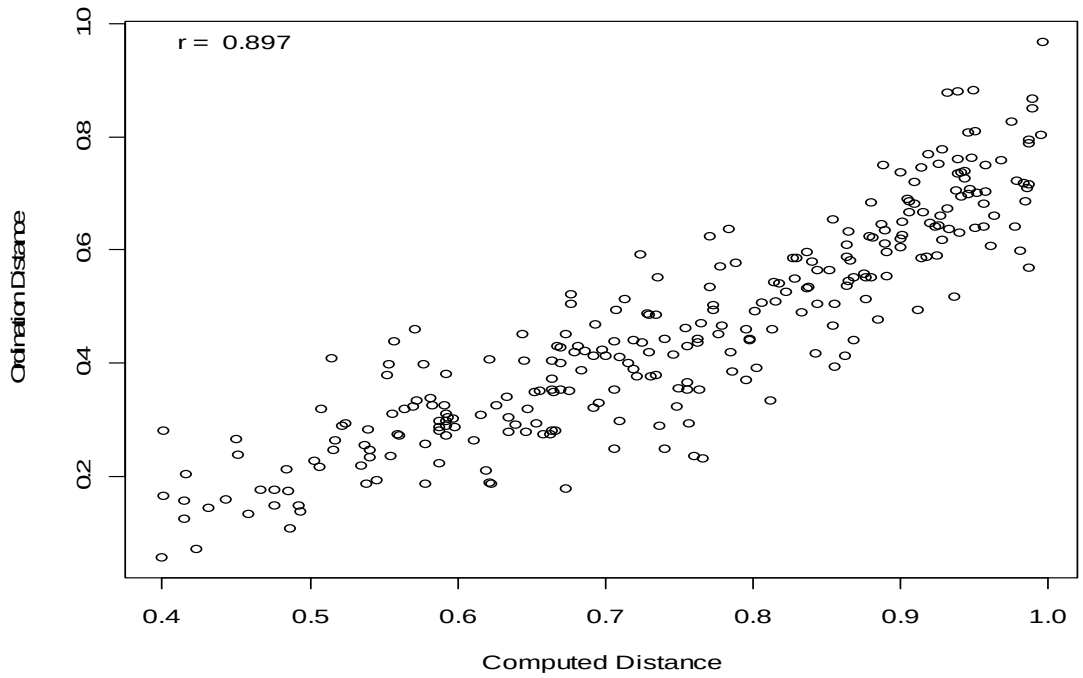


Figure 2.9. Correlation of three-dimensional NMDS ordination and computed distances of sample plots, giving an indication of the NMDS ordination quality (r=0.897).

In addition to illustrating the separation of identified clusters on the 3-dimensional NMDS ordination, each sample was also classified to habitat type using Mueggler and Stewart's (1980) Grassland and Shrubland Habitat Types of Western Montana. The habitat type classification providing the best description is discussed in the individual association descriptions. It is interesting to note, however, that the associations derived from this analysis were significantly associated with the pre-determined Mueggler and Stewart (1980) habitat type classification (p==0.008; Table 2.9).

Continuous environmental variables were tested to determine how much deviance the ordination explained using D^2 values obtained by fitting each variable to the ordination coordinates using a GAM on the smooth of all three axes (Table 2.4). D^2

values were low for all variables (Table 2.4), indicating that the distribution of dissimilarities is not strongly influenced by any of the measured and modeled continuous environmental variables. REAP had the highest D^2 value (0.3699). Gaussian GAM surfaces were fit to the first two dimensions of the 3-dimensional NMDS ordination (Figure 2.13 through 2.21). GAM contours indicate that relationships are often non-linear.

While the continuous environmental variables may not be explained well by the NMDS ordination, these variables can further be tested for significance in determining cluster membership using p-values and chi-squared values obtained from a Kruskal-Wallis Rank Sum test (Kruskal and Wallis, 1952). These p-values (Table 2.5) help to quantify the variation of clusters across continuous environmental variables observed in Figure 2.22. Northing Coordinate was the only continuous variable that was significant to cluster membership. All other variables were never significant (Table 2.5).

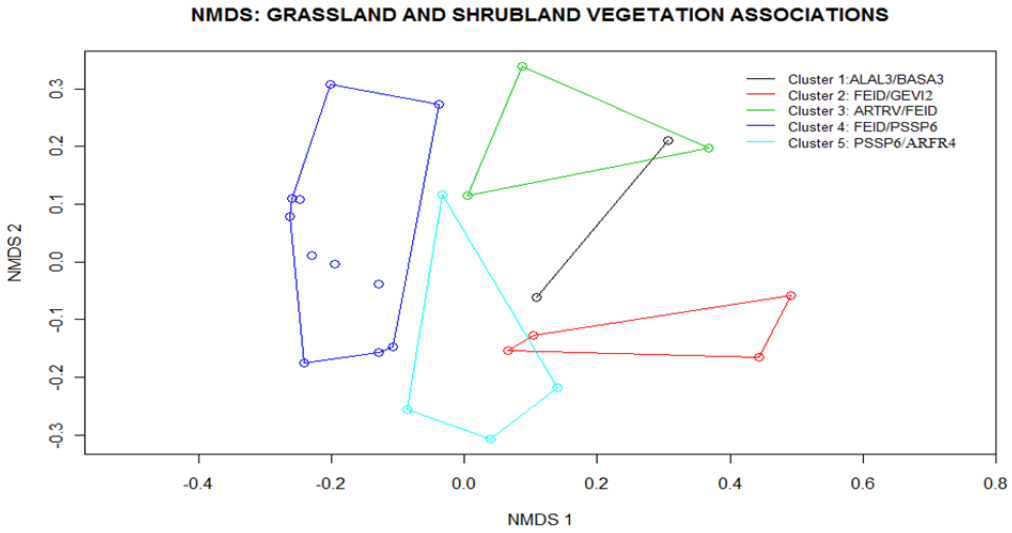


Figure 2.10. First two axes of three-dimensional NMDS ordination where associations are outlined with and identified by unique symbols.

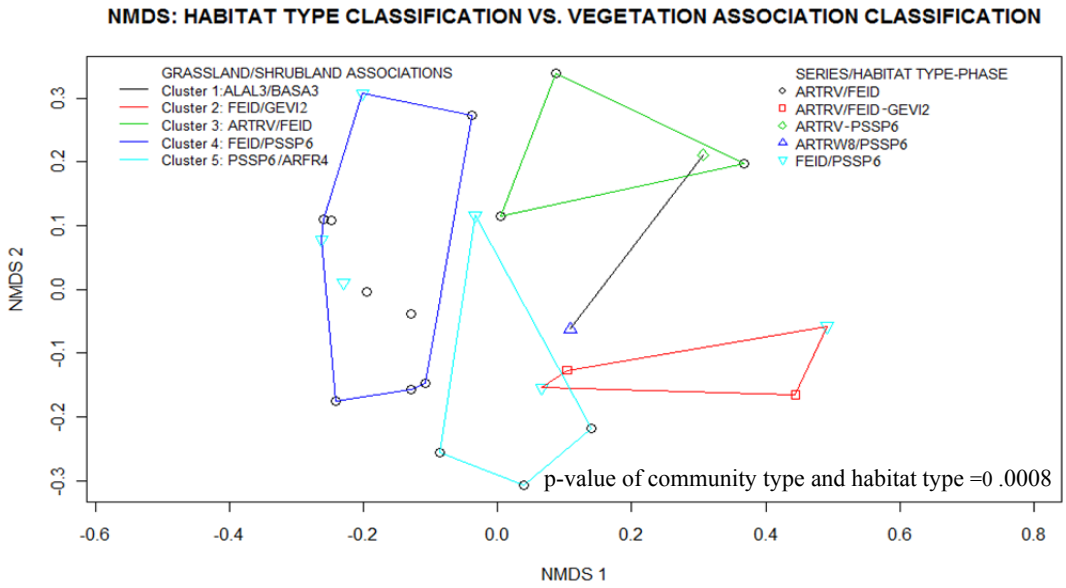


Figure 2.11. First two axes of three-dimensional NMDS ordination where points are habitat types and associations identified in this analysis are outlined.

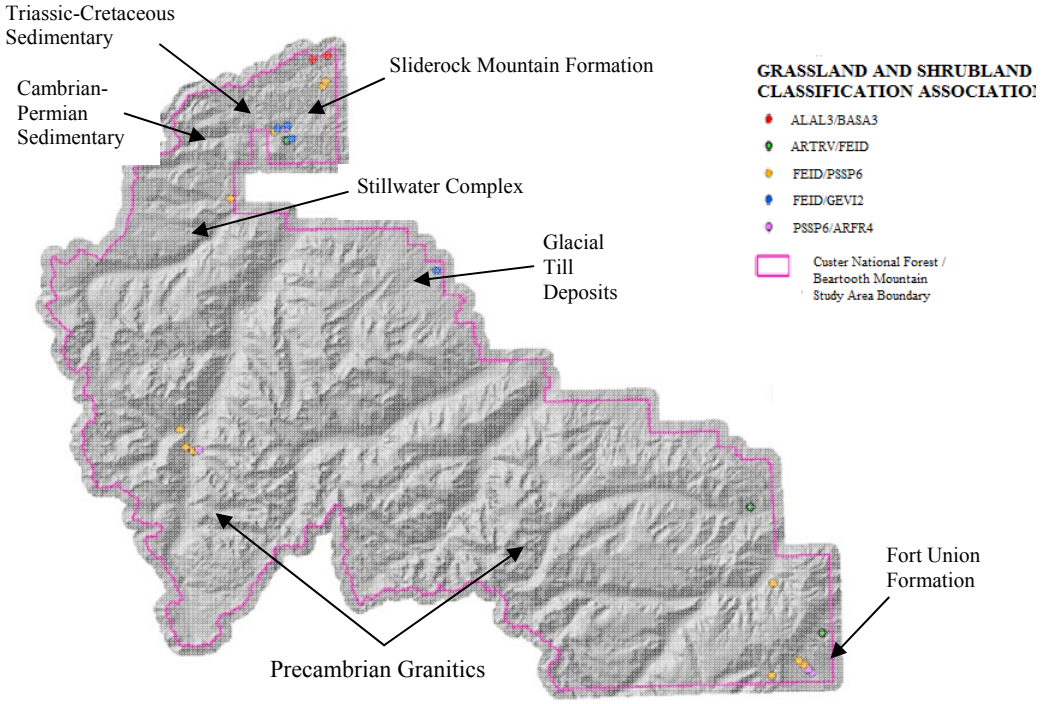


Figure 2.12. Hillshade relief and broad geologic map of study area where membership of grassland/shrubland samples to grassland/shrubland association is indicated by differently colored points.

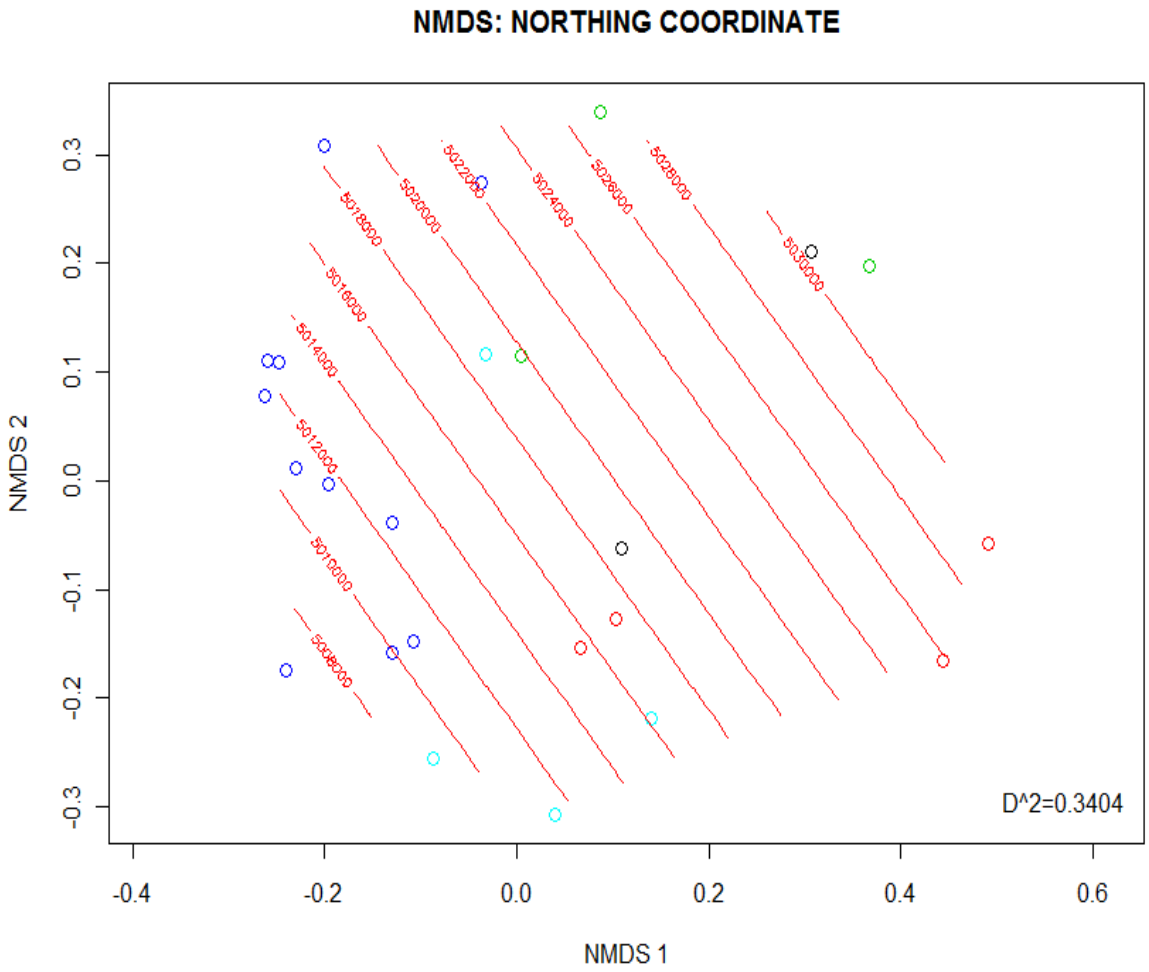


Figure 2.13. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.3404$ for smooth of Northing coordinate on all three dimensions.

Cluster 1 : Black : *Alyssum alyssoides/Balsamorhiza sagittata* (ALAL3/BASA3)
Cluster 2 : Red : *Festuca idahoensis/Geranium viscosissimum* (FEID/GEVI2)
Cluster 3 : Green : *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* (ARTRV/FEID)
Cluster 4 : Blue : *Festuca idahoensis/Elymus spicatus* (FEID/PSSPS)
Cluster 5 : Cyan : *Elymus spicatus/Artemisia frigida* (PSSPS/ARFR4)

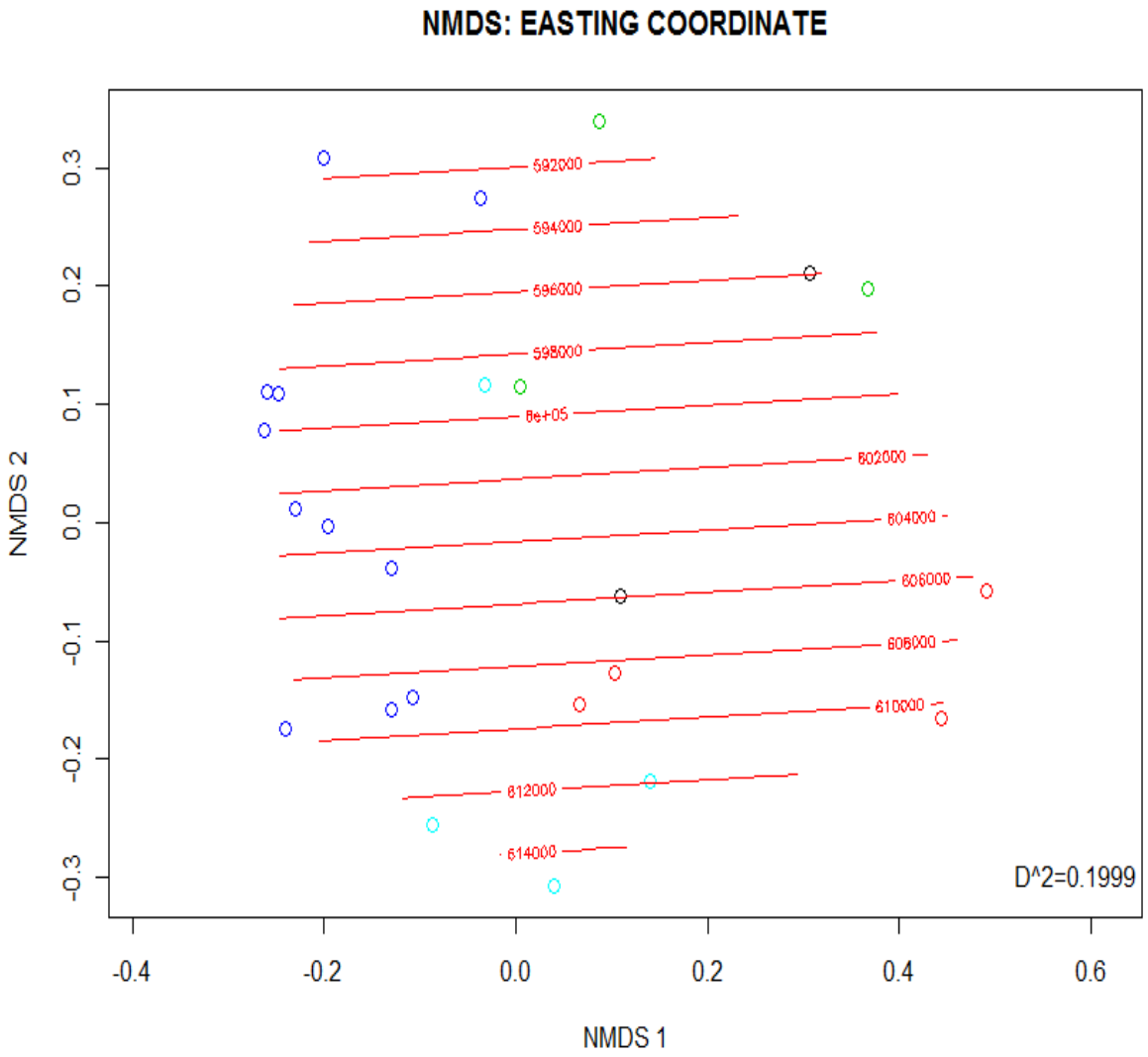


Figure 2.14. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.1999$ for smooth of Easting coordinate on all three dimensions.

Cluster 1 : Black : *Alyssum alyssoides/Balsamorhiza sagittata* (ALAL3/BASA3)
Cluster 2 : Red : *Festuca idahoensis/Geranium viscosissimum* (FEID/GEVI2)
Cluster 3 : Green : *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* (ARTRV/FEID)
Cluster 4 : Blue : *Festuca idahoensis/Elymus spicatus* (FEID/PSSPS)
Cluster 5 : Cyan : *Elymus spicatus/Artemisia frigida* (PSSPS/ARFR4)

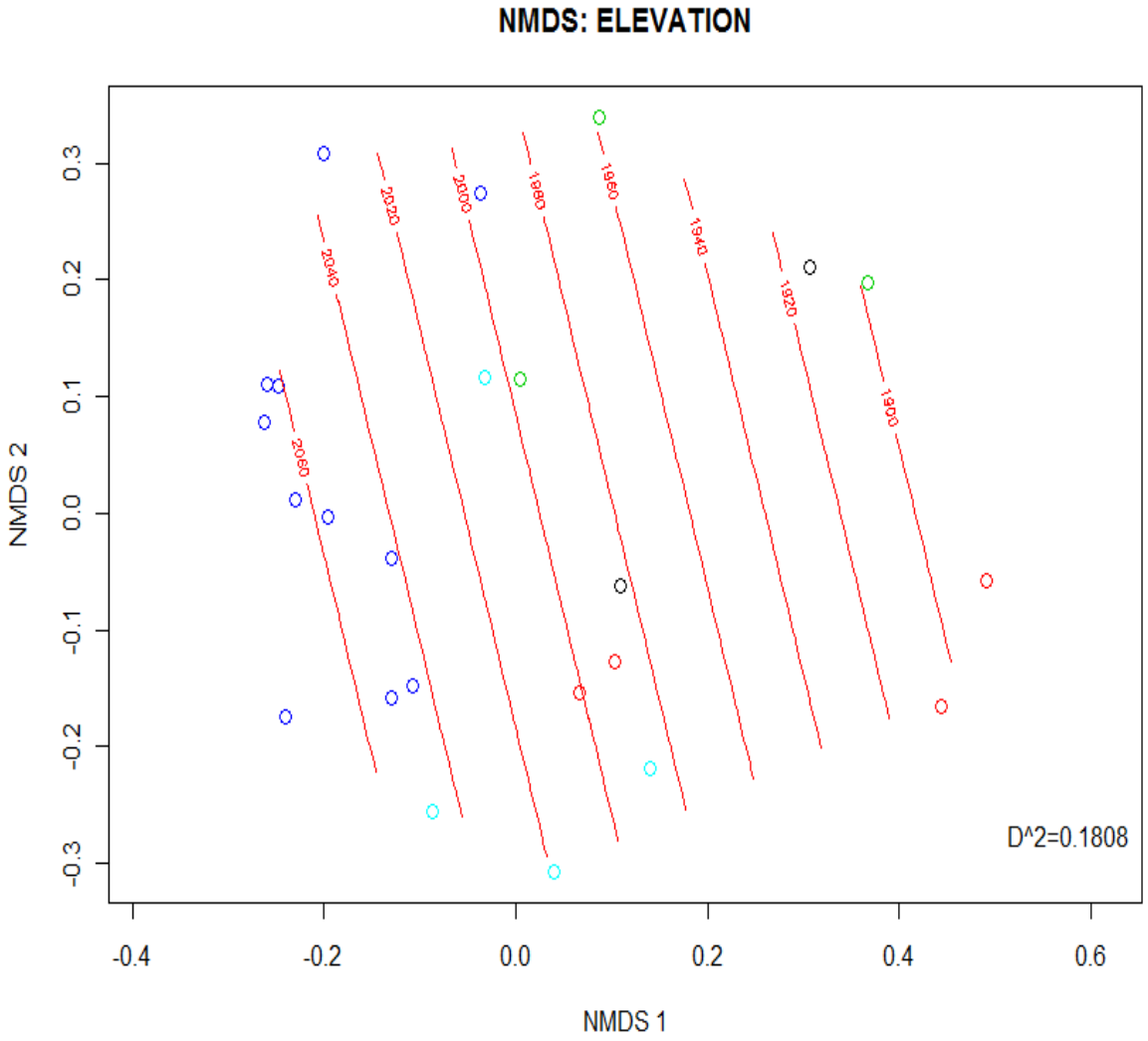


Figure 2.15. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.1808$ for smooth of elevation on all three dimensions.

Cluster 1 : Black : *Alyssum alyssoides/Balsamorhiza sagittata* (ALAL3/BASA3)
Cluster 2 : Red : *Festuca idahoensis/Geranium viscosissimum* (FEID/GEVI2)
Cluster 3 : Green : *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* (ARTRV/FEID)
Cluster 4 : Blue : *Festuca idahoensis/Elymus spicatus* (FEID/PSSPS)
Cluster 5 : Cyan : *Elymus spicatus/Artemisia frigida* (PSSPS/ARFR4)

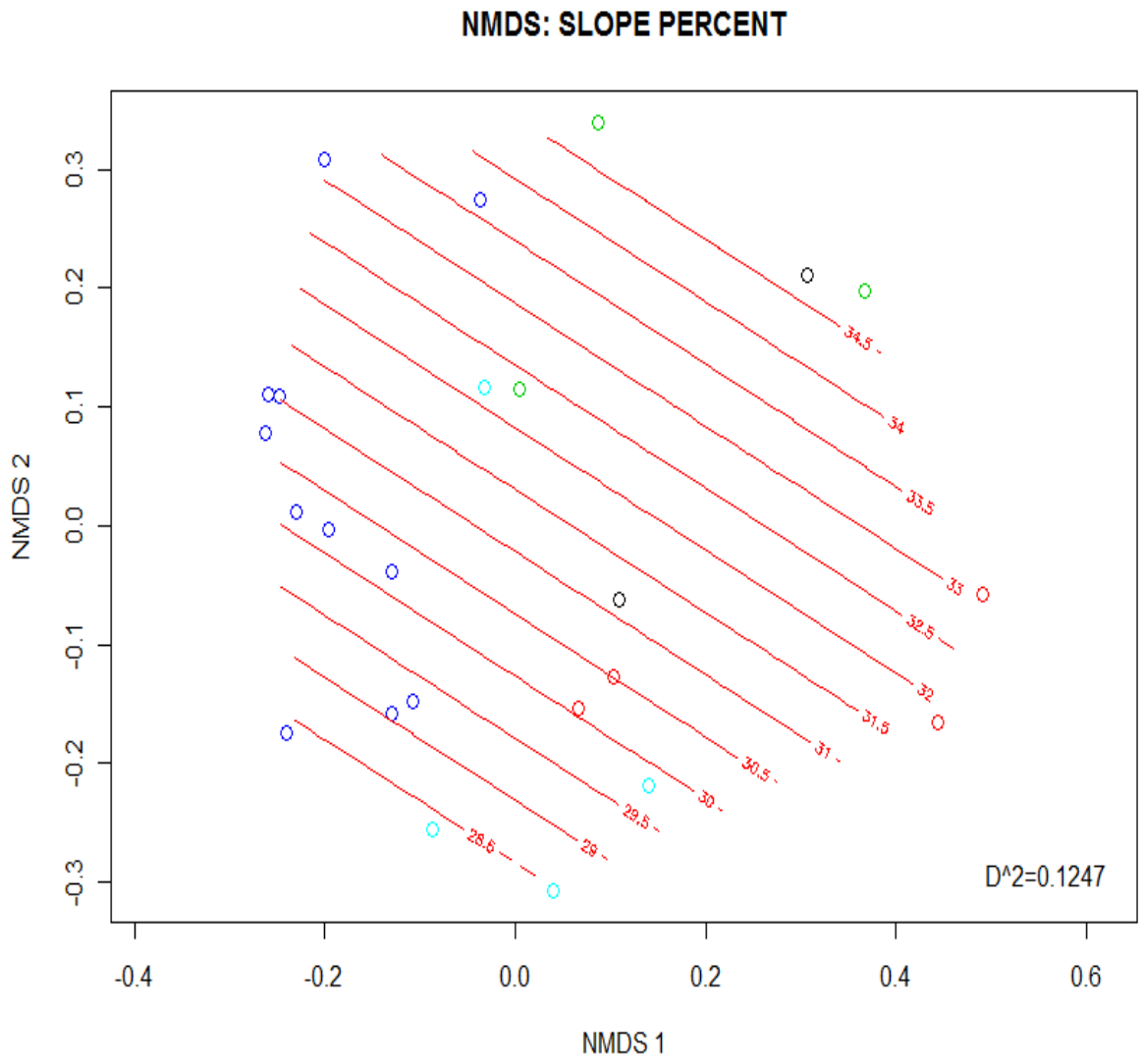


Figure 2.16. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.1247$ for smooth of slope percent (%) on all three dimensions.

Cluster 1 : Black : *Alyssum alyssoides/Balsamorhiza sagittata* (ALAL3/BASA3)
Cluster 2 : Red : *Festuca idahoensis/Geranium viscosissimum* (FEID/GEVI2)
Cluster 3 : Green : *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* (ARTRV/FEID)
Cluster 4 : Blue : *Festuca idahoensis/Elymus spicatus* (FEID/PSSPS)
Cluster 5 : Cyan : *Elymus spicatus/Artemisia frigida* (PSSPS/ARFR4)

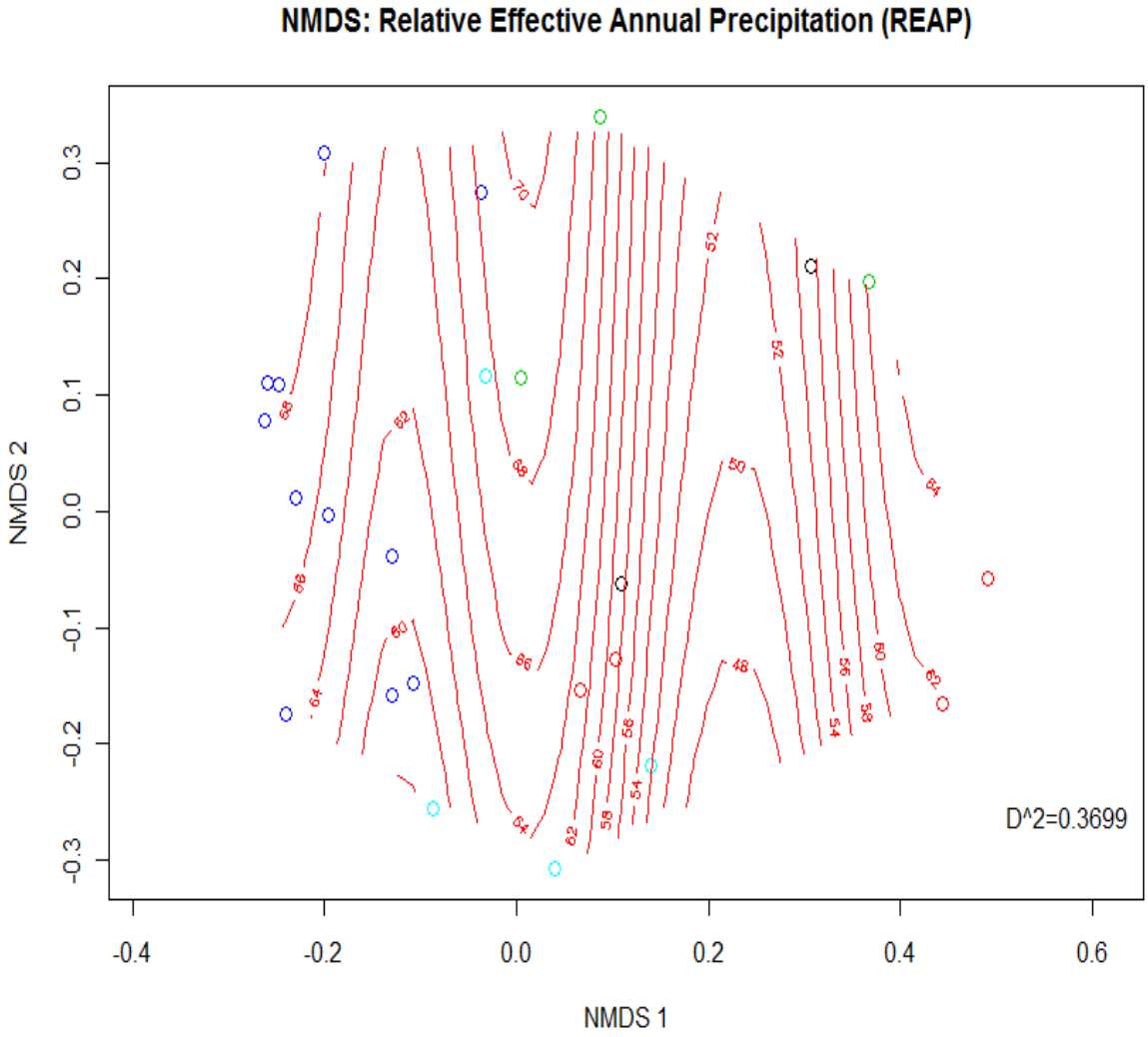


Figure 2.17. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.3699$ for smooth of relative effective annual precipitation (REAP) on all three dimensions.

Cluster 1 : Black : *Alyssum alyssoides/Balsamorhiza sagittata* (ALAL3/BASA3)
Cluster 2 : Red : *Festuca idahoensis/Geranium viscosissimum* (FEID/GEVI2)
Cluster 3 : Green : *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* (ARTRV/FEID)
Cluster 4 : Blue : *Festuca idahoensis/Elymus spicatus* (FEID/PSSPS)
Cluster 5 : Cyan : *Elymus spicatus/Artemisia frigida* (PSSPS/ARFR4)

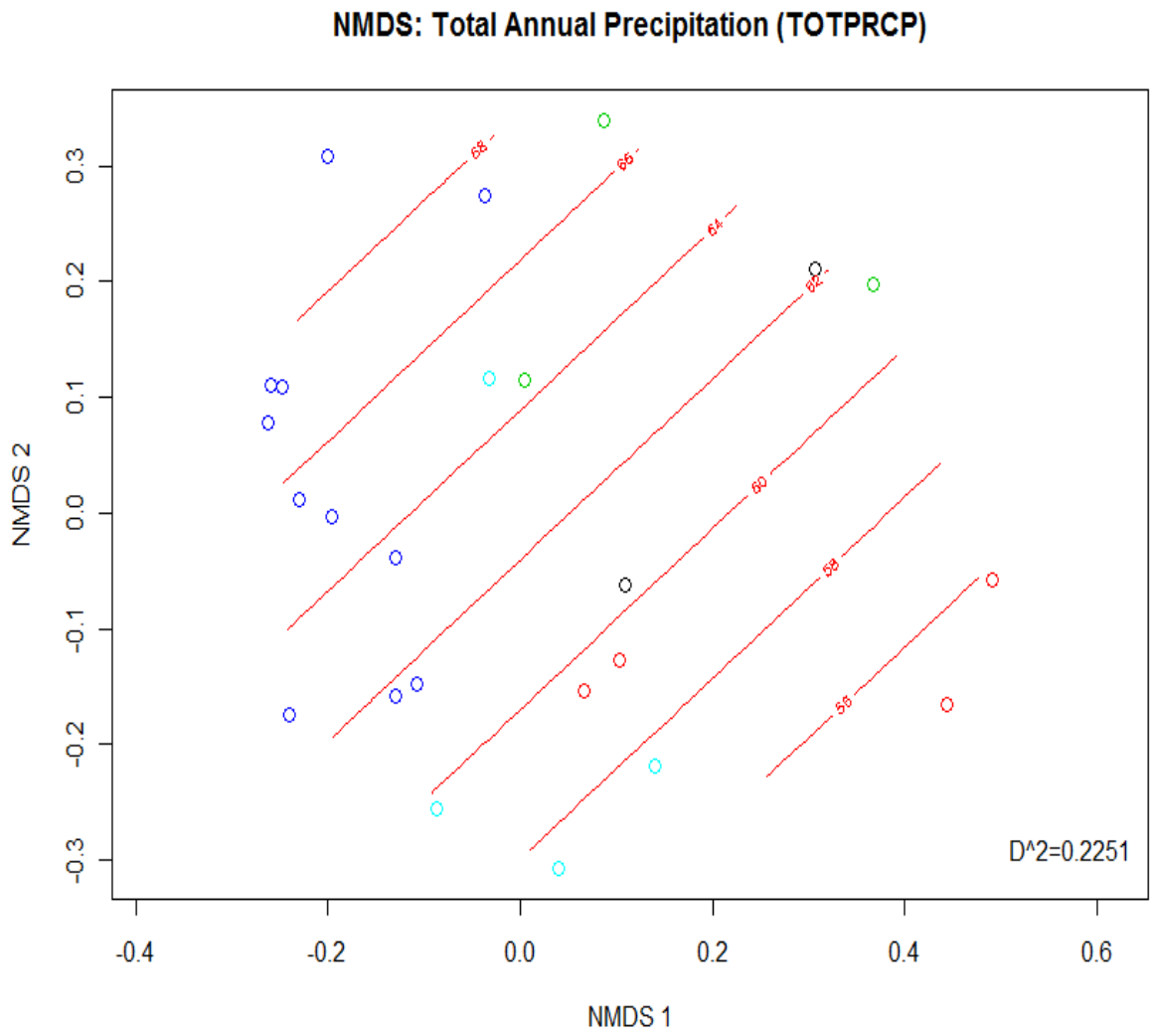


Figure 2.18. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.2251$ for smooth of total annual precipitation (TOTPRCP) on all three dimensions.

Cluster 1 : Black : *Alyssum alyssoides/Balsamorhiza sagittata* (ALAL3/BASA3)
Cluster 2 : Red : *Festuca idahoensis/Geranium viscosissimum* (FEID/GEVI2)
Cluster 3 : Green : *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* (ARTRV/FEID)
Cluster 4 : Blue : *Festuca idahoensis/Elymus spicatus* (FEID/PSSPS)
Cluster 5 : Cyan : *Elymus spicatus/Artemisia frigida* (PSSPS/ARFR4)

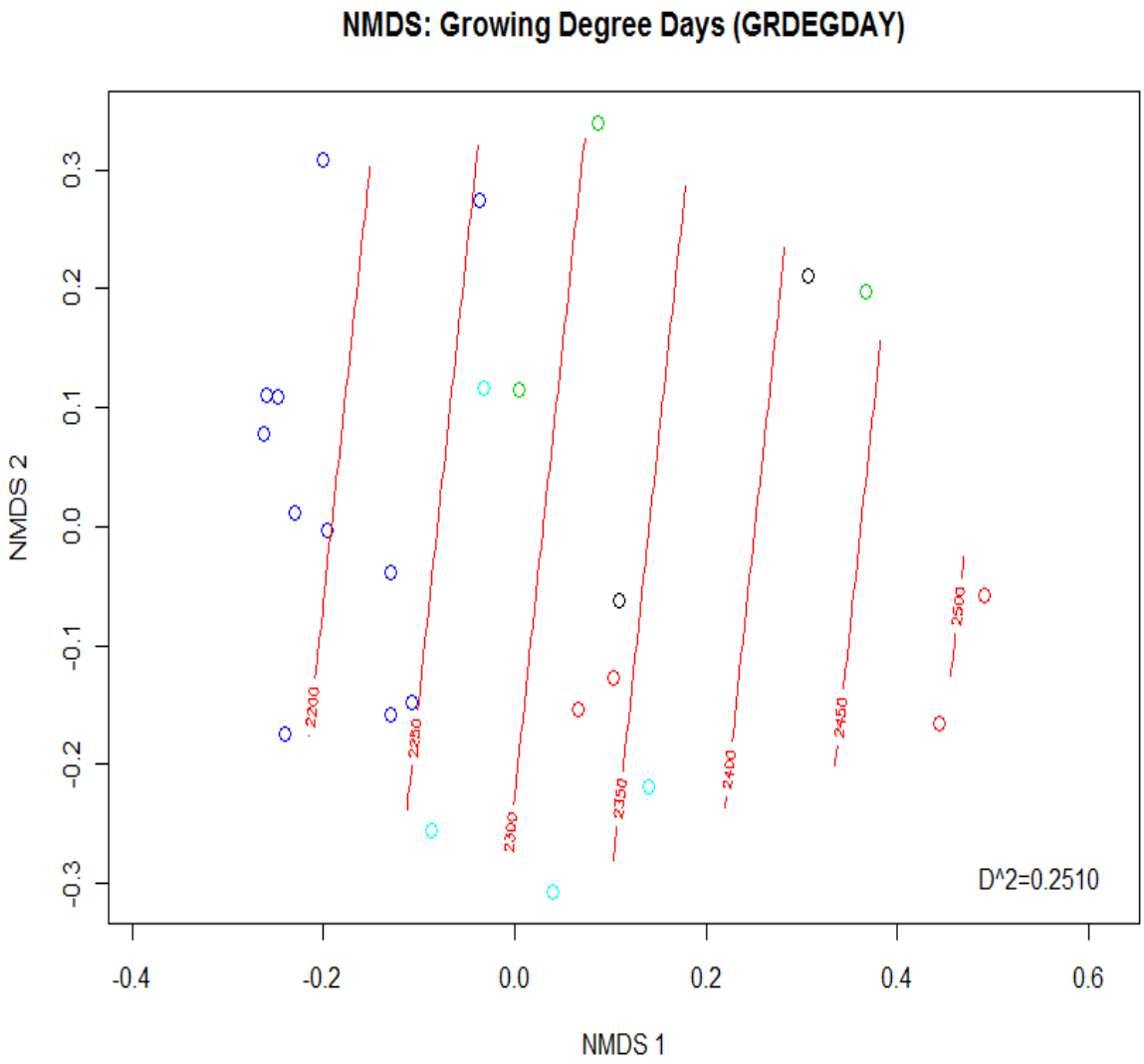


Figure 2.19. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.251$ for smooth of growing degree day (GRDEGDAY) on all three dimensions.

Cluster 1 : Black : *Alyssum alyssoides/Balsamorhiza sagittata* (ALAL3/BASA3)
Cluster 2 : Red : *Festuca idahoensis/Geranium viscosissimum* (FEID/GEVI2)
Cluster 3 : Green : *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* (ARTRV/FEID)
Cluster 4 : Blue : *Festuca idahoensis/Elymus spicatus* (FEID/PSSPS)
Cluster 5 : Cyan : *Elymus spicatus/Artemisia frigida* (PSSPS/ARFR4)

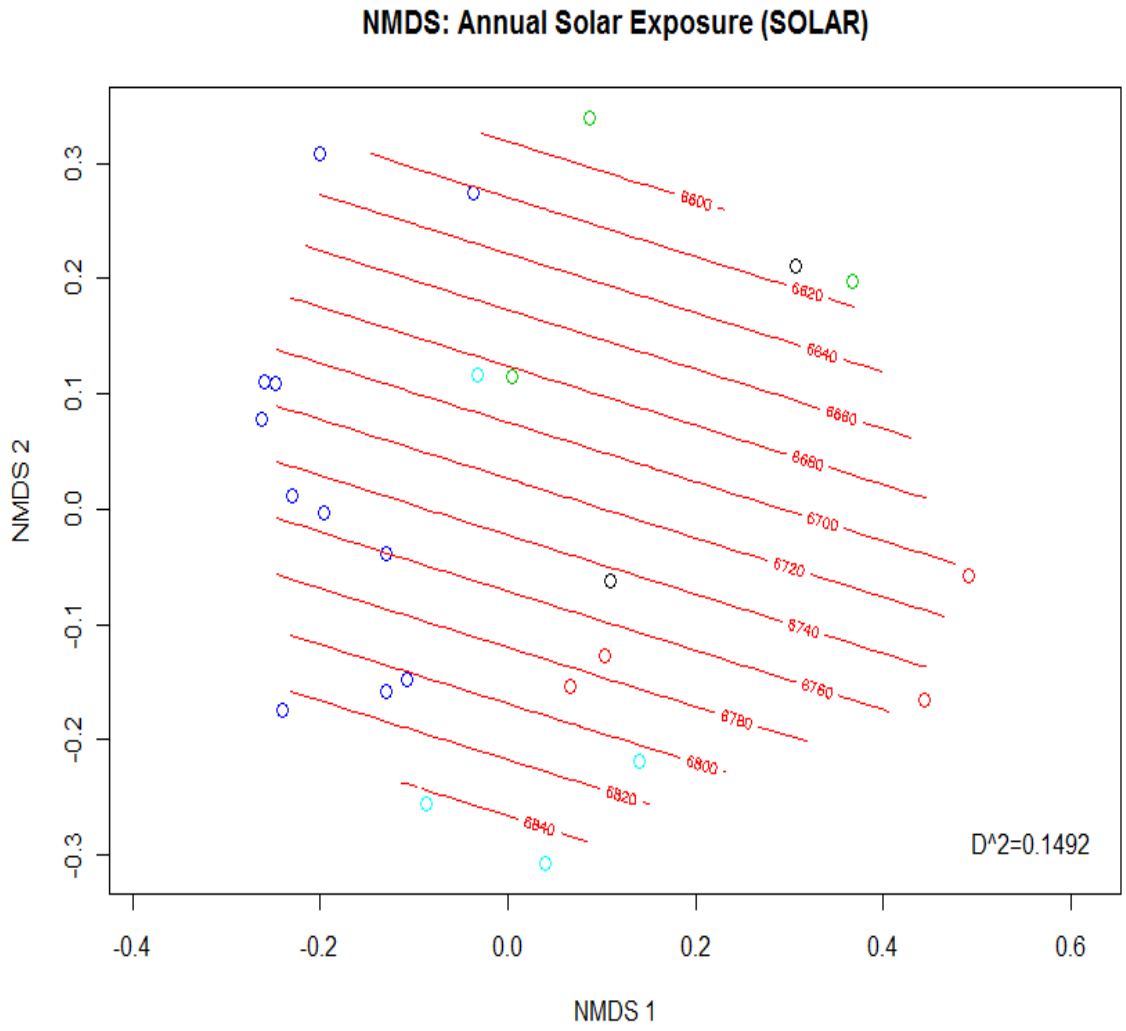


Figure 2.20. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.1492$ for smooth of units annual solar exposure (SOLAR).

Cluster 1 : Black : *Alyssum alyssoides/Balsamorhiza sagittata* (ALAL3/BASA3)
Cluster 2 : Red : *Festuca idahoensis/Geranium viscosissimum* (FEID/GEVI2)
Cluster 3 : Green : *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* (ARTRV/FEID)
Cluster 4 : Blue : *Festuca idahoensis/Elymus spicatus* (FEID/PSSPS)
Cluster 5 : Cyan : *Elymus spicatus/Artemisia frigida* (PSSPS/ARFR4)

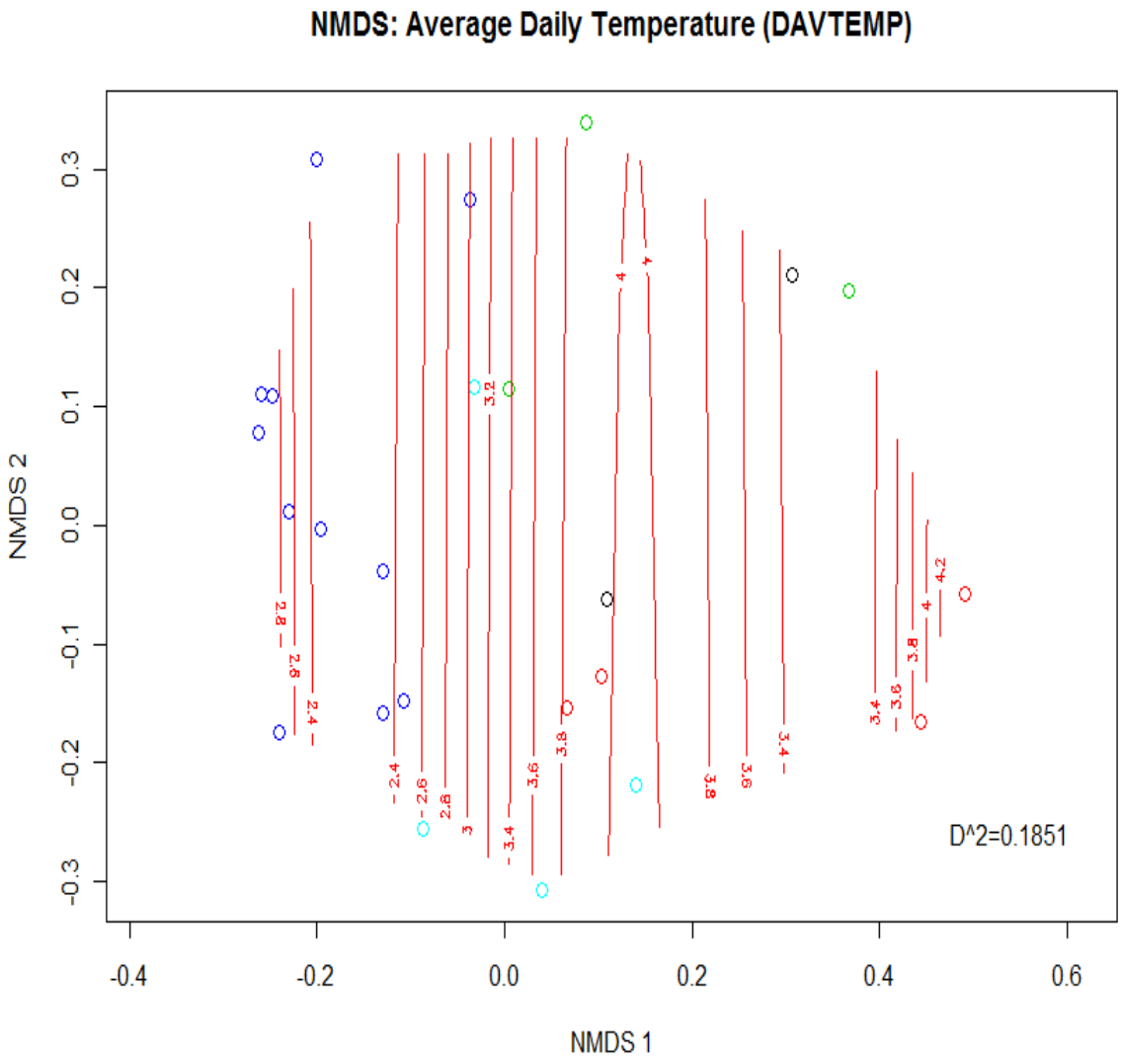


Figure 2.21. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.1851$ for smooth of average daily temperature (DAVTEMP) on all three dimensions.

Cluster 1 : Black : *Alyssum alyssoides/Balsamorhiza sagittata* (ALAL3/BASA3)
Cluster 2 : Red : *Festuca idahoensis/Geranium viscosissimum* (FEID/GEVI2)
Cluster 3 : Green : *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* (ARTRV/FEID)
Cluster 4 : Blue : *Festuca idahoensis/Elymus spicatus* (FEID/PSSPS)
Cluster 5 : Cyan : *Elymus spicatus/Artemisia frigida* (PSSPS/ARFR4)

Table 2.4. D^2 values of GAMs fit to continuous environmental variables, based on the three dimensional NMDS ordination. All models are Gaussian.

VARIABLE	**GAM D^2**
Northing Coordinate (UTM)	0.3404
Easting Coordinate (UTM)	0.1999
Elevation (m)	0.1808
Slope Percent (%)	0.1247
Relative effective annual precipitation (REAP)	0.3699
Total precipitation (TOTPRCP)	0.2251
Growing degree day (GRDEGDAY)	0.2510
Annual solar exposure (SOLAR)	0.1492
Average daily temperature (DAVTEMP)	0.1851

Table 2.5. P-values and chi-squared values from Kruskal-Wallis Rank Sum Test for each of the continuous environmental variables. P-values < 0.1 are bolded. d.f.= 4

VARIABLE	**p-value**	**Chi-squared value**
Northing Coordinate (UTM)	**0.0771**	8.4289
Easting Coordinate (UTM)	0.7462	1.9435
Elevation (m)	0.1624	6.5383
Slope Percent (%)	0.2263	5.657
Relative effective annual precipitation (REAP)	0.2626	5.2504
Total precipitation (TOTPRCP)	0.6656	2.3835
Growing degree day (GRDEGDAY)	0.2034	5.9439
Annual solar exposure (SOLAR)	0.8738	1.2258
Average daily temperature (DAVTEMP)	0.1265	7.1829

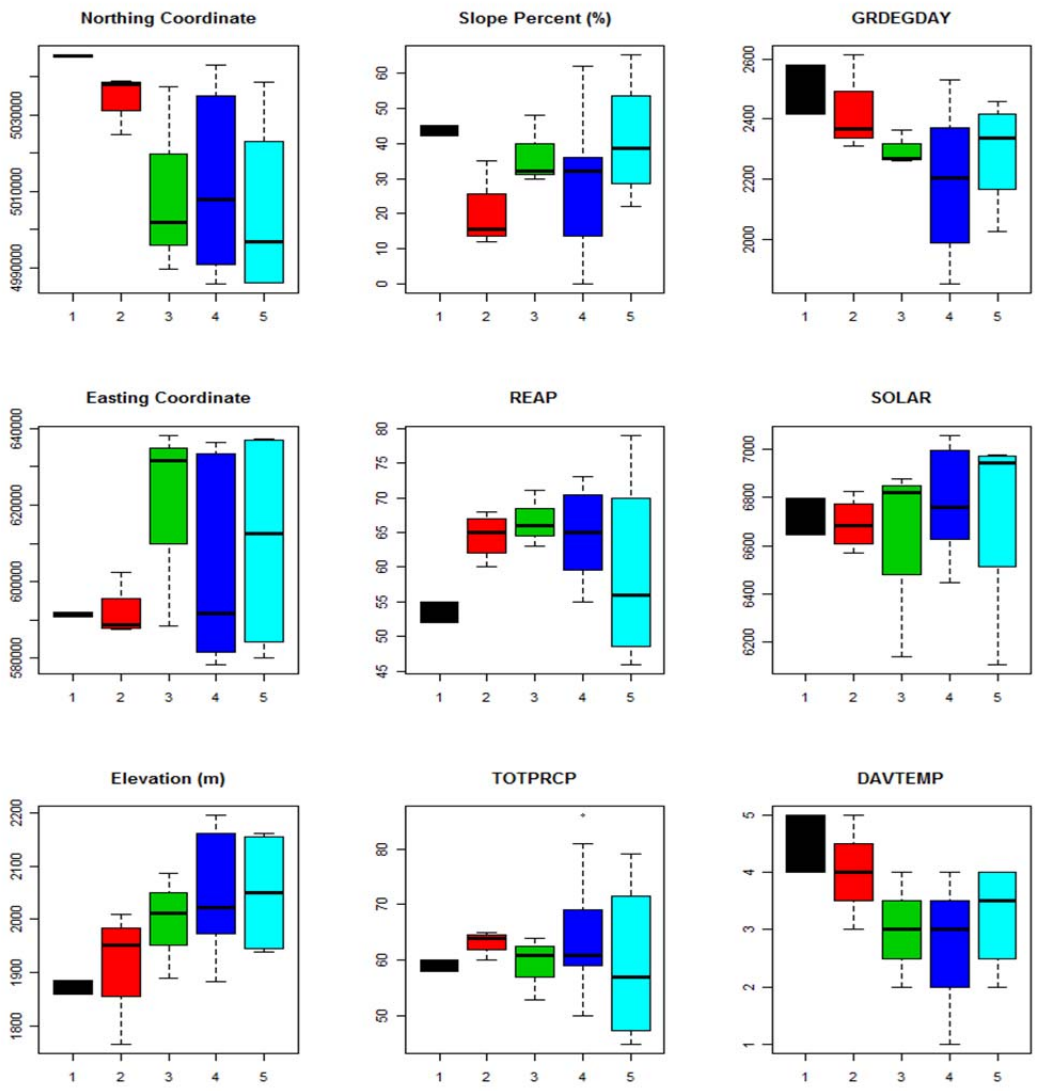


Figure 2.22. Boxplots of continuous environmental variables: Northing coordinate, Easting coordinate, elevation (m), slope percent (%), relative effective annual precipitation (REAP), total annual precipitation (TOTPRCP), greatest daily degree (GRDEGDAY), annual solar exposure (SOLAR) and average daily temperature (DAVTEMP).

Cluster 1: *Alyssum alyssoides/Balsamorhiza sagittata* (ALAL3/BASA3)
Cluster 2: *Festuca idahoensis/Geranium viscosissimum* (FEID/GEVI2)
Cluster 3: *Artemisia tridentata* var. *vaseyana/Festuca idahoensis*(ARTRV/FEID)
Cluster 4: *Festuca idahoensis/Elymus spicatus* (FEID/PSSPS)
Cluster 5: *Elymus spicatus/Artemisia frigida* (PSSPS/ARFR4)

Table 2.6. Ordtest p-values for topographic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level.

	ASAL3 / BASA3	**FEID / GEVI2**	**ARTRV / FEID**	**FEID / PSSPS**	**PSSPS / ARFR4**	**p-val**
Topographic Position						0.782
Backslope	1	3	1	4	3	0.394
Footslope	0	0	2	2	1	0.538
Shoulder	1	1	0	5	0	0.824
Summit	0	0	0	0	0	1
Toeslope	0	0	0	0	0	1
Primary Landform						0.287
Hillslope	0	0	1	2	2	0.664
Moraine	0	0	0	1	0	1
Mountain Slope	1	2	2	2	0	0.161
Pediment	0	1	0	1	0	0.288
Ridge	1	1	0	1	1	0.392
U-shaped Valley	0	0	0	3	1	0.343
V-shaped Valley	0	0	0	1	0	0.387
Slope Complex						0.959
Complex Broken	0	0	0	0	0	1
Complex Patterned	0	0	0	0	0	1
Complex Undulating	0	0	0	0	0	1
Simple Concave	0	0	0	3	0	1
Simple Convex	2	1	1	3	0	1
Simple Linear	0	3	2	5	4	0.849
Slope Complexity						1
Complex	0	0	0	0	0	1
Simple	2	4	3	11	4	1
Verticle Slope Shape						0.307
Broken	0	0	0	0	0	1
Concave	0	2	0	2	0	0.568
Convex	2	1	2	8	2	0.233
Linear	0	1	1	1	2	1
Patterened	0	0	0	0	0	1
Undulating	0	0	0	0	0	1
Horizontal Slope Shape						0.961
Broken	0	0	0	0	0	1
Concave	0	0	0	3	0	0.969
Convex	2	1	1	3	0	0.617
Linear	0	3	2	5	4	0.863
Patterened	0	0	0	0	0	1
Undulating	0	0	0	0	0	1

Table 2.7. Ordtest p-values for climatic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level.

	ASAL3 / BASA3	**FEID / GEVI2**	**ARTRV / FEID**	**FEID / PSSPS**	**PSSPS / ARFR4**	**p-val**
Soil Temperature Regime (STR)						0.19
Cryic	0	3	2	7	1	0.217
Frigid	2	1	1	4	3	0.197
Gelic	0	0	0	0	0	1
Soil Moisture Regime (SMR)						0.468
Aquic	0	0	0	0	0	1
Udic	0	3	1	6	1	0.425
Ustic	2	1	2	5	3	0.463
Soil Moisture Sub Class (SMSC)						0.78
Aquic	0	0	0	0	0	1
Aridic	0	0	0	0	2	0.607
Oxyaquic	0	0	0	0	0	1
Typic	2	4	2	8	2	0.853
Udic	0	0	0	0	0	1
Ustic	0	0	1	3	0	0.612
Aspect Class						0.282
E	0	1	1	1	0	**0.04**
ENE	0	0	0	0	0	1
ESE	0	0	0	1	0	0.511
N	0	0	0	0	0	1
NE	0	2	0	0	0	0.793
NNE	0	1	0	1	0	0.378
NNW	0	0	0	0	0	1
NW	0	0	0	0	0	1
S	0	0	0	1	1	0.628
SE	2	0	1	2	1	**0.066**
SSE	0	0	0	0	0	1
SSW	0	0	0	0	1	0.639
SW	0	0	0	2	0	0.618
W	0	0	0	0	0	1
WNW	0	0	1	1	0	0.572

Table 2.8. Ordtest p-values for geologic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level.

	ASAL3 / BASA3	**FEID / GEVI2**	**ARTRV / FEID**	**FEID / PSSPS**	**PSSPS / ARFR4**	**p-val**
Soil Depth						0.856
Deep	2	4	3	8	3	0.874
Moderate	0	0	0	2	0	0.936
Shallow	0	0	0	1	1	0.507
Soil Particle Size						0.577
clayey skeletal	0	0	0	0	0	1
coarse loamy	0	0	0	0	0	1
fine loamy	0	3	1	0	1	0.141
fragmental	0	0	0	0	0	1
loamy	0	0	0	0	0	1
loamy skeletal	2	1	2	8	2	0.768
sandy	0	0	0	0	0	1
sandy skeletal	0	0	0	2	1	0.678
Soil SubGroup						**0.025**
Aridic Argiustolls	0	0	0	0	1	0.416
Aridic Haplustalfs	0	0	0	0	1	0.652
Lithic Haplustolls	0	0	0	0	1	0.317
Lithic Ustorthents	0	0	0	1	0	0.586
Pachic Argicryolls	0	2	0	1	0	0.147
Pachic Argiustolls	0	1	1	0	0	**0.073**
Pachic Calciustolls	0	0	0	1	0	0.817
Pachic Haplocryolls	0	1	0	2	0	0.618
Pachic Haplustolls	2	0	0	0	0	**0.021**
Typic Argiustolls	0	0	0	1	0	0.953
Typic Cryorthents	0	0	0	1	1	0.672
Typic Haplocryolls	0	0	0	1	0	1
Typic Haplustolls	0	0	0	1	0	0.696
Ustic Haplocryalfs	0	0	1	1	0	0.286
Ustic Haplocryepts	0	0	0	1	0	0.378
Ustic Haplocryolls	0	0	1	0	0	0.912

Table 2.9. Ordtest p-values for the categorical variable, disturbance and PNV classification, based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level.

	ASAL3 / BASA3	**FEID / GEVI2**	**ARTRV / FEID**	**FEID / PSSPS**	**PSSPS / ARFR4**	**p-val**
Disturbance				**0.068**		
Cattle	0	0	0	1	0	0.712
Derby Fire: Fishtail Moraine	2	1	0	2	0	**0.038**
Derby Fire: Meyers Creek	0	3	1	1	1	0.202
Derby Fire: Red Lodge	0	0	0	1	0	0.399
Insect	0	0	1	0	0	1
Line Creek Fire	0	0	1	3	2	0.858
Stillwater Fire	0	0	0	3	1	0.35
Habitat Type Classification				**0.008**		
ARTRV/FEID	0	0	3	8	3	**0.031**
ARTRV/FEID-GEVI	0	2	0	0	0	**0.07**
ARTRV/PSSPS	1	0	0	0	0	**0.076**
ARTRW/PSSPS	1	0	0	0	0	0.21
FEID/PSSPS	0	2	0	3	1	0.469

Grassland and Shrubland Association Descriptions

Cluster 1: *Alyssum alyssoides/Balsamorhiza sagittata* (ALAL3/BASA3) Association (n=2)

Vegetation. This is an early seral, or somewhat disturbed, association. This is evidenced by the presence and abundance of *Bromus tectorum*. *Balsamorhiza sagittata* and *Alyssum alyssoides* are consistently present and abundant (>15% cover). *Lupinus argenteus* is consistently present and well represented (>5%). *Lomatium triternatum, Vicia americana, Achillea millefolium, Allium textile, Cerastium arvense, Collomia linearis, Crepis intermedia* and *Phacelia linearis* are consistently occurring forbs.

Elymus spicatus and *Poa secunda* are the most consistently occurring native graminoid species. *Elymus spicatus* occurs with an average of 8% cover. *Festuca idahoensis* is absent or poorly represented. *Artemisia tridentata* var. *wyomingensis* was well represented on one of the two sites that comprise this cluster. This association seems to be compositionally similar to the *Elymus spicatus/Artemisia frigida* type also classified in this analysis, though *Artemisia frigida* is conspicuously absent.

Environment. This association was found on the warmest and driest sites observed in the study area. Although the cluster is only based on two samples, both occur between 1,850 and 1,900 m (the lowest of grassland/shrubland communities) on southeast-facing convex sites with approximately 45% slope. The soil temperature regime is frigid, the soil moisture regime is ustic and the soil moisture subclass is typic. Soils are deep, formed from metamorphic colluviums and have loamy skeletal soil particle size. Only the samples in this association had soils that were classified as Pachic Haplustolls. The *Elymus spicatus/Artemisia frigida* association occurs at higher elevations than the *Alyssum alyssoides/Balsamorhiza sagittata* association, but is also characteristically drier than other associations.

Other Classifications. Lesica (1993) did not describe a similar community type association for the foothills of Line Creek Plateau. All samples of this association occurred in the northern-most extremity of the Beartooth Mountains study area on the opposite side of the study area from Line Creek Plateau and in soils derived from different geologic parent materials.

However, the samples in this association classified reasonably well to the *Artemisia tridentata* var. *vaseyana/Elymus spicatus* habitat type identified and described by Mueggler and Stewart (1980). One sample included in this association was lacking both *Artemisia tridentata* var. *vaseyana* and *Artemisia tridentata* var. *wyomingensis,* but contained burned stumps of what was presumed to be *Artemisia tridentata* var. *vaseyana*. The *Artemisia tridentata* var. *vaseyana/Elymus spicatus* habitat type is considered a moderately arid type. It commonly occurs on shallow to moderately deep soils formed from a variety of parent material. Low shrubs, such as *Artemisia frigida* and *Gutierrezia sarothrae* and graminoid species, such as *Koeleria cristata, Poa sandbergii, Stipa comata* and *Bouteloua gracilis* are common to the *Artemisia tridentata* var. *tridentata/Elymus spicatus* habitat type. *Artemisia tridentata* var. *wyomingensis* may also prevail in this habitat type (Mueggler and Stewart, 1980). Heavy grazing results in decreased cover of *Elymus spicatus*, *Balsamorhiza sagittata* and *Crepis acuminata* and increased cover of *Bouteloua gracilis*, *Poa sandbergii*, *Artemisia frigida*, *Gutierreiza sarothrae* and *Opuntia polycantha*. The abundance of *Elymus spicatus*, *Balsamorhiza sagittata* and *Crepis acuminata* and absence of *Bouteloua gracilis*, *Poa sandbergii*, *Artemisia frigida* and *Gutierreiza sarothrae* may indicate that these sites have not been heavily grazed and that changes in composition, such as increased *Bromus tectorum* and *Alyssum alyssoides* cover and decreased *Artemisia tridentata* var. *vaseyana* cover, are likely the result of recent fires.

Cluster 2: *Festuca idahoensis/Geranium viscosissimum* (FEID/GEVI2) Association (n=4)

Vegetation. This association is characterized by the dominance of *Poa pratensis* and *Elymus spicatus* in the graminoid layer along with the presence, not dominance, of *Festuca idahoensis*. *Geranium viscosissimum*, *Taraxacum officinale*, *Arnica sororia*, *Campanula rotundifolia*, *Silene latifolia* and *Potentilla gracilis* var. *flabelliformis* are the most consistently associated forb species and are also indicator species. *Carex petasata*, *Bromus carinatus* var. *linearis*, *Poa pratensis* and *Achnatherum occidentale* are indicator species and the most consistently associated graminoid species. *Galium boreale*, *Lupinus sericeus*, *Camelina microcarpa*, *Agoseris glauca*, *Delphinium bicolor*, *Geum triflorum* and *Thlaspi arvense* are consistently present in the forb layer but are not indicator species. *Artemisia frigida* is consistently absent from the shrub layer, indicating that this association is wetter than the *Elymus spicatus/Artemisia frigida* and *Festuca idahoensis/Elymus spicatus* associations.

Environment. This association occurs at lower elevations than the *Festuca idahoensis-Elymus spicatus* association, on sites that receive approximately the same amount of precipitation. This association is restricted to northeast and east- facing sites with < 35% slope. The *Festuca idahoensis-Elymus spicatus* association is more likely to occur on more southerly and westerly slopes. The soil moisture regime of the *Festuca idahoensis/Geranium viscosissimum* association is cryic, the soil moisture regime is udic and the soil moisture subclass is typic. Soils are deep and formed from andesite colluvium. The soil particle size is fine loamy. Soils were classified as Pachic

Argiustolls, Pachic Haplocryolls and Pachic Argicryolls. Several soils of samples in the *Festuca idahoensis/Elymus spicatus* association and one of in the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* association were classified similarly. Pachic mollisols with diagnostic argyllic horizons were not observed in the *Alyssum alyssoides/Balsamorhiza sagittata* or *Elymus spicatus/Artemisia frigida* associations.

Other Classifications. Lesica (1993) did not describe a similar community in the foothills of Line Creek Plateau, located on the eastern margin of the Beartooth Mountains study area. This is not particularly disturbing, as all of the samples included in this association occurred in the northwestern portion of the study area and were found in intermediate volcanic and glacial deposits not present near Line Creek Plateau.

Two of the samples included in this association were the only samples in the study area to be classified as the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type-*Geranium viscosissimum* phase described by Mueggler and Stewart (1980). The other two samples in this association were classified to the *Festuca idahoensis/ Elymus spicatus* habitat type described by Mueggler and Stewart (1980). Similarities in species composition indicate that the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type-*Geranium viscosissimum* phase (Mueggler and Stewart, 1980) is very similar to the *Festuca idahoensis/Geranium viscosissimum* association described here. It is likely that the samples of this association would better reflect the compositional characteristics described by Mueggler and Stewart (1980) if not for recent fires which have resulted in the absence or low abundance of *Artemisia tridentata* var. *vaseyana*. The *Geranium viscosissimum* phase of the *Artemisia tridentata* var.

vaseyana/Festuca idahoensis habitat type is characterized by increased graminoid richness and increased forb abundance. The *Festuca idahoensis/Geranium viscosissimum* association exhibits both of these characteristics. Species common to the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type-*Geranium viscosissimum* phase (Mueggler and Stewart, 1980) and the *Festuca idahoensis-Geranium viscosissimum* phase described here include: *Danthonia intermedia, Bromus carinatus* var. *linearis, Agropyron caninum, Stipa occidentatlis* and *Carex raynoldsii*, as well as, *Geranium viscosissimum, Potentilla gracilis, Potentilla arguta, Helianthella uniflora* and *Eriogonum umbellatum*.

There are also similarities in environment between the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type-*Geranium viscosissimum* phase (Mueggler and Stewart, 1980) and the *Festuca idahoensis/Geranium viscosissimum* association described here. Both are associated with northeast and east facing sites with <35% slope and are more common in deep soils. However, while the *Geranium viscosissimum* phase is reported to occur at the highest elevations and most mesic portions of the *Artemisia tridentata* var. *vaseyana*/*Festuca idahoensis* habitat type, the *Festuca idahoensis*/*Geranium viscosissimum* association occurs at slightly lower elevations than both the *Festuca idahoensis-Elymus spicatus* and *Artemisia tridentata* var. *vaseyana*/*Festuca idahoensis* associations identified here.

Cluster 3: *Artemisia tridentata* var. *vaseyana/*
Festuca idahoensis (ARTRV/FEID) Association (n=3)

Vegetation. This association is dominated by *Artemisia tridentata* var. *vaseyana* (> 30% cover) in the shrub layer. *Pinus flexilis* is regenerating in 66% of plots, occurs in low abundance and was identified as an indicator species. *Mertensia oblongifolia*, another indicator species, is present in 66% of plots and occurs in low abundance. *Achillea millefolium* var. *lanulosa, Antennaria microphylla, Crepis intermedia,* and *Eremogone congesta* are consistently occurring forbs that were not identified as indicator species. *Carex petasata*, *Elymus spicatus*, *Koeleria macrantha* and *Leucopoa kingii* are consistently occurring graminoids that were not identified as indicator species. *Elymus spicatus* generally occurs with < 10% cover and *Festuca idahoensis* with > 10% cover. *Selaginalla* spp. are common in low to moderate abundance.

Environment. This association occurs between 1,880 and 2,100 m elevation on sites with 30 to 50% slope. This association occupies slightly steeper slopes and lower elevations than the *Festuca idahoensis/Elymus spicatus* association generally does, but similar, though often more compact, ranges of all other modeled environmental gradients. This soil temperature regime is generally cryic, the soil moisture regime is generally ustic and the soil moisture subclass is generally typic and occasionally ustic. Soils were deep and formed from granitic, conglomerate and andesite colluvium and till. Soils were classified as Ustic Haplocryolls, Ustic Haplocralfs and Pachic Argiustolls. The only other soils classified as Ustic soils occurred in samples of the *Festuca idahoensis/Elymus spicatus* association. All of the samples included in this association had not recently.

Other Classifications. Lesica (1993) described an *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* community type in the foothills and low elevation mountains of Line Creek Plateau in the Beartooth Mountains that is compositionally similar to the type described here. Lesica (1993) noted that the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* is highly intermixed with *Pinus flexilis* woodland.

Samples in this association were also all classified to the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type described by Mueggler and Stewart (1980). The high abundance of *Artemisia tridentata* var. *vaseyana* and other similarities in species composition indicate that the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type identified by is very similar to the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* association identified here.

The *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type (Mueggler and Stewart, 1980) is considered a moderately mesic shrubland type and is found almost exclusively south of 46°30' latitude in western Montana between 1,800 and 2,400 m elevation on slopes of <40% . It is characterized by the presence and dominance *Artemisia tridentata* var. *vaseyana* in the shrub layer and *Festuca idahoensis* in the graminoid layer. *Elymus spicatus* and *Koeleria cristata* are consistently associated graminoid species. *Geum triflorum* is the most consistent and generally abundant forb. *Chrysothamnus* spp. and *Artemisia frigida* may occur in drier portions of this habitat type.

Cluster 4: *Festuca idahoensis-Elymus spicatus* (FEID-PSSP6) Association (n=11)

Vegetation. This association is dominated by *Festuca idahoensis* in the graminoid layer (>10%). *Elymus spicatus* is also consistently present but always occurs with lower abundance than *Festuca idahoensis*. *Artemisia tridentata* var. *vaseyana* is commonly present in low abundance in the shrub layer. *Antennaria microphylla* and *Artemisia frigida* are consistently associated and well represented. *Selaginella* spp. are also common in low to moderate abundance.

Environment. This is the most common shrubland/grassland association identified in this analysis. It occurs between 1,800 and 2,200 m elevation on all aspects and slopes. The soil temperature regime and soil moisture regime are generally either cryic and udic or frigid and ustic. The soil moisture subclass is either typic or ustic. Soils represented in the association ranged from shallow to deep, were formed from metamorphic, granitic, limestone, andesite or mixed colluvium and alluvium and spanned the widest range of soil classifications. This association occurs at generally higher elevations than the *Festuca idahoensis/Geranium viscosissimum* and *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* associations and at similar elevations to the *Elymus spicatus/Artemisia frigida* association. The *Elymus spicatus/Artemisia frigida* association is generally warmer, drier and found on steeper slopes than *the Festuca idahoensis/Elymus spicatus* association. The *Festuca idahoensis/Elymus spicatus* association was observed in both burned and unburned portions of the study area.

Other Classifications. Lesica (1993) described an *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type for Line Creek Plateau. He found *Festuca idahoensis, Elymus spicatus, Agropyron dasystachyum* and *Stipa comata* were the most commonly associated graminoids, *Cerastium arvense, Lupinus sericeus* and *Balsamorhiza incana* were the most commonly association forbs and *Artemisia frigida* was the most commonly associated subshrub species. Lesica (1993) noted that this habitat type is intermixed with *Pinus flexilis* woodland types and would likely become a Pinus flexilis community under atypically long fire-free intervals.

Samples of this association were also classified to the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* and *Festuca idahoensis-Elymus spicatus* habitat types described by Mueggler and Stewart (1980). Due to recent fires, several sites classified as the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type had low cover of *Artemisia tridentata* var. *vaseyana* leaving the existing vegetation compositionally more similar to the *Festuca idahoensis/Elymus spicatus* habitat type.

Cluster 5: *Elymus spicatus/Artemisia frigida* (PSSP6/ARFR4) Association (n=4)

Vegetation. This association is characterized by the dominance and abundance of *Elymus spicatus*, which clearly dominates the graminoid layer (> 10%), the presence of *Hesperostipa comata* in the graminoid layer and the presence of *Artemisia frigida* in the shrub layer. *Artemisia frigida* occasionally becomes well represented while *Hesperostipa comata* cover is always low. *Packera cana, Tragopogon dubius, Zigadenus venenosus*

var. *gramineus* and *Artemisia tridentata* var. *vaseyana* are consistently present in low abundance.

Environment. This is the warmest and driest association occurring between 1,900 and 2,200 m elevation. It is most commonly found on south, southwest and southeast-facing simple linear slopes with 20 to 70% slope. Although it occupies similar environmental ranges as the *Festuca idahoensis-Elymus spicatus* association, it occurs on steeper slopes with lower mean total precipitation. The soil temperature regime is frigid, the soil moisture regime is ustic and the soil moisture subclass is aridic or typic. The soil particle size is loamy skeletal, fine loamy or sandy skeletal. Soils were classified as Aridic Argiustolls, Aridic Haplustalfs, Lithic Haplustolls and Typic Cryorthents. The only soils classified as Aridic in the study area occurred in this association, as did one of two soils classified as Lithic and one of two classified as an entisol. In general, the soils in this association are drier and less developed than in other associations.

Other Classifications. Samples included in this association were classified to either the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type or the *Festuca idahoensis/Elymus spicata* habitat type using Mueggler and Stewart (1980). None was classified to the *Artemisia tridentata* var. *vaseyana/Elymus spicatus* type identified by Mueggler and Stewart (1980) due to the prevalence of *Festuca idahoensis* with at least 5% cover. In several instances, the eventual dominance of *Artemisia tridentata* var. *vaseyana* was inferred due to trace abundance in the current composition and evidence of a recent burn and/or the presence of burned *Artemisia tridentata* var.

vaseyana stumps in the plot. These samples were classified to the *Artemisia tridentata* var. *vaseyana* series (Mueggler and Stewart, 1980). Only one of the plots in this cluster was completely lacking *Artemisia tridentata* var. *vaseyana*. This site was identified as the *Festuca idahoensis-Elymus spicatus* habitat type. However, due to the unusually high abundance of *Elymus spicatus* (>20%) in these samples, the consistently low abundance of *Festuca idahoensis,* the implied eventual dominance of *Artemisia tridentata* var*. vaseyana* and the presence of *Artemisia frigida*, I suspect that this association represents a drier version of the *Artemisia tridentata* var. *vaseyana*/*Elymus spicatus* habitat type described by Mueggler and Stewart (1980).

The *Artemisia tridentata* var. *vaseyana/Elymus spicatus* (*Artemisia tridentata/Agropyron spicatum*) habitat type is dominated by *Artemisia tridentata* var. *vaseyana* in the shrub layer (~15%) and *Elymus spicatus* in the graminoid layer (Mueggler and Stewart, 1980). Low shrubs, such as *Artemisia frigida* and *Gutierrezia sarothrae*, are usually present. *Koeleria cristata, Poa sandbergii, Stipa comata* and *Bouteloua gracilis* are consistently associated graminoids. *Artemisia frigida, Gutierrezia sarothrae*, *Poa sandbergii* and *Bouteloua gracilis* are increasors following grazing. The *Artemisia tridentata* var. *vaseyana/Elymus spicatus* (*Artemisia tridentata/Agropyron spicatum*) habitat type is a moderately arid type found on shallow to moderately deep soils from 1,200 to 1,800 m (4,000 to 6,000 ft).

The *Elymus spicatus/Artemisia frigida* association occurs at elevations more similar to the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type described by Mueggler and Stewart (1980), but is more similar to the *Artemisia tridentata*

var. *vaseyana/Elymus spicatus* (*Artemisia tridentata/Agropyron spicatum*) habitat type in all other respects. Both the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type and the *Festuca idahoensis/Elymus spicata* habitat type are described as being characteristically wetter.

None of the samples was classified to Mueggler and Stewart's (1980) *Elymus spicatus/Agropyron smithii* habitat type or their *Festuca idahoensis-Agropyron smithii* habitat type, but several exhibited similar vegetation composition characteristics. *Elymus spicatus* is dominant in the *Elymus spicatus-Agropyron smithii* community type and *Festuca idahoensis* is dominant in the *Festuca idahoensis-Agropyron smithii* habitat type. Both generally have an abundance of rhizomatous wheatgrasses (*Agropyron smithii* and/or *Agropyron dasystachyum*) and *Poa cusickii, Koeleria cristata* and *Artemisia frigida* are commonly represented. *Gutierrezia sarothrae* is commonly present or abundant in *Elymus spicatus/Agropyron smithii* habitat type, while *Phlox hoodii, Gaillardia aristata*, *Antennaria rosea* and *Achillea millefolium* are the most consistent and prominent forbs in the *Festuca idahoensis-Agropyron smithii* habitat type. Both types occur most frequently east of the Continental Divide between 1,200 and 1,800 m elevation and are considered moderately arid habitat types.

Discussion

Five grassland and shrubland associations were identified using cluster analysis performed on vegetation composition data from 24 grassland/shrubland samples. The grassland/shrubland associations classified and described here are well-resolved, as was

evidenced by optimization of geometric criteria, identification of ecologically meaningful indicator species, reasonable separation of associations on NMDS ordinations and the representation of unique habitat type ensembles in each association. The similarities observed between newly described associations and previously described habitat types provide additional confidence that the grassland/shrubland samples of the Beartooth Mountains study area were classified into distinct, repeating and identifiable plant associations.

The *Alyssum alyssoides/Balsamorhiza sagittata* association was observed on the warmest and driest sites on southeast-facing slopes. Soils of both samples in this association were classified as Pachic Haplustolls. Both samples in this association were classified to the *Artemisia tridentata* var. *vaseyana/Elymus spicatus* habitat type, which is considered a moderately arid type, using Mueggler and Stewart (1980). This association may represent an early seral and/or disturbed version of Mueggler and Stewart's (1980) *Artemisia tridentata* var. *vaseyana/Elymus spicatus* habitat type.

The *Festuca idahoensis/Geranium viscosissimum* association is characterized by the dominance of *Poa pratensis* and *Elymus spicatus* in the graminoid layer along with the presence, not dominance, of *Festuca idahoensis*. This association occurs at slightly lower elevations than the *Festuca idahoensis-Elymus spicatus* association, on sites that receive approximately the same amount of precipitation, but is restricted to northeast and east-facing sites with < 35% slope. All samples included in this association were classified to the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type-*Geranium viscosissimum* phase using Mueggler and Stewart (1980). Similarities in

species composition and environment indicate that the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type-*Geranium viscosissimum* phase described by Mueggler and Stewart (1980) is very similar to the *Festuca idahoensis/Geranium viscosissimum* association described here, with the exception that samples included in the *Festuca idahoensis/Geranium viscosissimum* association experienced recent burns, resulting in the low abundance or absence of *Artemisia tridentata* var. *vaseyana*. The *Geranium viscosissimum* phase of the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type is characterized by increased graminoid richness and increased forb abundance, both of which are exhibited in the *Festuca idahoensis/Geranium viscosissimum* association. Both the *Festuca idahoensis/Geranium viscosissimum* association and the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type-*Geranium viscosissimum* phase are associated with northeast and east facing sites with <35% slope and are more common in deep soils. However, while the *Geranium viscosissimum* phase is reported to occur at the highest elevations and most mesic portions of the *Artemisia tridentata* var. *vaseyana*/*Festuca idahoensis* habitat types (Mueggler and Stewart, 1980), the *Festuca idahoensis*/*Geranium viscosissimum* association occurs at slightly lower elevations than both the *Festuca idahoensis-Elymus spicatus* and *Artemisia tridentata* var. *vaseyana*/*Festuca idahoensis* associations identified here.

The *Artemisia tridentata* var. *vaseyana / Festuca idahoensis* association is a well-classified association that is consistently dominated by *Artemisia tridentata* var. *vaseyana* (> 30% cover) in the shrub layer. *Pinus flexilis* is also commonly reproducing and was

identified as an indicator species of this association. *Elymus spicatus* generally occurs with < 10% cover and *Festuca idahoensis* with > 10% cover. The *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat described by Mueggler and Stewart (1980) is considered a moderately mesic shrubland type and is found almost exclusively south of 46°30' latitude in western Montana between 1,800 and 2,400 m elevation on slopes of <40%.

The *Festuca idahoensis-Elymus spicatus* association is dominated by *Festuca idahoensis* in the graminoid layer. *Elymus spicatus* is also consistently present in the graminoid layer, but always occurs with lower abundance. *Artemisia tridentata* var. *vaseyana* occurs occasionally in low abundance in the shrub layer. Using Mueggler and Stewart (1980), samples of this association classified to the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type and *Festuca idahoensis-Elymus spicatus* habitat type. Samples classified as the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type frequently had low cover of *Artemisia tridentata* var. *vaseyana* due to recent fires, leaving the existing vegetation compositionally more similar to the *Festuca idahoensis-Elymus spicatus* habitat type.

The *Elymus spicatus/Artemisia frigida* association is characterized by the dominance and abundance of *Elymus spicatus* and the presence of *Hesperostipa comata* and *Artemisia frigida* as frequent and minor components of the understory. This association occurs on the warmest and driest sites occupied by higher elevation grassland/shrubland associations. It most commonly occurs on steep slopes with southerly aspects. Although it occupies similar environmental ranges as the *Festuca*

idahoensis-Elymus spicatus association, it occurs on steeper slopes with lower mean total precipitation. Samples included in this association were classified to either the *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* habitat type or the *Festuca idahoensis-Elymus spicatus* habitat type using Mueggler and Stewart (1980). None was classified to the *Artemisia tridentata* var. *vaseyana/Elymus spicatus* habitat type identified by Mueggler and Stewart (1980) due to the prevalence of *Festuca idahoensis* with at least 5% cover, though samples may better fit descriptions of this habitat type.

The *Alyssum alyssoides/Balsamorhiza sagittata* association occupies the lowest elevation sites, experiences the highest average daily temperatures and represents relatively low ranges of relative effective annual precipitation, second only to the *Elymus spicatus/Artemisia frigida* association. The *Festuca idahoensis/Geranium viscosissimum* association occurs at the lowest elevations on sites spanning higher relative effective annual precipitation ranges and lower slope percents than the *Alyssum alyssoides/Balsamorhiza sagittata* association, which occupies similar ranges of all other measured and modeled continuous environmental variables. The *Festuca idahoensis/Geranium viscosissimum* and *Alyssum alyssoides/Balsamorhiza sagittata* associations occurred only in the northeast quadrant of the study area (Figure 2.12). The *Elymus spicatus/Artemisia frigida* association spans the same elevation range as the *Festuca idahoensis-Elymus spicatus* association, but occurs on generally steeper slopes. The *Festuca idahoensis-Elymus spicatus* and *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* associations both occupy sites receiving the highest total annual precipitation and spanning the highest relative effective annual precipitation ranges. While the

Festuca idahoensis-Elymus spicatus association occurs on sites receiving the highest annual solar exposure levels, it also occurs on sites with the lowest average daily temperatures and growing degree days, or shortest growing season, of all five grassland/shrubland associations.

Lesica (1993) suggested that the observed mosaic of grasslands, shrublands and *Pinus flexilis* woodlands at low elevations of Line Creek Plateau in the Beartooth Mountains is predominantly the result of fire. He hypothesized that the foothills would likely become dominated by *Pinus flexilis* woodland in the absence of fire. While I do not intend to conduct such a study here, it would be interesting to use historical fire data to determine if any correlation can be found between existing shrubland/grassland association/habitat type and time since and frequency of past fires. Such a study would require combining samples identified as *Pinus flexilis* woodland in Chapter 3 with those identified as grassland and shrubland samples here in Chapter 2.

Conclusion

The goal of this chapter was to classify and describe the grassland and shrubland associations of the Beartooth Mountains study area, located in south central Montana, and to compare newly derived grassland and shrubland associations with existing habitat type classifications for ecologically relavent regions in Montana. Samples were well classified, as was evidenced by optimization of geometric criteria, the identification of indicator species with meaningful ecological value and by the representation of unique, consistent and meaningful habitat type classification ensembles within each association.

Further attention should be paid to the spatial distribution of shrubland, grassland and woodland associations at low elevations as the mosaic seems to be strongly driven not only by changing environmental gradients but by the nature and periodicity of disturbance.

Literature Cited

Bray, J.R. and Curtis J.T. 1957. An ordination of the upland forest communities of Southern Wisconsin. Ecological Monopraphs. 27:325-349.

Choate, C.M.; Habeck, J.R. 1967. Alpine plant communities at Logan Pass, Glacier National Park, Montana. Proceedings of the MontanaAcademy of Sciences. 27: 36-54.

Cleland, D.T., Avers, P.E., McNab, W.H., Jensen, M.E., Bailey, R.G., King, T. and Russell. W. F. 1997. Chapter Nine: National Hierarchical Framework of Ecological Units. *Ecosystem Management: Applications for Sustainable Forest and Wildlife Resources.* Library of Congress Cataloging-in-Publication Data. Yale University, USA.

Daubenmire, R. F. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecological Monographs 22: 301-330.

Daubenmire, R. 1966. Vegetation: Identification of typal communities. Science 151(3708): 291-298.

Dorn, R.D. 1977. *Manual of the vascular plants of Wyoming*. Garland Publishing, NY.

Dorn, R. D. 1984. *Vascular plants of Montana*. Mountain West Publishing, Cheyenne, WY.

Dufrêne, M., and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67: 345-366.

Gordon, A.D. 1999. *Classification*. 2nd Edition. Chapman & Hall/CRC, Boca Raton, FL.

Haskins, D.M., Correll, Cynthia, S., Foster, R.A., Chatoian, J.M., Fincher, J.M., Strenger, S., Keys, J.E., Maxwell, J.R. and King, T. 1998. A Geomorphic Classification System. USDA Forest Service Department of Agriculture. Version 1.4.

Hitchcock, C.L., and Cronquist, A. 1973. *Flora of the Pacific Northwest*. University of Washington Press, Seattle, WA.

Jennings, Michael D., Faber-Langendoen, D., Loucks, O.L., Peet, R.K., Roberts, D. 2009. Standards for associations and alliances of the U.S. National Vegetation Classification. Ecological Monographs, 79(2): 173-199.

Johnson, P.L. and Billings, W.D. 1962. The alpine vegetation of the Beartooth Plateau in relation to Cryopedogenic processes and patterns. Ecological Monographs 32: 105-135.

Kaufman, L. and Rousseeuw, P.J. 1990. Finding groups in data: an introduction to cluster analysis. John Wiley & Sons, Inc, NY.

Kenkel, N.C., Juhasz-N.P., Podani, J. 1989. On sampling procedures in population and community ecology. Vegetatio. 83: 195-207.

Kruskal, J.B. and Wish, M. 1978. Multidimensional Scaling. Sage University Paper series on Quantitative Applications in the Social Sciences, number 07-011. Sage Publications, Newbury Park, CA.

Kruskal, W.H. and Wallis, W.A. 1952. Use of Ranks in One-Criterion Variance Analysis. Journal of the American Statistical Association. 47 (260): 583-621.

Lavin, M. and Seibert, C. 2011. Grasses of Montana. Montana State University Herbarium. Department of Olant Sciences and Plant Pathology. Bozeman, MT

Lesica, P. 1993. Vegetation and flora of the Line Creek Plateau Area, Carbon County, Montana. Unpublished report to U.S. Forest Service. Montana Natural Heritage Program. Helena. 30 pp.

Mueggler, W.F. and W.L. Steward. 1980. Grassland and Shrubland Habitat Types of Western Montana. USDA Forest Service General Technical Report INT-66, Odgen, Utah.

Roberts, D.W. 2007. labdsv: Ordination and Multivariate Analysis for Ecology. R package version 2.11.1.

Roberts, D.W. 2011. optpart: Optimal partitioning of similarity relations. R package version 2.11.1.

Pfister, R.D., and Arno, S.F. 1980. Classifying forest habitat types based on potential climax vegetation. Forest Science 26: 52-70

Pfister, R.D., Kovalchik, B.L., Arno, S.F. and Presby, R.C. 1977. Forest Habitat Types of Montana. USDA Forest Service General Technical Report INT-34, Ogden, Utah.

R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Shoeneberger, P.J., Wysocki, D.A., Benham, E.C., Broderson, W.D. (ed.). 2002. Field book for describing and sampling soils. Version 2.0. USDA-NRCS, National Soil Survey Center. Lincoln, NE.

Silhouette, cluster package for R, Maechler, M., Rousseeuw, P., Struyf, A., Hubert, M. (2005). Cluster Analysis Basics and Extensions; unpublished

Spribille, T., Stroh, H.G. & Triepke, F.J. 2001. Are habitat types compatible with floristically-derived associations? Journal of Vegetation Science. 12: 791-796.

Steele, R., Cooper, S.V., Ondov, D.M., Roberts, D.W. & Pfister, R.D. 1983. Forest Habitat Types of Eastern Idaho-Western Wyoming. USDA Forest Service Intermountain Research Station General Technical Report INT-144, Ogden, UT.

Vaseth, R. and C. Montagne. 1980. *Geologic parent materials of Montana Soils*. Montana Agricultural Experiment Station Bulletim 721, Bozeman, MT.

Venables, W. N. & Ripley, B. D. (2002) Modern Applied Statistics with S. Fourth Edition. Springer, New York. ISBN 0-387-95457-0

Wells, A. 1998. Custer National Forest National Cooperative Soil Survey and Terrestrial Ecological Unit Inventory: Pre-Mapping, Preliminary Data Analysis, and Study Design Development. Unpublished document.

Wilson, J.B. 1991. Does vegetation science exist? J. Veg. Sci. 2: 289-290.

Winters, E., Fallon, D., Haglund, J., DeMeo, T., Nowacki, G., Tart, D., Ferwerda, M., Robertson, G., Gallegos, A., Rorick, A., Cleland, D.T., Robbie, W. 2005. Terrestrial Ecological Unit Inventory technical guide. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington, DC: U.S. Department of Agriculture. Forest Service. Washington Office, Ecosystem Management Coordination Staff. 245p.

Wood, 2004. mgcv: GAMs with GCV/AIC/REML smoothness estimation and GAMMs by PQL. R package version 2.7-10.

CHAPTER 3

CLASSIFICATION OF WOODLAND AND FORESTED VEGETATION ASSOCIATIONS OF THE BEARTOOTH MOUNTAINS STUDY AREA AND COMPARISON WITH EXISTING WOODLAND AND FORESTED HABITAT TYPE CLASSIFICATIONS

Contribution of Authors and Co-Authors

Manuscripts in Chapters 2, 3, 4

Chapter 3:

Author: Kristin L. Williams

Contributions: Supervised and conducted field data collection activities, managed and analyzed data and wrote the manuscript.

Co-author: Dave W. Roberts

Contributions: Obtained funding, supervised project, provided statistical consultation and edited text at all stages of manuscript development.
Journal to be submitted to: *Western North American Naturalist*

Manuscript Information Page

- Kristin L. Williams and Dave W. Roberts
- *Western North American Naturalist*
- Status of manuscript (check one)
  _x_Prepared for submission to peer-reviewed journal
  ___Officially submitted to peer-reviewed journal
  ___Accepted by a peer-reviewed journal
  ___Published in a peer-reviewed journal

Abstract

The objective of this chapter was to classify and describe the woodland and forested vegetation associations found in the Beartooth Mountains study area. Twelve woodland/forested associations were classified and described in this analysis. As elevation increased, the overstory generally transitioned through *Pinus flexilis*, *Pseudotsuga menziesii* var. *glauca*, *Abies lasiocarpa, Pinus contorta* var. *latifolia*, *Picea engelmanii* and *Pinus albicaulis* dominated associations. *Pinus ponderosa* was conspicuously absent from the study area. Newly described associations were then compared to woodland and forested habitat types previously classified and described for adjacent forest lands, including: Forest Habitat Types of Montana (Pfister et al., 1977) and Forest Habitat Types of Eastern Idaho-Western Wyoming (Steele et al., 1983) and associations described for Line Creek Plateau in the Beartooth Mountains study area (Lesica, 1993). Finally, I created an ammended dichotomous key to previously described habitat types observed in the study area and a dichotomous key to the woodland and forested associations identified in this analysis.

Introduction

Vegetation ecologists commonly seek to characterize plant species distributions across the landscape. The recurrence of similar plant assemblages wherever the net influence of climate, soil, animal, disturbance and time factors have provided roughly equivalent environments was recognized early in vegetation studies (Daubenmire, 1966). Due to changing climate regimes and increasing demands placed on natural resources, the documentation and classification of vegetation, as tools for organizing and interpreting ecological information and context, are integral to biological conservation, resource management and scientific research (Pfister and Arno, 1980; Jennings et al., 2009).

Classification is the art and science of grouping objects considered to be similar in some respect (Kaufman and Rousseeuw, 1990; Gordon, 1999). In vegetation studies, researchers generally classify samples based on some aspect of floristic composition. Habitat types and community type associations are the most commonly used basic hierarchical units of floristic composition analysis (Spribille et al., 2001) in the western United States. Habitat types seek to classify land based on the vegetation composition sites are capable of supporting in late succession (Daubenmire, 1952; Pfister and Arno, 1980). The late succession association of plants characteristic of a habitat is referred to as the potential natural vegetation (PNV). Community types seek to classify vegetation associations based on existing species composition, regardless of a sites potential to support a particular late seral or climax association. As such, a single community type may include samples classified to multiple habitat types, depending on the nature, frequency and distribution of stand-altering disturbances in the landscape. The recent

resurgence of interest in vegetation classification and adoption of U.S. National Vegetation Classification (NVC) standards for associations and alliances (Jennings et al., 2009) has renewed interest in the theory behind and relative ecological usefulness of both frameworks.

The habitat type classification system is based on plant succession theory, a basic tenet of which states that the most shade tolerant or "climax" species present in a stand will eventually dominate in the absence of disturbance. Samples are first divided into 'series' comprised of stands with the same indicated climax tree species (Daubenmire, 1952, Pfister and Arno, 1980, Steele et al., 1981). Even if the indicated climax tree species occurs in low abundance, its presence alone is indicative of the successional trajectory of the stand. Series represent major environmental differences reflected by the distributions of climax tree species. Habitat types are subdivisions of series that represent environmental differences represented by total vegetation composition (Pfister and Arno, 1980). While a given habitat type should reflect all land areas capable of supporting the same potential natural vegetation association in late succession, it is not necessarily a reflection of similarities in existing vegetation between samples (Pfister and Arno, 1980).

Classification by community type association uses the floristic characteristics of species assemblage and abundance to group samples with similar composition and physiognomy into clusters that are consistently recognizable using diagnostic features (Jennings et al., 2009). NVC defines plant associations as "a vegetation classification unit defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions, and physiognomy (Jennings et al., 2009)."

Alliances are conceptually similar to 'series' and are defined by NVC (Jennings et al., 2009) as "a vegetation classification unit containing one or more associations, and defined by a characteristic range of species composition, habitat conditions, physiognomy, and diagnostic species, typically at least one of which is found in the uppermost or dominant stratum of the vegetation."

The habitat type concept emphasizes the diagnostic potential of climax-dominant species and uses the presumed climax development to assign samples to series (and land to habitat types) regardless of existing vegetation. The association/alliance concept emphasizes the composition of existing vegetation (Jennings et al., 2009; Pfister and Arno, 1980). NVC associations and habitat types are likely similar in stands where the potential climax species have attained dominance. In stands where the climax species remains subordinate to a seral species, ecologically interesting discrepancies between NVC associations and habitat types are bound to emerge (Jennings et al., 2009).

The primary objective of this chapter was to classify the vegetation of mid-elevation forested community associations of the Beartooth Mountains study area into compositionally and ecologically distinct associations. Samples were also classified to habitat type using existing habitat type classifications relevant to the Beartooth Mountains study area, specifically Forest Habitat Types of Montana (Pfister et al., 1977) and Forest Habitat Types of Eastern Idaho-Western Wyoming (Steele et al., 1983). In order to use and compare habitat type and community type classifications in the field, I created an amended dichotomous key to habitat types, including only those types observed in the Beartooth Mountains study area, as well as a dichotomous key to the

newly classified community types identified in this chapter. Finally, I provided a description of the characteristic vegetation composition and environmental variability found in each community type and compared my community type descriptions with the forested habitat types described by Steele et al. (1983) and Pfister et al. (1977) and the community type associations previously identified by Lesica (1993) for Line Creek Plateau in the Beartooth Mountains study area.

Study Area

The Beartooth Mountains study area is dominated by forested and woodland vegetation between the perimeter of the high elevation plateaus and lower elevation foothills, where *Pinus flexilis* woodlands intermix with *Artemisia tridentata* var. *vaseyana* shrublands and *Festuca idahoensis-Elymus spicatus* grasslands. At middle and upper elevations, soils are predominately weathered from coarse hard-grained metamorphic gneiss and granitics (Chapter One, Figure 1.3). However, inclusions of sedimentary parent materials also occur at high elevations, though soils derived from sedimentary parent materials are much more common at lower elevations (Chapter One, Figure 1.3).

The Beartooth Mountains experience a continental climate regime that is characterized by hot, dry summers and cold, wet winters. Winds are predominantly from the west, resulting in both large and fine-scale moisture gradients (Johnson and Billings, 1962, Lesica, 1993). On a large scale, the western portion of the study area receives more precipitation than the eastern portion due to orographic effects. On a smaller scale, windward west-facing slopes are blown free of snow while lee east-facing slopes receive

additional snow accumulation (Johnson and Billing, 1962, Lesica, 1993). The timing and form in which precipitation is received also changes along a gradient trending from north to south. The northern portion of the study receives the majority of annual precipitation during the months of March, April, May and June in the forms of snow and rain, while the southern portion of the study area receives precipitation during the months of November, December, and January primarily in the form of snow (Wells, 2008).

In the lowest elevations of the forested zone of the study area, *Pinus flexilis* woodlands are intermixed with *Artemisia tridentata* var. *vaseyana* shrublands and *Festuca idahoensis-Elymus spicatus* grasslands. *Pinus flexilis* can also occur at high elevations on limestone parent material. *Pseudotsuga menziesii* var. *glauca* is often the indicated forest climax on warmer, more sheltered slopes than those occupied by *Pinus flexilis* at low elevations. Forests with an abundance of *Pinus contorta* var. *latifolia* are common between lower and upper timberline, with abundance generally decreasing as elevation and exposure increase. At mid and upper elevations, *Abies lasiocarpa* is often the indicated climax species. *Picea engelmannii* can become the indicated climax in extremely cold and/or wet forested sites. Near upper timberline, *Pinus albicaulis* becomes dominant and *Abies lasiocarpa* and *Picea englemannii* become stunted and/or subdominant.

These forest types all experienced frequent fires prior to the commencement of fire suppression (Lesica, 1993). *Pseudotsuga menziesii* var. *glauca/Physocarpus malvaceus, Pseudotsuga menziesii* var. *glauca /Juniperus communis* var. *depressa* and *Abies lasiocarpa/Arnica cordifolia* habitat types are prone to low intensity, stand-

thinning fires (Fischer and Clayton, 1993). In the absence of fire, forests representing these habitat types can become overstocked and the possibility of stand-replacing fires is increased. Forests of the *Abies lasiocarpa/Vaccinium scoparium* habitat type have a stand-replacing fire interval of ca. 50-100 years (Fischer and Clayton, 1983). Growth in these stands is typically slow. The continued dominance of *Pinus contorta* var. *latifolia* in this habitat type indicates that decreased fire frequency has not yet seriously impacted succession dynamics in the Beartooth Mountains (Lesica, 1993). The drier, limestone-dominated eastern periphery has a higher occurrence of *Pinus flexilis* woodland grading into *Pseudotsuga menziesii* var. *glauca* forests at higher elevations. It is likely that these shrubland-forest ecotones had higher fire frequencies prior to suppression (Arno and Gruell, 1983). Due to the predominance of steep slopes in the forest zone, extensive representations of riparian communities are rare or absent (Lesica, 1993).

Methods

Study Design

The data were collected for the purposes of a United States Forest Service (USFS) and Natural Resource Conservation Service (NRCS) collaborative inventory/mapping project called a Terrestrial Ecological Unit Inventory (TEUI). TEUI's are an attempt to produce large scale, consistent and integrated ecosystem inventory, classification and mapping management tools for all public lands nationwide. The TEUI approach to land classification and mapping is based on a National Hierarchy of Ecological Units, a hierarchical land unit classification system within which soil and vegetation map units are

nested (Cleland, 1997). The National Hierarchy classification system begins by grouping land areas into broad classes based on large-scale climatic and physiographic factors. More detailed, nested categories are then classified based on systematically smaller-scale climatic, geological, geomorphic, vegetative, and topographic factors (Winthers et al., 2005). The lowest nested category is called an 'ecological unit'. Each ecological unit represents a unique combination of geologic, climatic, geomorphologic and topographic characteristics.

Field seasons were restricted to the weeks between mid June and late August due to persistent spring snowpack and early snowfall in the late summer/early fall. The study area was pre-stratified into ecological units using TEUI protocol, vegetation data were collected according to TEUI protocol and soil samples were collected according to NRCS standards and protocol.

Plot locations were selected to reflect all dominant and characteristic vegetation types of each ecological unit prior to sampling. Dominant community types within each unit were estimated using aerial photos, satellite imagery and topographic maps. Plots were distributed within each ecological unit to represent the diversity of slopes, elevations, aspects and dominant community types in each ecological unit. Special attention was also paid to the distribution of sample plots across larger environmental gradients, such as the prevalent west to east moisture gradient, within each ecological unit.

This extensive stratification process reflects the ongoing efforts of ecologists to standardize protocol and satisfy the principles and procedures of classical sampling

theory. While many of the fundamental principles (e.g. randomization) underlie all sampling decisions, it is also important to recognize that the objectives of an ecological study may differ considerably from objectives studied using classical theory (Kenkel et al., 1989). Specifically, classical theory is concerned with the estimation of population parameters of discrete, recognizable units while vegetation ecology is concerned with the recognition of patterns in community assemblage and distribution where the sampling unit (i.e. a plot) is arbitrarily defined (Kenkel et al., 1989).

Plot Selection

Once arriving at the target plot coordinates, field researchers confirmed that the plot position represented uniformity of environment, was large enough to include normal species composition and had homogenous vegetation throughout. Obvious ecotones were not sampled. Within the stratified sampling protocol, characteristics were identified for each target sample plot, including: desired slope percent, aspect and vegetation community type. If the site is not representative of the dominant community type, slope percent and aspect value specified the field technicians moved the sample plot to the closest plot center reflecting target parameters. If a plot reflecting the target parameters could not be found, the sample plot was either not collected or an alternate plot was chosen to reflect the dominant vegetation observed at or close to the target sample plot position.

Plot Size

In order to more accurately estimate tree cover on sites of varying slope percent, vegetation data were collected using variable-radius macroplots and variable-radius microplots. All variable-radius macroplots have a minimum radius of 11.35 m, resulting in a 405 m^2 ($1/10^{th}$ of an acre) area plot. All variable-radius microplots have a minimum radius of 2.1 m, resulting in a 6.6 m^2 area plot. Radius length was increased proportionally with slope percent.

Vegetation Data

All species occurring within the perimeter of the community macroplot were recorded and their abundance estimated. Since plants show huge plasticity between individuals and it is often impossible to define an individual, abundance of each species can be effectively and efficiently characterized using aboveground canopy cover estimates (Wilson, 1991). Canopy cover is defined as the percentage of ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage of plants where small openings within the canopy are included in the cover estimate (Winthers et al., 2005). Cover was estimated according to the following classes:

- 0.1 = "trace" = species with less than 1 percent cover (1% = 1.1m radius).
- The nearest 1 percent for species with cover between 1 and 10 percent.
- The nearest 5 percent for species with cover between 10 and 30 percent cover.
- The nearest 10 percent for species with cover exceeding 30 percent cover.

Using the same cover classes, cover was recorded separately for each lifeform category. Lifeform categories include: graminoid (GR), forb (FB), shrub (SH), and tree

(TR and TO). Tree layer subcategories were defined by height (TR: <=2.0 m, TO: >2.0 m). The possibility of overlap between tree sublayers requires that overstory and regeneration cover for each tree species be estimated or measured directly, not calculated by summing the sublayer cover values.

Plant Taxonomy Considerations

Plants were primarily identified using Plants of Wyoming (Dorn, 1977). Where the collected species could not be identified using Plants of Wyoming (Dorn, 1977), Plants of Montana (Dorn, 1984) was used. For particularly difficult identifications, several floras were consulted, including: Flora of the Pacific Northwest (Hitchcock and Cronquist, 1963), The Intermountain Flora (various authors, various years) and Grasses of Montana (Lavin and Seibert, 2011). NRCS species codes were recorded according to Dorn's taxonomy where possible. Where no NRCS code was available for Dorn's taxonomy, the NRCS synonym code was used. When referencing species belonging to associations, community types or habitat types described by other authors, the taxonomy used in the original publication was retained.

Soil Data Collection

Soil pedon data were collected according to NRCS standards using codes and procedures outlined in the NRCS publication Field Book for Describing and Sampling Soils (Shoeneberger et al., 2002). Geologic information was collected according to the standards in Forest Service Manual 2881. Surficial geology, origin and kind were identified using the terms and definitions listed in the FRIS Terra data dictionary.

Geomorphic information was collected to the standards in A Geomorphic Classification System (Haskins et al. 1998).

A soil pit was dug near the center of each macroplot in an area that appeared to be representative of the soils supporting the target vegetation. All soil pits were dug to a depth of 1 m where possible. If lithic contact was made prior to reaching 1 m, the type of lithic layer contacted and depth to contact was recorded.

Soil horizons were identified and the depth, texture, color (either wet or dry but must be indicated) and pH were recorded for each. Textures included texture modifiers, such as: percent gravel, cobble, stone, boulder, etc. Additionally, root pore percentage, clay film percentage, calcium carbonate accumulation and redoximorphic features were estimated within each horizon. Where redoximorphic and/or calcium carbonate features were observed, the beginning depth and end depth of that feature were recorded along with color classes specific to the feature. Finally, soil was classified using the NRCS soil classification system.

A soil sample was collected from each soil horizon and the organic horizon. Samples were chosen to be representative of the horizon they were taken from and included samples of gravel or cobble, calcium carbonate accumulations or redoximorphic features were encountered. Soil horizon samples were organized into soil profile boxes in order of horizon. A total of ten representative samples was sent to the lab for analysis. These samples were used as quality control to confirm the textures, colors, pHs and soil classifications determined by soil technicians in the field.

Environmental Site Data

In addition to vegetation composition and soil data, descriptive documentation and environmental gradient characteristics were collected at each site. There are no NRCS Snotel stations within the boundaries of the study area. In order to evaluate the distribution of plant community associations with respect to climatic gradients occurring within the study area, climate variables were modeled using climate data from nearby Snotel sites, including: Beartooth Lake, WY, Burnt Mtn., MT and Cole Creek, MT. The Snotel station at Beartooth Lake provides a good approximation of the climate at high elevations and the stations at Burnt Mtn. and Cole Creek provide a good approximation of the climate at lower elevations (Chapter One, Figure 1.2). Modeled variables include: relative effective annual precipitation (REAP), total precipitation (TOTPRCP), growing degree days (GRDEGDAY), average daily temperature (DAVTEMP) and annual solar exposure (SOLAR).

Relative effective annual precipitation (REAP) uses precipitation, slope, aspect and soil properties to indicate the amount of moisture available at a given location. As such, two sites receiving the exact same annual precipitation may have very different effective precipitation due to other site factors. Total annual precipitation (TOTPRCP) is calculated by summing the inches of precipitation received, either as snow or rain, in a year. Growing degree days (GRDEGDAY) are calculated by subtracting a base temperature (usually 10°C) from the average of the daily maximum and minimum temperatures of a location. The minimum temperature is bounded by the base temperature and the maximum temperature is generally bounded by 30°C, as most plants

grow in this range. The annual GRDEGDAY is calculated by summing daily GRDEGDAY. Growing degree days (GRDEGDAY) is an indicator of both the length and warmth of the growing season of a location. Annual average daily temperature (DAVTEMP) is calculated by summing the monthly averages and dividing by 12. Monthly average daily temperatures are calculated by summing the daily maximum temperatures with the daily minimum temperatures and dividing by two. Annual average daily (DAVTEMP) is a rough estimate of the overall annual temperature of a location. The solar loading (SOLAR) variable estimates incoming solar electromagnetic radiation given latitude, slope and aspect information for the summer solstice in watt hours/m².

Measured and modeled environmental variables are identified as continuous and categorical variables and listed below.

Continuous:

- Northing Coordinate (UTM's)
- Easting Coordinate (UTM's)
- Elevation (m)
- SlopePercent (%)
- Aspect (°)
- Relative Effective Annual Precipitation (REAP)
- Total Annual Precipitation (TOTPRCP)
- Growing Degree Days (GRDEGDAY)
- Annual Solar Exposure (SOLAR)
- Average Daily Temperature (DAVTEMP)

Categorical:

- Topographic Position
- Primary Landform
- Vertical Slope Shape
- Horizontal Slope Shape
- Slope Complexity
- Geologic Parent Material
- Parent Material Kind

- Soil Depth
- Soil Particle Size
- Soil Temperature Regime
- Soil Moisture Regime
- Soil Moisture Sub-Class
- NRCS Soil Classification
- Disturbance History
- Potential Natural Vegetation Classification

Statistical Analysis

Two hundred vegetation community plots with associated soil profile pits were collected during the 2008 and 2009 summer field seasons. These two hundred sample plots were then divided into the following three groups based on physiognomy and elevation: low-elevation grassland/shrubland samples (<10% tree cover, < 2,500 m elevation), mid-elevation woodland and forested samples (>10% tree cover, all elevations), high-elevation alpine samples (<10% tree cover, > 2,500 m). The following is the analysis of the 105 samples identified as 'forested'. The vegetation data were analyzed using several multivariate techniques, including: cluster analysis, nonmetric multidimensional scaling ordinations (NMDS), summaries of the occurrence and significance of both continuous and categorical environmental variables and plant species cover and constancy tables by identified cluster. Multivariate statistics were performed in R (R Development Core Team, 2011).

The Bray-Curtix index (Bray and Curtis, 1957) was used to create a dissimilarity matrix of vegetation composition data for the alpine samples. Vegetation data were not transformed or standardized. Distance analysis (DISANA, labdsv package for R;

Roberts, 2011) was used to identify structure in the dissimilarity matrix and to identify plots that were highly dissimilar from all other plots (i.e outliers).

Cluster analysis was performed using OPTBEST (optpart package for R; Roberts, 2011) a fixed cluster, PARTANA optimizing algorithm (cluster library for R; Kaufman and Rousseeuw, 1990) and OPTSIL (optpart package for R; Roberts, 2011), a Silhouette width-maximizing reallocation algorithm performed on original BESTOPT models. STRIDE (optpart package for R; Roberts, 2011) plots were used to identify cluster number solutions likely to result in the maximization of geometric criteria (PARTANA ratio and Silhouette width).

Dufrêne and Legendre's (1997) indicator value algorithm, INDVAL, was used to assess the ecological significance of various clustering solutions. The algorithm determines indicator species by identifying those species exhibiting the highest constancy and fidelity in each cluster. Indicator values were calculated for each species as follows:

$$INDVAL_{ij} = A_{ij} \times B_{ij}$$

Where $INDVAL_{ij}$ is the indicator value of species *i* in sites of cluster *j,* A_{ij} is the relative mean abundance of species *i* in sites of cluster *j*, and B_{ij} is the frequency of occurrence of species *i* in sites of cluster *j*.

Final classifications were chosen based on the characteristics of: 1) high PARTANA ratios, 2) high Silhouette width averages, both within and across clusters, and 3) high ecological significance as determined by species indicator values. Communities were named using the two most abundant significant indicator species in each cluster,

unless otherwise described. If only one species was identified as an indicator species, only that species name was used in the cluster name.

The unconstrained ordination technique NMDS (Non-Metric Multidimensional Scaling; Kruskal and Wish, 1978) was applied to a Bray-Curtis dissimilarity matrix of vegetation community abundance data (labdsv package; Roberts, 2007, MASS package; Venables and Ripley, 2002). Environmental variables were evaluated for explanatory value using the D^2 values (defined below) of GAMs (generalized additive models, mgcv package for R; Wood, 2004) fit to the ordination in combination with the p- and chi-squared values obtained from a Kruskal-Wallis rank sum test. The D^2 value of deviance was defined as:

$$D^2 = (\text{null deviance} - \text{residual deviance}) / \text{null deviance}.$$

Results

Vegetation Compostion

A total of 356 plant species was recorded from 105 sample plots. Since I considered tree species growing in different strata separately, the data are composed of 363 unique species/strata entries. *Carex rossii* occurs on 66 plots and is the most frequent species (Table 3.1). *Pinus contorta* var. *latifolia* and *Pseudotsuga menziesii* var. *glauca* are the two most abundant species (Table 3.1.). The 10 most abundant species and 10 most frequent species are listed in Table 3.1 and Figure 3.1. Of the 363 unique species/strata, 79 occur in only one plot (Figure 3.1). Species richness ranges from 5 to

61, with a mean of 22.3 species per plot (Figure 3.2). Three samples contained around 60 species, an abnormally high richness value for these samples (Figure 3.2).

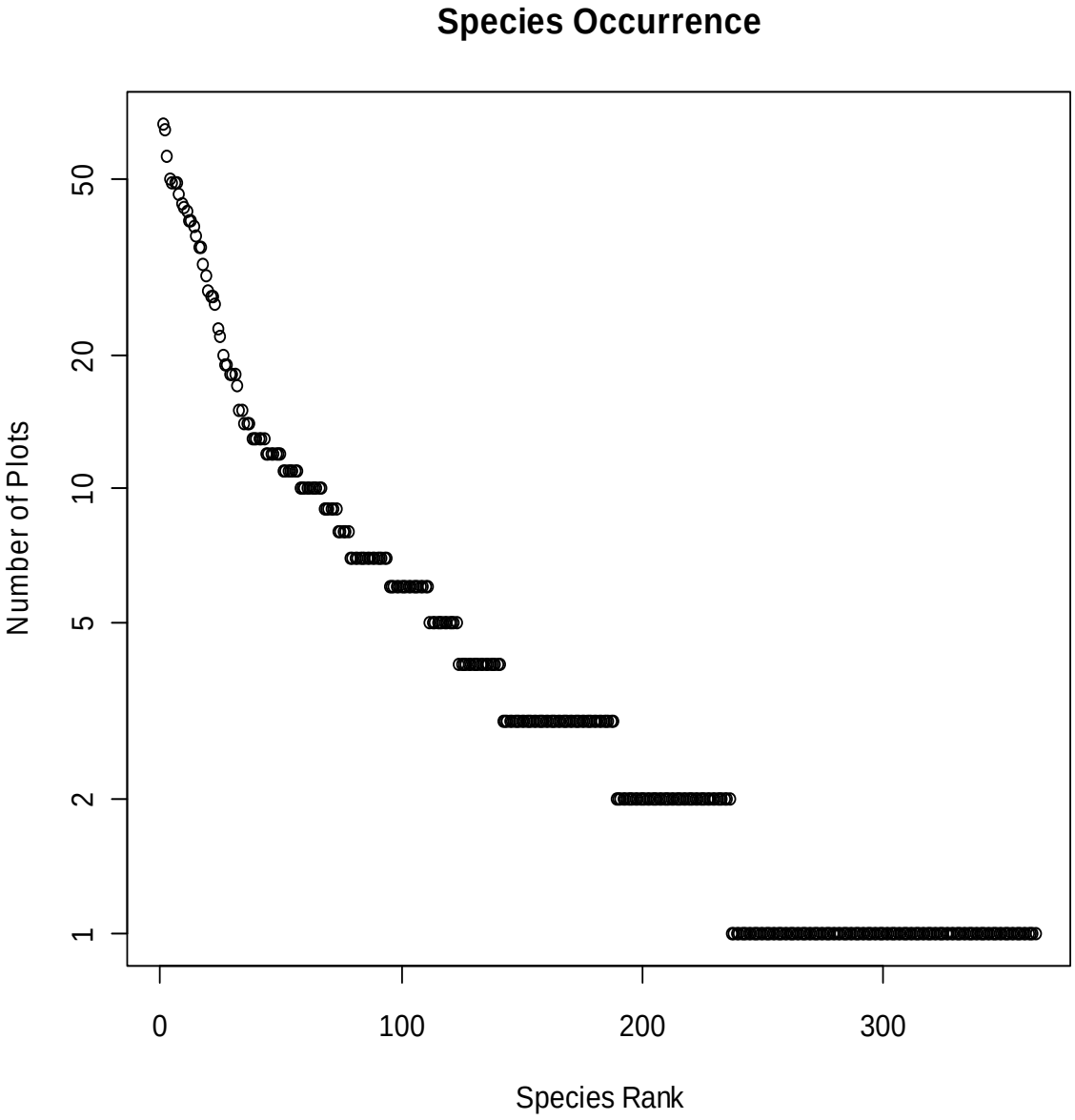


Figure 3.1. Species occurrence on each plot, across all species.

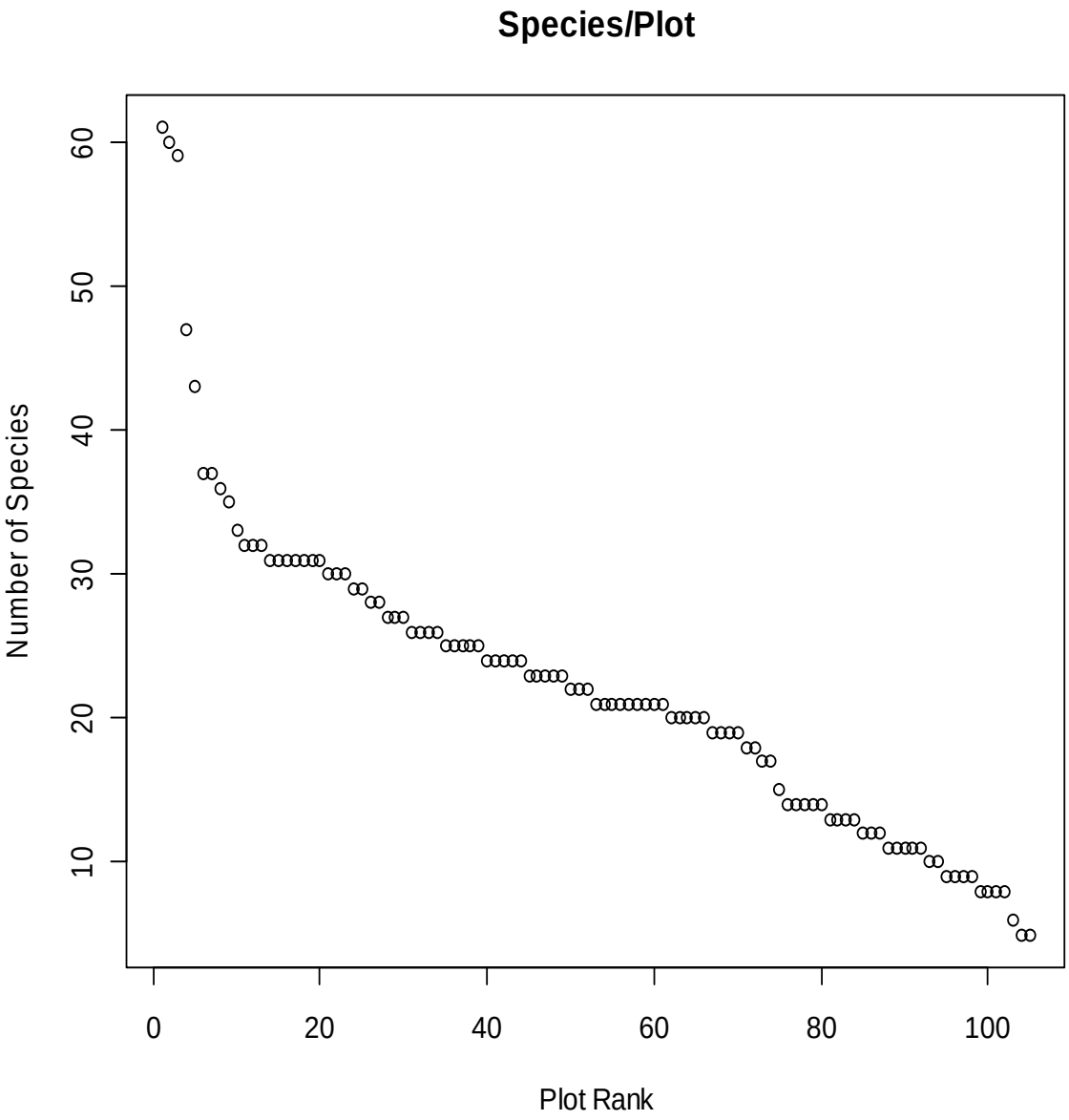


Figure 3.2. Number of species per plot, across all plots.

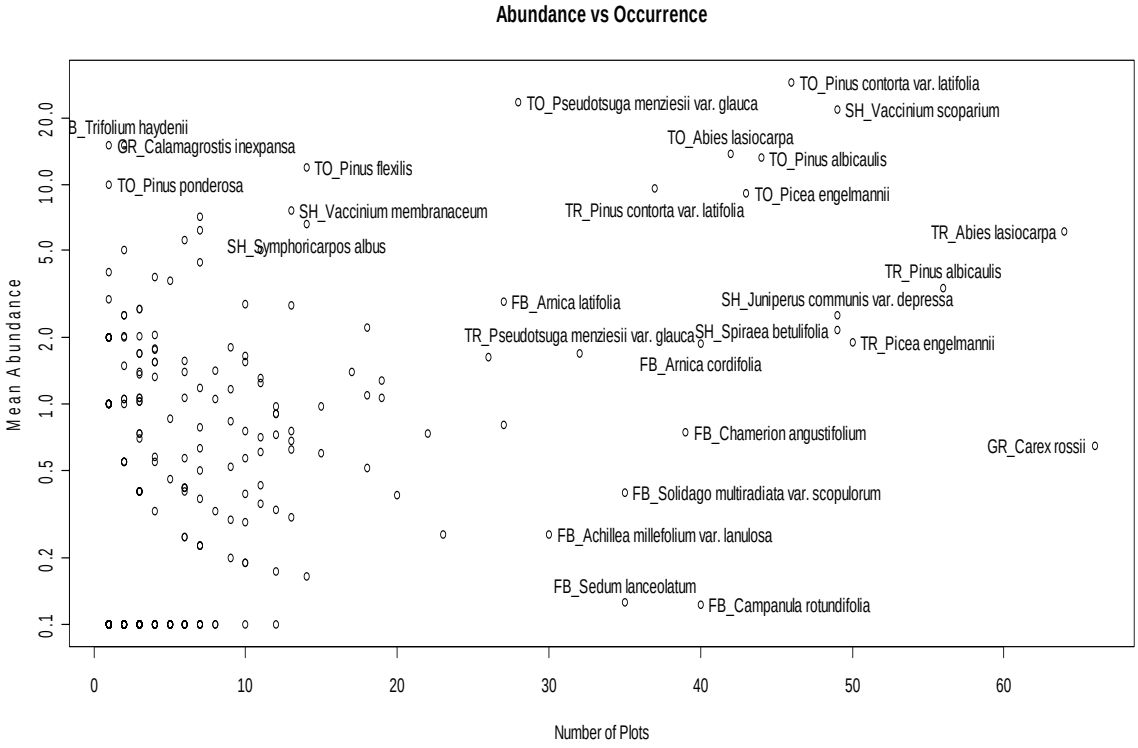


Figure 3.3. Mean species abundance versus number of plots in which the species occurred.

Table 3.1. The 10 most abundant species and 10 most frequent species. Mean % cover is rounded to the nearest whole number.

10 Most Abundant Species	**Mean % Cover**	**10 Most Frequent Species**	Number of Occurrences
TO_*Pinus contorta* var. *latifolia*	29	GR_*Carex rossii*	66
TO_*Pseudotsuga menziesii* var. *glauca*	24	TR_*Abies lasiocarpa*	64
SH_*Vaccinium scoparium*	22	TR_*Pinus albicaulis*	56
FB_*Trifolium haydenii*	15	TR_*Picea engelmannii*	50
GR_*Calamagrostis inexpansa*	15	SH_*Vaccinium scoparium*	49
TO_*Abies lasiocarpa*	14	SH_*Spiraea betulifolia*	49
TO_*Pinus albicaulis*	13	SH_*Juniperus communis* var. *depressa*	49
TO_*Pinus flexilis*	12	TO_*Pinus contorta* var. *latifolia*	46
TO_*Pinus ponderosa*	10	TO_*Pinus albicaulis*	44
TR_*Pinus contorta* var. *latifolia*	10	TO_*Picea engelmannii*	43

Correlation of Enivironmental Variables

Correlation between continuous environmental variables was tested using Pearson's correlation coefficient. Values closer to 1 and -1 indicate correlation and values closer to 0 indicate a lack of correlation. Correlations between modeled variables and elevation are generally strongly negative or positive. Growing degree days (GRDEGDAY) and average daily temperature (DAVTEMP) are strongly positively correlated (0.96) and elevation is strongly negatively correlated with both Growing degree days (GRDEGDAY) and average daily temperature (DAVTEMP) (-0.96 and -0.92 respectively). Relative effective annual precipitation (REAP) and elevation, total annual precipitation (TOTPRCP) and elevation and relative effective annual precipitation (REAP) and total annual precipitation (TOTPRCP) are all strongly positively correlated (0.8, 0.81 and 0.89 respectively). Average daily temperature (DAVTEMP) is moderately negatively correlated with relative effective annual precipitation (REAP) and total annual precipitation (TOTPRCP) (-0.75 and -0.78 consequetively). Unlike the rest of the modeled environmental variables, annual solar exposure (SOLAR) is not correlated with elevation. Annual solar exposure (SOLAR) is, however, moderately correlated with slope percent (-0.54). All other continuous variables were somewhat weakly correlated.

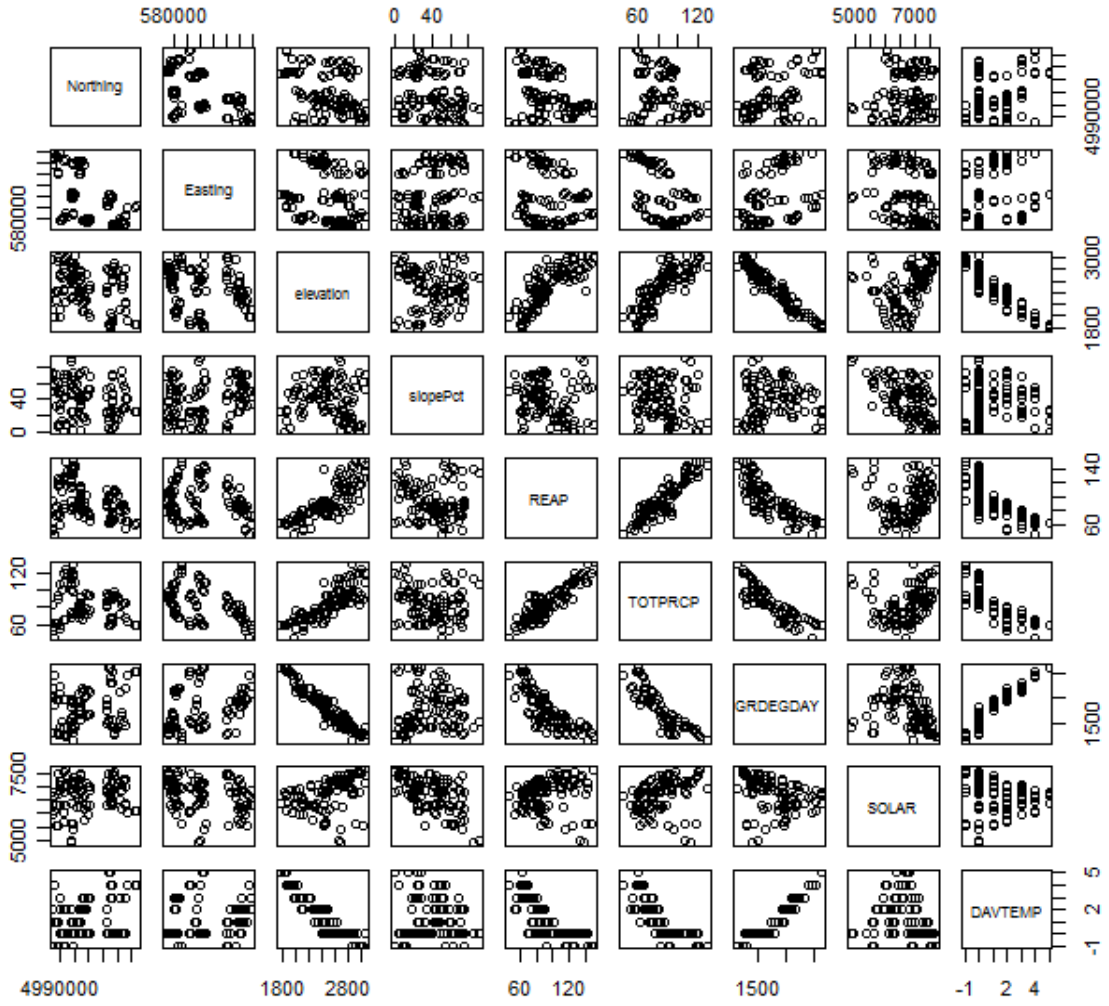


Figure 3.4. Correlations of site environmental variables: Easting coordinate, Northing coordinate, elevation (m) and slope percent (%), relative effective annual precipitation (REAP), total annual precipitation (TOTPRCP), growing degree days (GRDEGDAY), annual solar exposure (SOLAR), average daily temperature (DAVTEMP).

Table 3.2. Correlation coefficient (Pearson's) for joint distribution of continuous environmental variables. Absolute values > 0.5 are in bold.

	Easting	Northing	Elevation	Slope Percent	REAP	TOTPRCP	GRDEGDAY	SOLAR	DAVTEMP
Easting	1	**-0.59**	-0.21	0.24	-0.15	-0.48	0.29	-0.24	0.18
Northing		1	-0.26	-0.19	-0.38	-0.17	0.27	0.12	0.31
Elevation			1	-0.05	**0.8**	**0.81**	**-0.96**	0.39	**-0.92**
Slope Percent				1	-0.12	-0.14	0.04	**-0.54**	0.002
REAP					1	**0.89**	**-0.81**	0.14	**-0.75**
TOTPRCP						1	-0.086	0.3	**-0.78**
GRDEGDAY							1	-0.34	**0.96**
SOLAR								1	-0.29
DAVTEMP									1

Cluster Analysis of Communities

The STRIDE analysis suggests that 6, 8, 11 and 16 cluster models produced the highest geometric criteria (Figure 3.8). Although the 6 and 8 cluster models seem appealing due to high PARTANA ratios and Silhouette widths, cluster membership was based almost entirely on the dominant tree species. In order to discern composition patterns amoung samples with the same dominant tree species, I looked at BESTOPT models and OPTSIL models based on the original BESTOPT models for clustering solutions with between 10 and 18 clusters. I selected a 12-cluster OPTSIL of a BESTOPTmodel to define communities. Samples in each cluster are well classified, as is evidenced by a high average silhouette width (average silhouette width = 0.27) and only four minor reversals in the Silhouette plot (Figure 3.9). The 11, 13 and 14 cluster models have average silhouette widths of 0.26 in combination with nine, nine and ten (respectively) silhouette reversals. Reversals represent negative silhouette values and occur when a plot is more similar to another cluster than the cluster it is in. The PARTANA ratio of the 12-cluster model is slightly lower than that of the 11 and 13-cluster models (p=5.01, p=5.02, p=5.03, respectively) and slightly higher than the PARTANA ratio of the 14-cluster model (p=4.97). The 12- cluster model has 57 significant indicator species, while the 11-cluster model has 63 and the 13-cluster model has 53. The 14 cluster solution has 65 significant indicator species, but produces a model that collapses to 12 clusters with a lower average silhouette width, more reversals and a lower PARTANA ratio than the actual 12 cluster solution. Cluster solutions with more

than 14 clusters all contained clusters represented by a single sample and had > 10 Silhouette reversal bars.

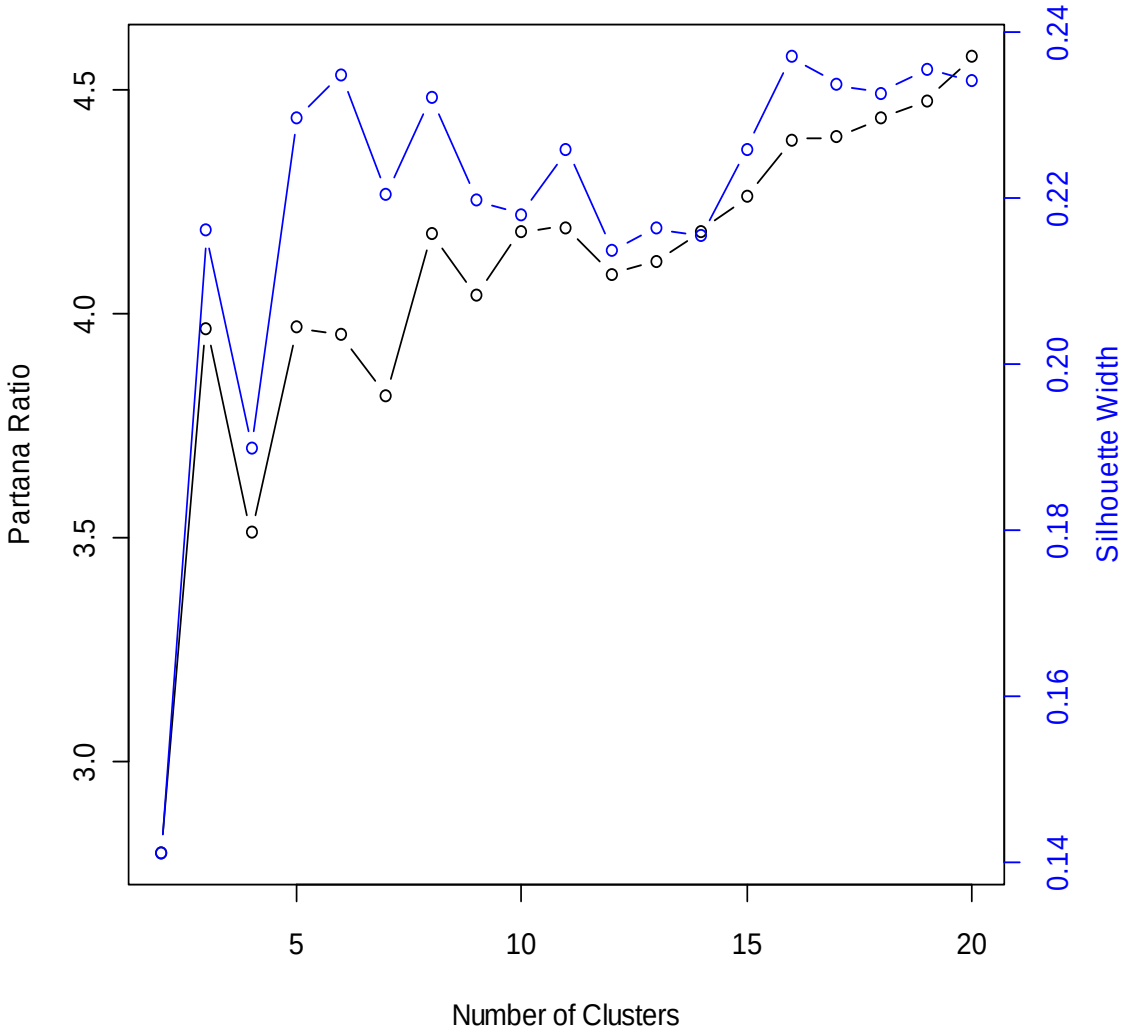


Figure 3.5. STRIDE analysis plot showing the PARTANA ratio and average Silhouette width for models containing 2 to 20 clusters.

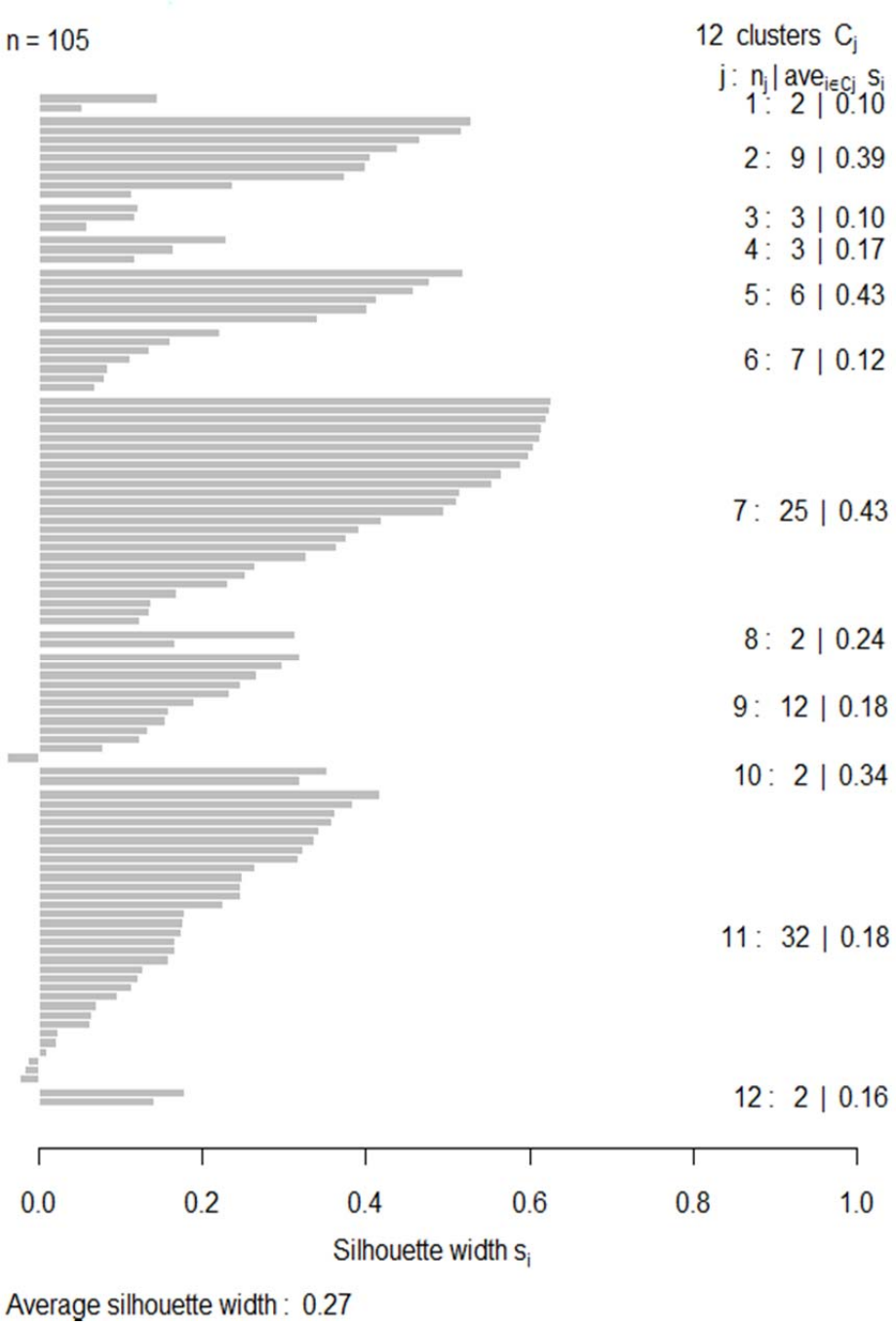


Figure 3.6. Silhouette width plot, indicating within cluster plot similarity for each of 12 clusters. Reversal bars represent negative silhouette width values which indicate poor similarity of a plot to the cluster in which it belongs. Cluster size and average Silhouette value for each cluster are displayed on right of plot.

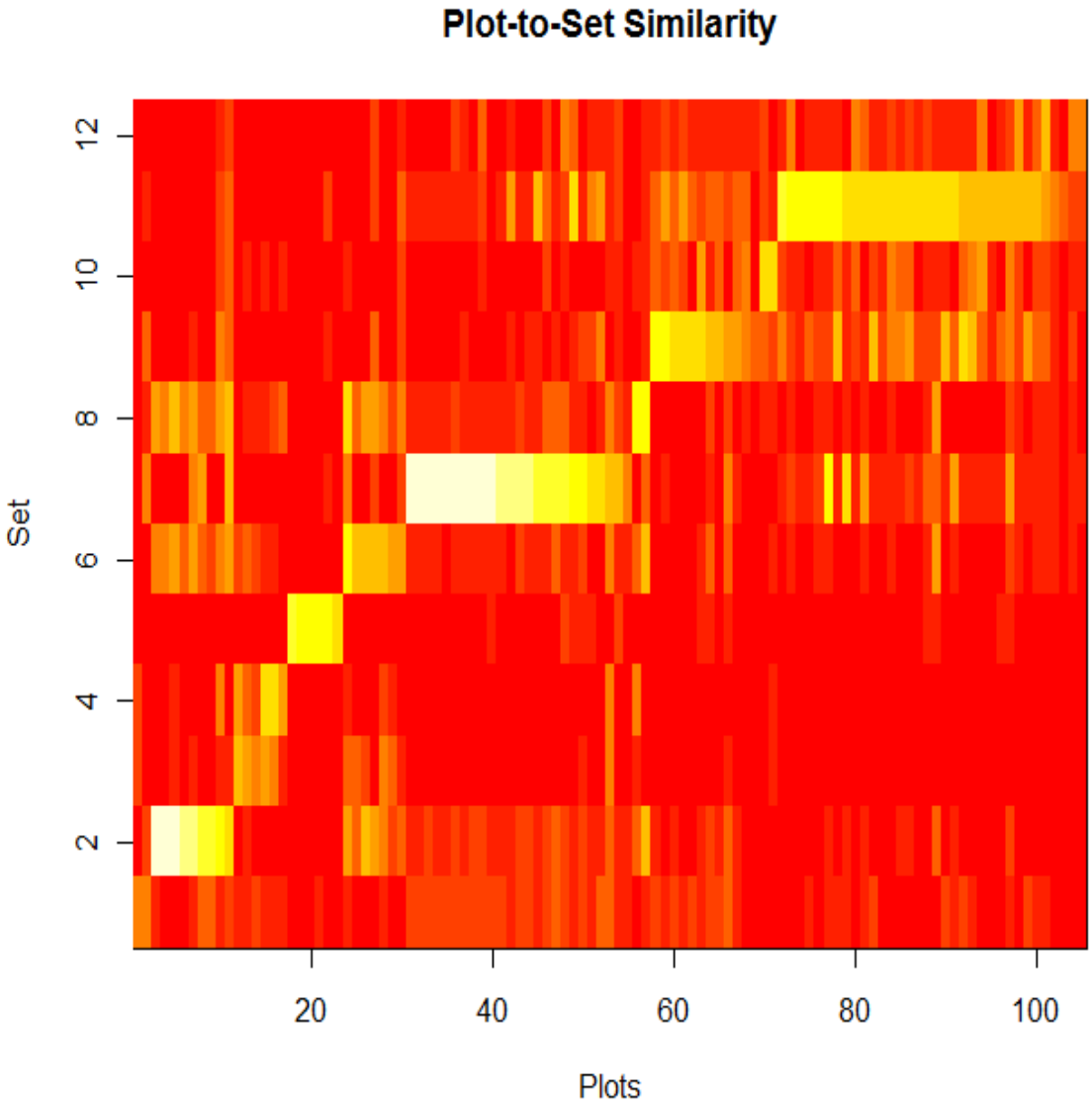


Figure 3.7. PARTANA plot, displaying the similarity of each plot within a cluster to each other plot in other clusters. White indicates high similarity, yellow moderate to high similarity and red a lack of similarity.

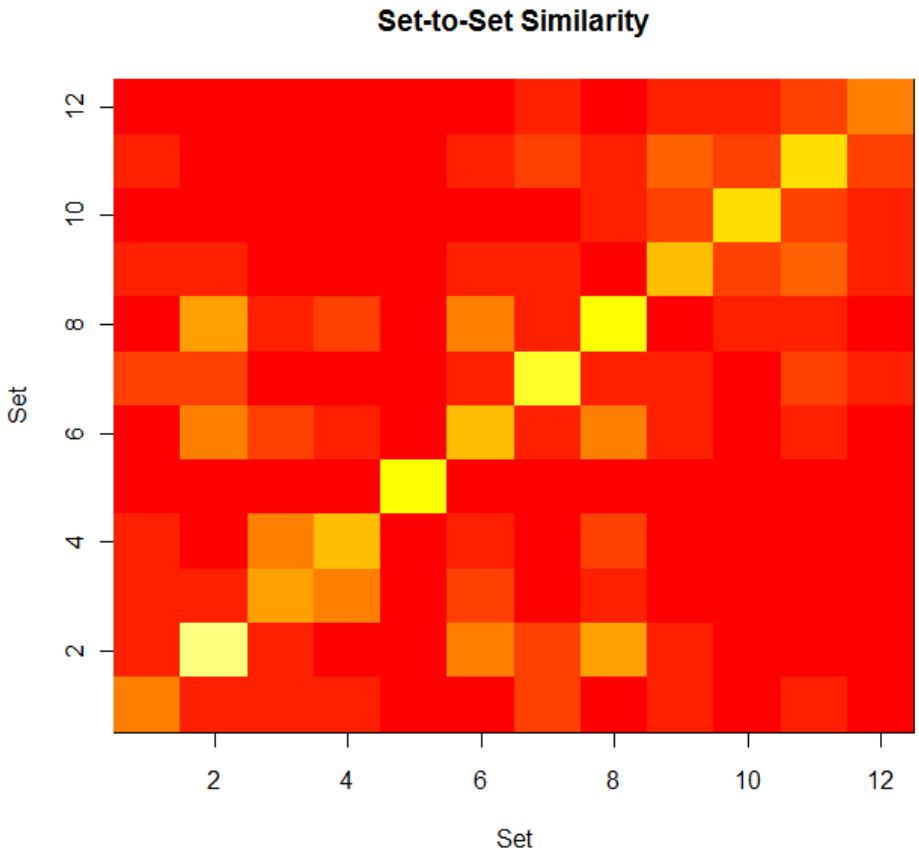


Figure 3.8. PARTANA plot, displaying the similarity of each cluster to each other cluster. White indicates high similarity, yellow moderate to high similarity and red a lack of similarity.

Based on the cluster analysis, I identified 12 forested associations, which I will present here in order of increasing mean elevation of the cluster. Cluster 1 was identified as an *Abies lasiocarpa/Symphoricarpos albus* association. Although *Abies lasiocarpa* was not identified as an indicator species (Table 3.3), it was included in the name because it is the indicated climax species of samples included in this association (Appendix F). I called cluster 2 the *Pseudotsuga menziesii* var. *glauca*/*Arnica cordifolia* association. *Arnica cordifolia* was not an indicator species (Table 3.3), but occurred with greater constancy and abundance than other species in the cluster (Appendix F). Cluster 3 is the

Pinus flexilis/Artemisia frigida association. Again, *Pinus flexilis* was not an indicator species (Table 3.3), but was the most consistently associated tree species and the most abundant tree species in the overstory (Appendix F). The fourth cluster was identified as the *Pinus flexilis/Agoseris glauca* association. *Pinus flexilis* was an indicator species (Table 3.3) for this cluster and had high abundance in the overstory. *Agoseris glauca* was not an indicator species (Table 3.3) but was the only other species to occur with 100% constancy (Appendix F), greater consistency but not abundance than the other two species identified as indicator species for this cluster (*Phacelia linearis* and *Phlox hoodii*). Cluster 5 is the *Pinus contorta* var. *latifolia* /*Ceanothus velutinus* association. Both species included in the name of this association are indicator species (Table 3.3) and abundant. The sixth cluster represents a *Pseudotsuga menziesii* var. *glauca/mixed xeric shrub* association. No indicator species were identified for this cluster (Table 3.3). *Pseudotsuga menziesii* var. *glauca* was by far the most consistent and abundant tree species in this cluster (Appendix F). The most consistently represented shrub species included: *Juniperus communis* var. *depressa, Juniperus scopulorum, Ribes cereum* var. *pedicellare and Spiraea betulifolia* (Appendix F). Cluster 7 was identified as a mid-seral *Pinus contorta* var.*latifolia/Spiraea betulifolia* association. Clusters 5 and 7 are both dominated by *Pinus contorta* var. *latifolia* and have *Spiraea betulifolia* as the most abundant indicator species (Table 3.3). The major difference between these two clusters is that Cluster 5 is dominated by regenerating *Pinus contorta* var. *latifolia* and cluster 7 is dominated by *Pinus contorta* var. *latifolia* in the overstory. Additionally, *Ceanothus velutinus* is much more frequent and well represented in Cluster 5 (Appendix F). The

eighth cluster was named the *Pseudotsuga menziesii* var. *glauca /Juniperus communis* var. *depressa* association. *Pseudotsuga menziesii* var. *glauca* was not an indicator species (Table 3.3) for this cluster, but was the most consistently associated and abundant tree species (Appendix F). *Juniperus communis* var. *depressa* was an indicator species (Table 3.3) and the most abundant species in the cluster. Cluster nine is the *Abies lasiocarpa/Arnica cordifolia* association. *Ribes lacustre* was identified as an indicator species (Table 3.3) for cluster nine, but occurred with less abundance than *Arnica cordifolia* which was the most abundant and consistent species in the cluster (Appendix F). Cluster 10 was identified as a high elevation *Picea engelmannii/Minuartia obtusiloba* association. This was the only association where *Picea engelmannii* was identified as an indicator species (Table 3.3) and also the only cluster where *Picea engelmannii* is the most dominant tree species (Appendix F). *Minuartia obtusiloba* was not an indicator species (Table 3.3) for this cluster, but occurred with more consistency and abundance than *Llyodia serotina* (Appendix F), the only species other than *Picea engelmannii* to be identified as an indicator species for cluster 10 (Table 3.3). Cluster 11 is the *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association. *Abies lasiocarpa* was not identified as an indicator species (Table 3.3) for this cluster, but occurred with similar consistency and abundance as *Pinus albicaulis* (Appendix F). *Arnica latifolia* was also identified as an indicator species for cluster 11 (Table 3.3) but was not used in the name because it occurs in much lower abundance than other species used in the association name. The twelfth cluster occurs at the highest elevations of the study area and was

named the *Pinus albicaulis/Arctostaphylos uva-ursi* association. Both species included in the name were identified as indicator species for this cluster.

Table 3.3. Indicator Species for each of 13 identified clusters.

	cluster	indicator	value probability
FB_Balsamorhiza sagittata	1	0.9866	0.002
SH_Amelanchier alnifolia	1	0.9677	0.001
FB_Geranium viscosissimum	1	0.9431	0.002
FB_Galium boreale	1	0.8907	0.002
FB_Fragaria virginiana	1	0.8799	0.005
FB_Cerastium arvense	1	0.8767	0.006
SH_Symphoricarpos albus	1	0.8264	0.003
SH_Prunus virginiana var. melanocarpa	1	0.8124	0.003
FB_Achillea millefolium var. lanulosa	1	0.6803	0.019
FB_Lupinus argenteus	1	0.6766	0.028
FB_Campanula rotundifolia	1	0.4988	0.035
FB_Apocynum androsaemifolium	1	0.4943	0.047
SH_Rosa woodsii	1	0.4546	0.043
TO_Pseudotsuga menziesii var. glauca	2	0.5998	0.002
FB_Tragopogon dubius	3	0.9000	0.002
SH_Artemisia frigida	3	0.8077	0.006
FB_Machaeranthera grindelioides	3	0.6667	0.002
FB_Cryptantha celosioides	3	0.4444	0.036
FB_Packera cana	3	0.3550	0.044
FB_Phacelia linearis	4	0.6667	0.002
TO_Pinus flexilis	4	0.6200	0.012
FB_Phlox hoodii	4	0.4444	0.026
TR_Pinus contorta var. latifolia	5	0.9548	0.001
SH_Ceanothus velutinus	5	0.8300	0.009
SH_Ribes viscosissimum	5	0.7758	0.009
SH_Shepherdia Canadensis	5	0.7496	0.017
SH_Rubus parviflorus	5	0.6648	0.002
GR_Carex geyeri Boott	5	0.6539	0.009
SH_Mahonia repens	5	0.6458	0.010
SH_Spiraea betulifolia	5	0.6319	0.014
FB_Eurybia conspicua	5	0.5384	0.028
SH_Vaccinium membranaceum	5	0.4640	0.043
FB_Anaphalis margaritacea	5	0.4000	0.021
TO_Pinus contorta var. latifolia	7	0.5931	0.001
SH_Juniperus communis var. depressa	8	0.7073	0.005
FB_Sedum lanceolatum	8	0.5526	0.023
FB_Trifolium haydenii	8	0.4999	0.048
FB_Erigeron compositus var. discoideus	8	0.4444	0.024
FB_Saxifraga bronchialis var. austromantana	8	0.4208	0.048
SH_Ribes lacustre	9	0.6764	0.007
TR_Abies lasiocarpa	9	0.6302	0.006
TO_Abies lasiocarpa	9	0.4565	0.017
TR_Picea engelmannii	10	0.8430	0.001
FB_Lloydia serotina	10	0.4706	0.047
TO_Picea engelmannii	10	0.4034	0.031
SH_Vaccinium scoparium	11	0.6202	0.001
TO_Pinus albicaulis	11	0.5758	0.003
FB_Arnica latifolia	11	0.4977	0.026

Table 3.3. Indicator Species for each of 13 identified clusters (continued).

	cluster	indicator	value probability
GR_Carex paysonis	12	0.9452	0.002
FB_Minuartia obtusiloba	12	0.8381	0.003
TR_Pinus albicaulis	12	0.6897	0.001
SH_Arctostaphylos uva-ursi	12	0.6075	0.025
GR_Luzula spicata	12	0.5854	0.013
FB_Silene acaulis var. subacaulescens	12	0.4969	0.028
FB_Sibbaldia procumbens	12	0.4638	0.041
GR_Carex phaeocephala	12	0.4489	0.028

NMDS Ordination and Evaluation of Environmental Variables

The 2-dimensional NMDS ordination of sample plots has a moderate r-value (0.758). The 3-dimensional NMDS ordination of sample plots has a higher r-value (0.84), reflecting a fairly efficient representation of the underlying dissimilarities (Figure 3.11). Although the NMDS ordination and the cluster analysis are both based on a Bray-Curtis dissimilarity index derived from the same sample presence and abundance information, the results are independent and can be used in conjuction to determine the efficacy and ecological interpretation of clustering solutions. Reasonable separation of clusters on the NMDS ordination suggests that communities are, indeed, distinct and classifiable groupings (Figure 3.12).

In addition to illustrating the separation of identified clusters on the 3-dimensional NMDS ordination, each sample was also classified to habitat type using Steele et al. (1983) Forest Habitat Types of Eastern Idaho-Western Wyoming and Pfister et al. (1977) Forest Habitat Types of Montana. The classification providing the best description is discussed in the individual association descriptions. Pfister et al. (1977) describe a *Pinus albicaulis-Abies lasiocarpa* habitat type that occurs above timberline, in which *Abies lasiocarpa* is stunted and *Pinus contorta* var.*latifolia* is absent. Steele et al. (1983)

described a *Pinus albicaulis/Carex rossii* habitat type that occurs at high elevations where all other indicator species are absent. Because both of these habitat types represent high elevation communities dominated by *Pinus albicaulis* where the understory is depauperate or inconsistent, I have combined samples classified to either of these habitat types into one type I have identified as '*Pinus albicaulis* timberline' (PIAL_timberline) for the purposes of this analysis.

Continuous environmental variables were tested to determine which variable explained the most deviance in the NMDS ordination using D^2 values obtained by fitting each variable to the ordination coordinates using a GAM on the smooth of all three axes. Gaussian GAM surfaces were fit to the first two dimensions of the 3-dimensional NMDS ordination (Figure 3.13 through 3.20). Elevation, relative effective annual precipitation (REAP), total annual precipitation (TOTPRCP), growing degree days (GRDEGDAY) and average daily temperature (DAVTEMP) all had high D^2 values (0.879, 0.692, 0.739, 0.847 and 0.795, respectively). GAM contours indicate that relationships are often non-linear.

While the continuous environmental variables may not be explained well by the NMDS ordination, these variables can further be tested for significance in determining cluster membership using p-values and chi-squared values obtained from a Kruskal-Wallis Rank Sum test (Kruskal and Wallis, 1990). These p-values and Chi-squared values (Table 3.5) help to quantify the variation of clusters across continuous environmental variables observed in Figure 3.22. Elevation, relative effective annual preciiation (REAP), total precipitation (TOTPRCP), growing degree days

(GRDEGDAY), annual solar exposure (SOLAR), average daily temperature (DAVTEMP), Easting Coordinate and slope percent were all significant to cluster memebership (p=6.314e-11, p=2.865e-11, p=8.239e-11, p=2.544e-11, p=5.566e-05, p=8.075e-10, p=0.003077 and p=0.0003420 respecitively). Northing coordinate was the only variable that was not significant to cluster membership (p=0.584).

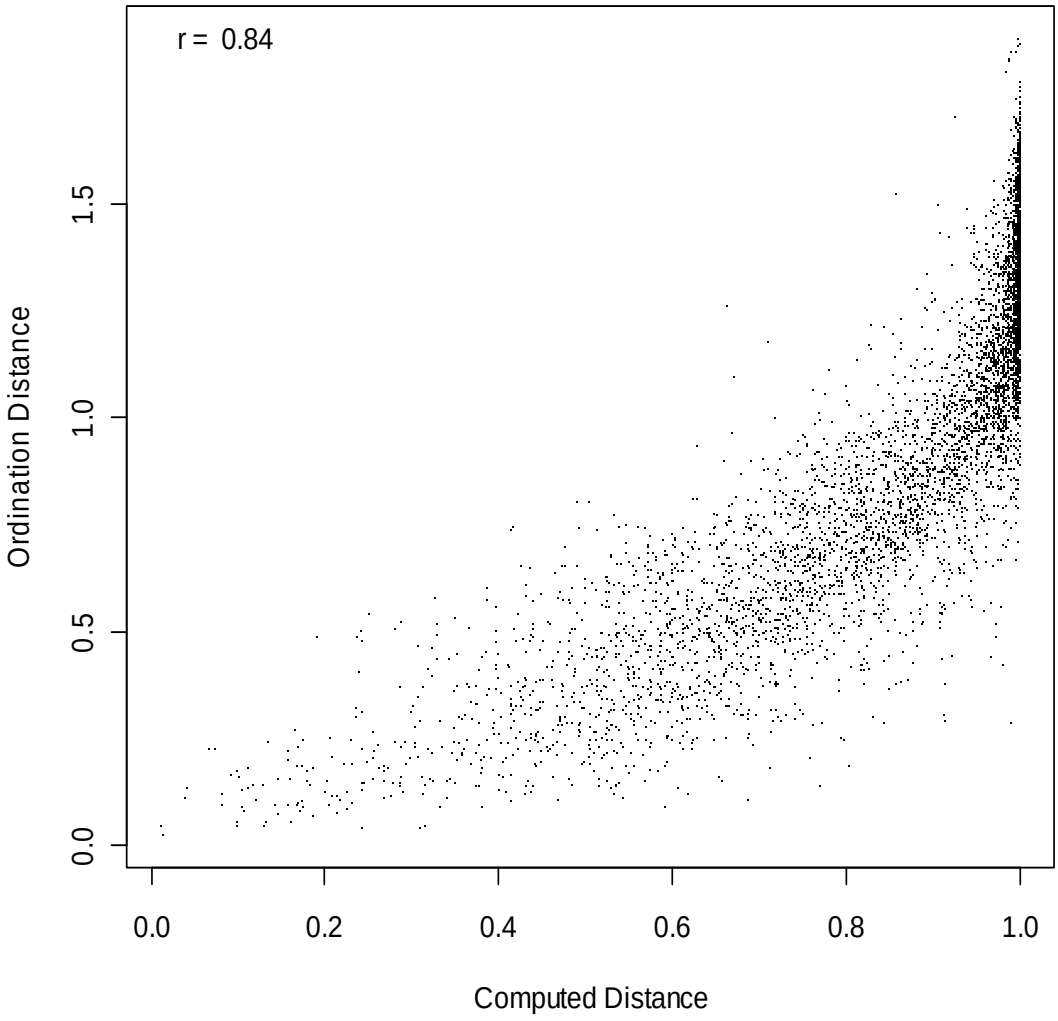


Figure 3.9. Correlation of three-dimensional ordination and computed distances of sample plots, giving an indication of the NMDS ordination quality (r=0.84).

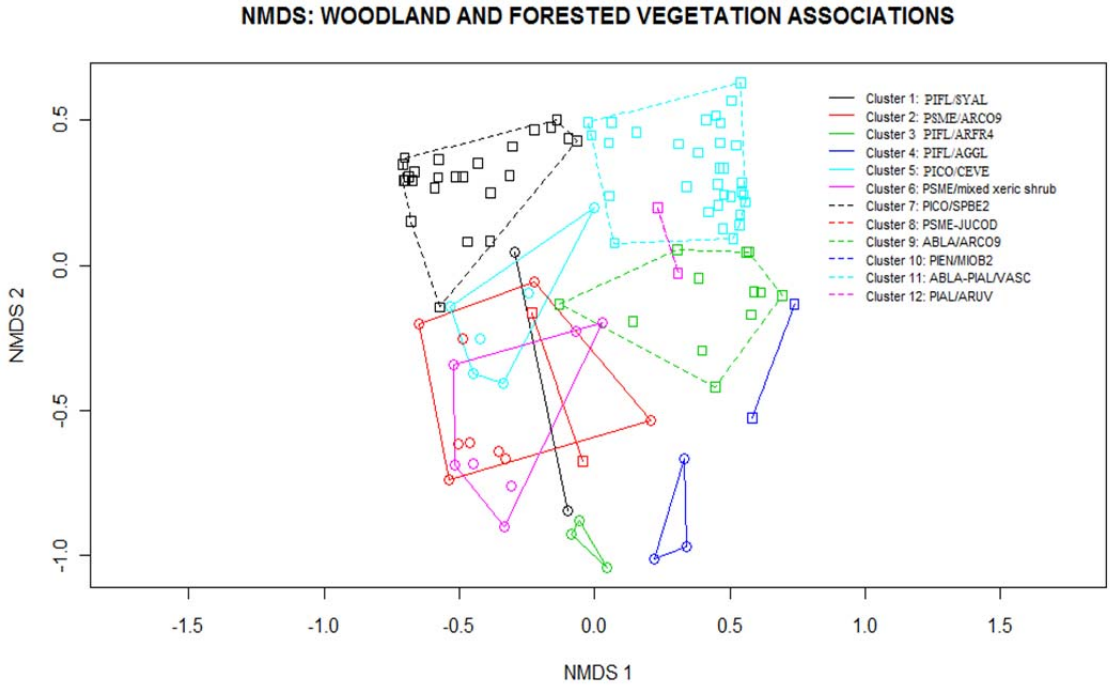


Figure 3.10. First two axes of three-dimensional NMDS ordination with associations outlined and identified by unique color-symbol combinations.

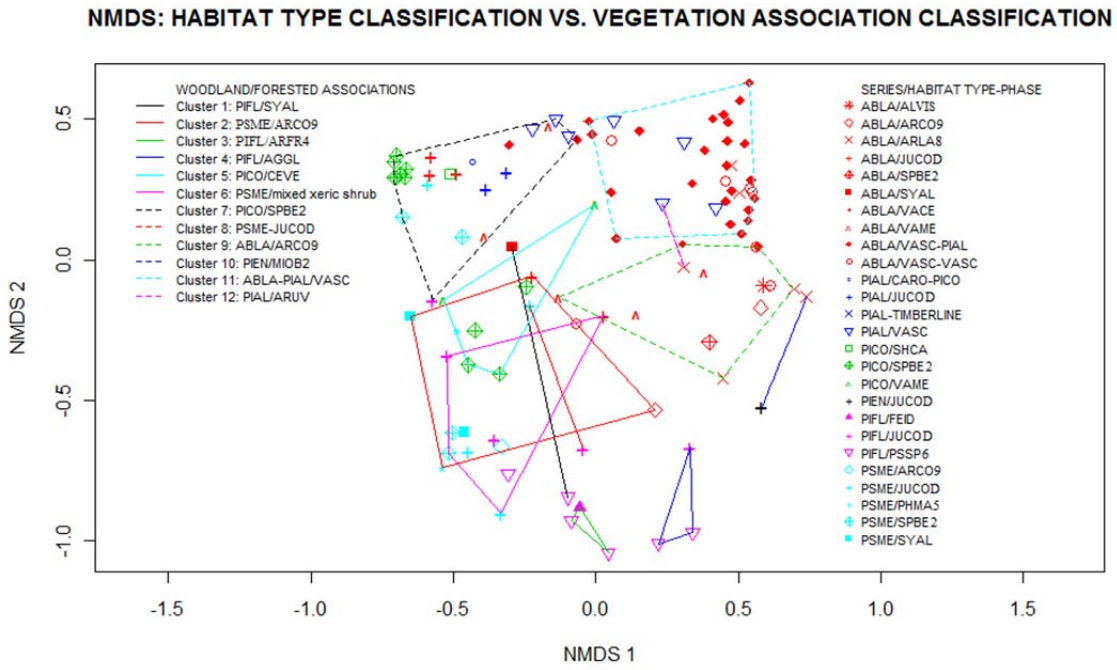


Figure 3.11. First two axes of three-dimensional NMDS ordination with associations outlined and habitat types identified by unique color-symbol combinations.

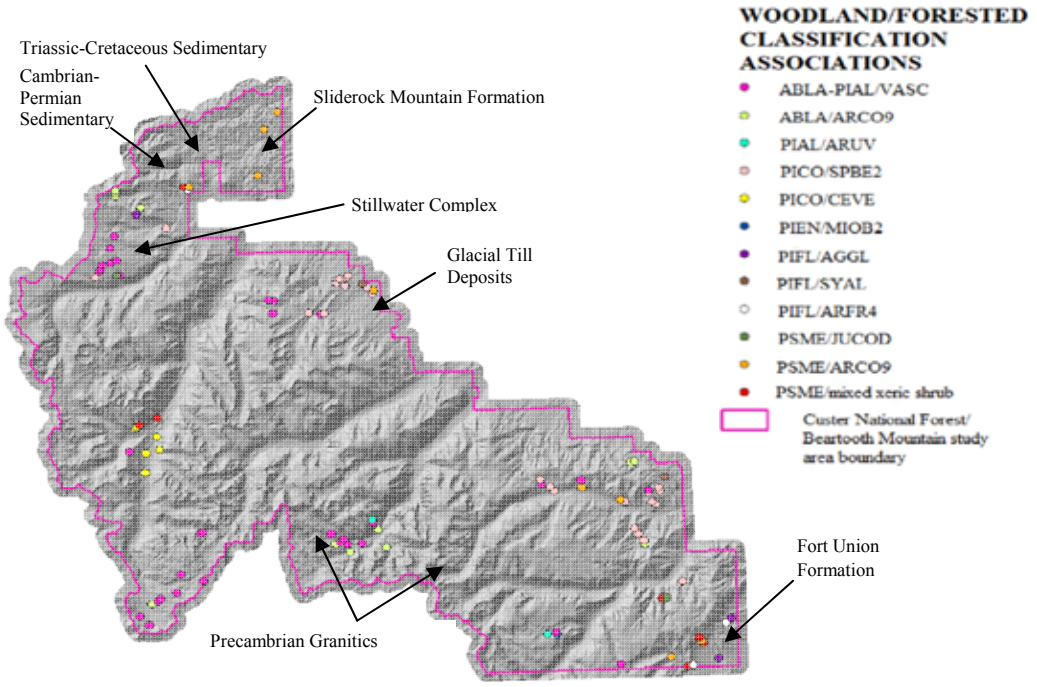


Figure 3.12. Hillshade relief and broad geologic map of study area where membership of woodland/forested samples to woodland/forested association is indicated by differently colored points.

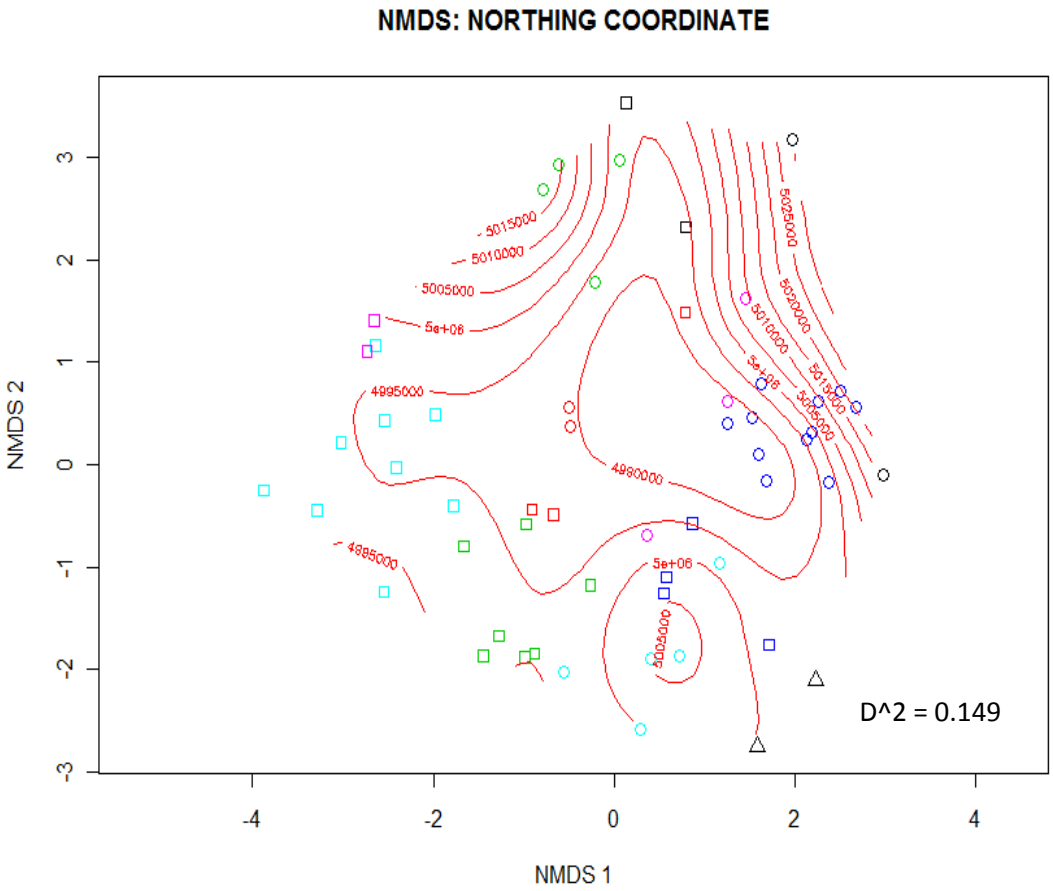


Figure 3.13. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.149$ for smooth of Northing coordinate on all three dimensions.

Cluster 1:	Black Circle	*Pinus flexilis/Symphoricarpos albus* association
Cluster 2:	Red Circle	*Pseudotsuga menziesii/Arnica cordifolia* association
Cluster 3:	Green Circle	*Pinus flexilis/Artemisia frigida* association
Cluster 4:	Blue Circle	*Pinus flexilis/Agoseris glauca* association
Cluster 5:	Cyan Circle	*Pinus contorta* var. *latifolia/Ceanothus velutinus* association
Cluster 6:	Violet Circle	*Pseudotsuga menziesii*/mixed xeric shrub association
Cluster 7:	Black Triangle	*Pinus contorta* var. *latifolia/Spiraea betulifolia* association
Cluster 8:	Red Triangle	*Pseudotsuga menziesii/Juniperus communis* var. *depressa* association
Cluster 9:	Green Triangle	*Abies lasiocarpa/Arnica cordifolia* association
Cluster 10:	Blue Triangle	*Picea engelmannii/Minuartia obtusiloba* association
Cluster 11:	Cyan Triangle	*Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association
Cluster 12:	Violet Triangle	*Pinus albicaulis/Arctostaphylos uva-ursi* association

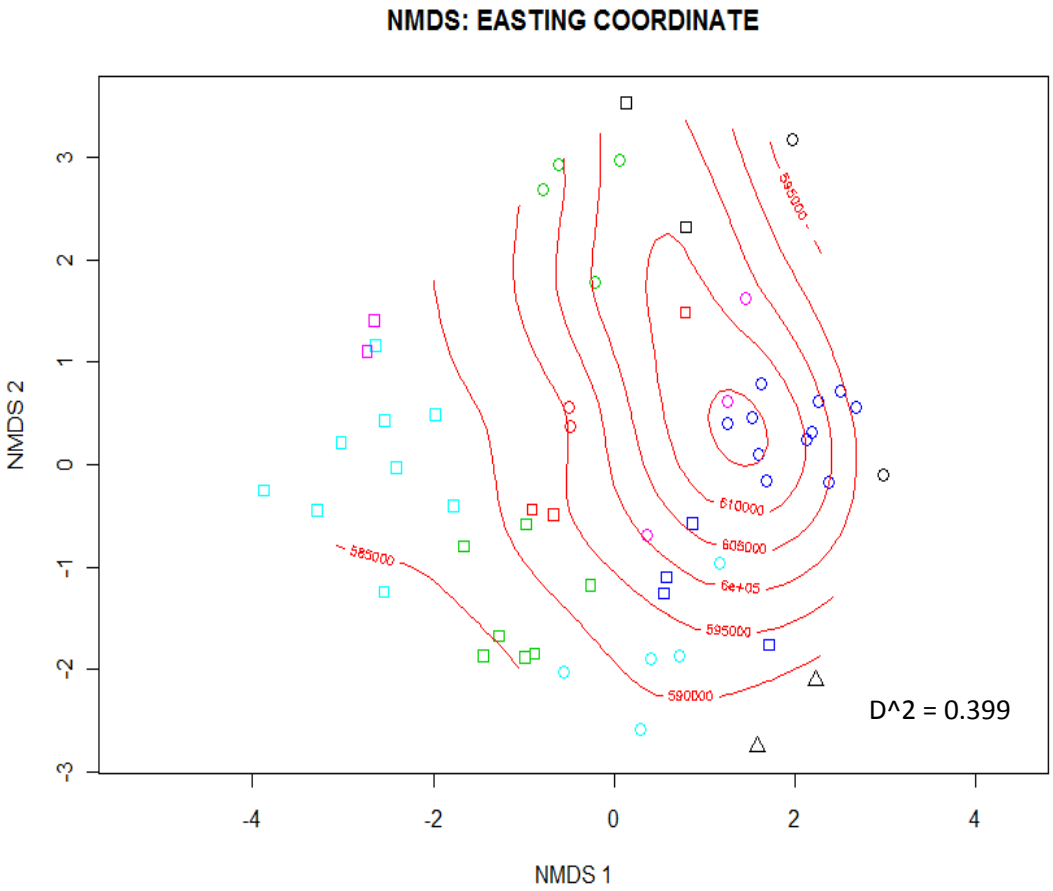


Figure 3.14. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.399$ for smooth of Easting coordinate on all three dimensions.

Cluster 1:	Black Circle	*Pinus flexilis/Symphoricarpos albus* association
Cluster 2:	Red Circle	*Pseudotsuga menziesii*/*Arnica cordifolia* association
Cluster 3:	Green Circle	*Pinus flexilis/Artemisia frigida* association
Cluster 4:	Blue Circle	*Pinus flexilis/Agoseris glauca* association
Cluster 5:	Cyan Circle	*Pinus contorta* var. *latifolia/Ceanothus velutinus* association
Cluster 6:	Violet Circle	*Pseudotsuga menziesii*/mixed xeric shrub association
Cluster 7:	Black Triangle	*Pinus contorta* var. *latifolia/Spiraea betulifolia* association
Cluster 8:	Red Triangle	*Pseudotsuga menziesii/Juniperus communis* var. *depressa* association
Cluster 9:	Green Triangle	*Abies lasiocarpa/Arnica cordifolia* association
Cluster 10:	Blue Triangle	*Picea engelmannii/Minuartia obtusiloba* association
Cluster 11:	Cyan Triangle	*Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association
Cluster 12:	Violet Triangle	*Pinus albicaulis/Arctostaphylos uva-ursi* association

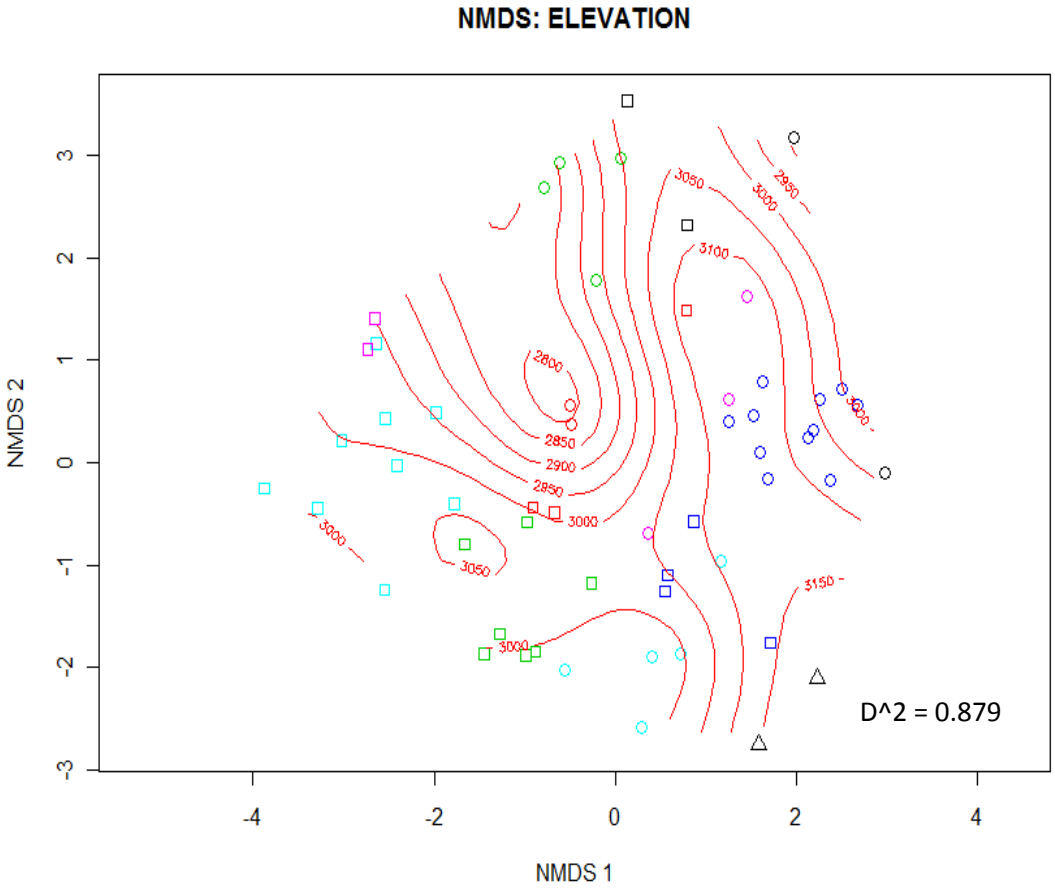


Figure 3.15. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.879$ for smooth of elevation (m) on all three dimensions.

Cluster 1:	Black Circle	*Pinus flexilis/Symphoricarpos albus* association
Cluster 2:	Red Circle	*Pseudotsuga menziesii/Arnica cordifolia* association
Cluster 3:	Green Circle	*Pinus flexilis/Artemisia frigida* association
Cluster 4:	Blue Circle	*Pinus flexilis/Agoseris glauca* association
Cluster 5:	Cyan Circle	*Pinus contorta* var. *latifolia/Ceanothus velutinus* association
Cluster 6:	Violet Circle	*Pseudotsuga menziesii*/mixed xeric shrub association
Cluster 7:	Black Triangle	*Pinus contorta* var. *latifolia/Spiraea betulifolia* association
Cluster 8:	Red Triangle	*Pseudotsuga menziesii/Juniperus communis* var. *depressa* association
Cluster 9:	Green Triangle	*Abies lasiocarpa/Arnica cordifolia* association
Cluster 10:	Blue Triangle	*Picea engelmannii/Minuartia obtusiloba* association
Cluster 11:	Cyan Triangle	*Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association
Cluster 12:	Violet Triangle	*Pinus albicaulis/Arctostaphylos uva-ursi* association

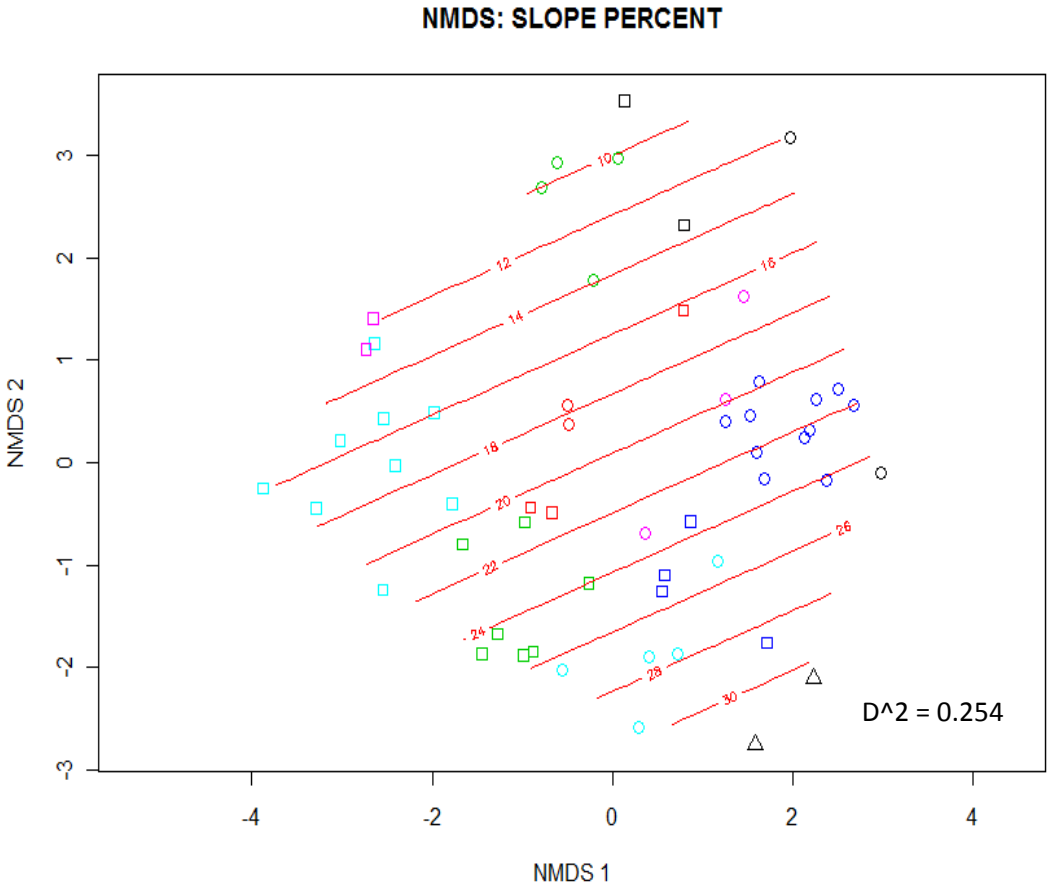


Figure 3.16. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.254$ for smooth of slope percent (%) on all three dimensions.

Cluster 1:	Black Circle	*Pinus flexilis/Symphoricarpos albus* association
Cluster 2:	Red Circle	*Pseudotsuga menziesii*/*Arnica cordifolia* association
Cluster 3:	Green Circle	*Pinus flexilis/Artemisia frigida* association
Cluster 4:	Blue Circle	*Pinus flexilis/Agoseris glauca* association
Cluster 5:	Cyan Circle	*Pinus contorta* var. *latifolia/Ceanothus velutinus* association
Cluster 6:	Violet Circle	*Pseudotsuga menziesii*/mixed xeric shrub association
Cluster 7:	Black Triangle	*Pinus contorta* var. *latifolia/Spiraea betulifolia* association
Cluster 8:	Red Triangle	*Pseudotsuga menziesii/Juniperus communis* var. *depressa* association
Cluster 9:	Green Triangle	*Abies lasiocarpa/Arnica cordifolia* association
Cluster 10:	Blue Triangle	*Picea engelmannii/Minuartia obtusiloba* association
Cluster 11:	Cyan Triangle	*Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association
Cluster 12:	Violet Triangle	*Pinus albicaulis/Arctostaphylos uva-ursi* association

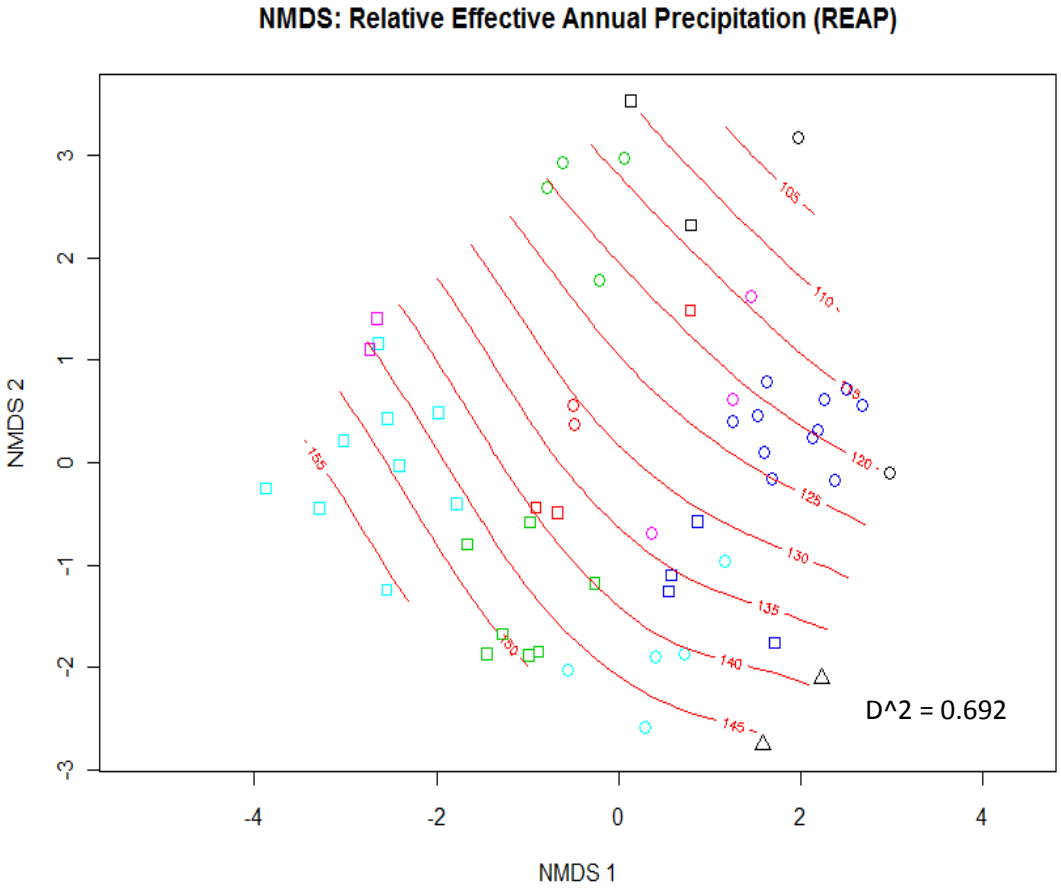


Figure 3.17. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.692$ for smooth of relative effective annual precipitation (REAP) on all three dimensions.

Cluster 1:	Black Circle	*Pinus flexilis/Symphoricarpos albus* association
Cluster 2:	Red Circle	*Pseudotsuga menziesii/Arnica cordifolia* association
Cluster 3:	Green Circle	*Pinus flexilis/Artemisia frigida* association
Cluster 4:	Blue Circle	*Pinus flexilis/Agoseris glauca* association
Cluster 5:	Cyan Circle	*Pinus contorta* var. *latifolia/Ceanothus velutinus* association
Cluster 6:	Violet Circle	*Pseudotsuga menziesii*/mixed xeric shrub association
Cluster 7:	Black Triangle	*Pinus contorta* var. *latifolia/Spiraea betulifolia* association
Cluster 8:	Red Triangle	*Pseudotsuga menziesii/Juniperus communis* var. *depressa* association
Cluster 9:	Green Triangle	*Abies lasiocarpa/Arnica cordifolia* association
Cluster 10:	Blue Triangle	*Picea engelmannii/Minuartia obtusiloba* association
Cluster 11:	Cyan Triangle	*Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association
Cluster 12:	Violet Triangle	*Pinus albicaulis/Arctostaphylos uva-ursi* association

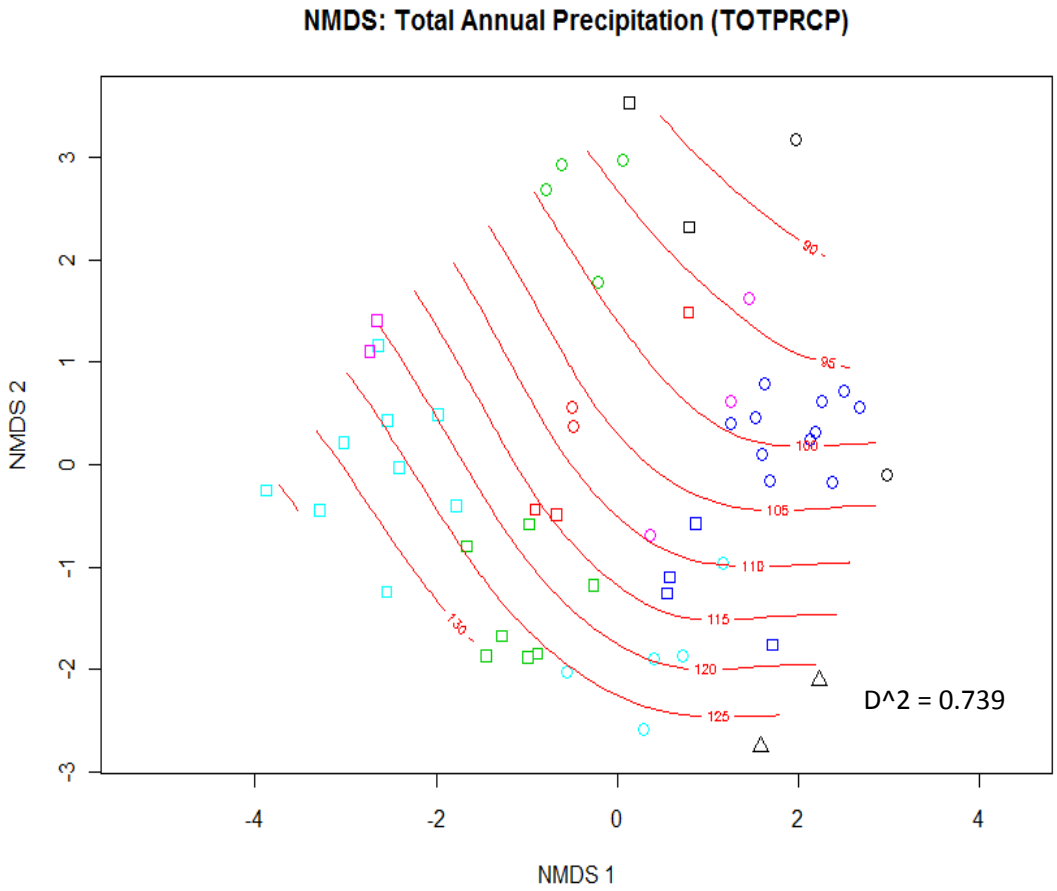


Figure 3.18. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.739 for smooth of total annual precipitation (TOTPRCP) on all three dimensions.

Cluster 1:	Black Circle	*Pinus flexilis/Symphoricarpos albus* association
Cluster 2:	Red Circle	*Pseudotsuga menziesii*/*Arnica cordifolia* association
Cluster 3:	Green Circle	*Pinus flexilis/Artemisia frigida* association
Cluster 4:	Blue Circle	*Pinus flexilis/Agoseris glauca* association
Cluster 5:	Cyan Circle	*Pinus contorta* var. *latifolia/Ceanothus velutinus* association
Cluster 6:	Violet Circle	*Pseudotsuga menziesii*/mixed xeric shrub association
Cluster 7:	Black Triangle	*Pinus contorta* var. *latifolia/Spiraea betulifolia* association
Cluster 8:	Red Triangle	*Pseudotsuga menziesii/Juniperus communis* var. *depressa* association
Cluster 9:	Green Triangle	*Abies lasiocarpa/Arnica cordifolia* association
Cluster 10:	Blue Triangle	*Picea engelmannii/Minuartia obtusiloba* association
Cluster 11:	Cyan Triangle	*Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association
Cluster 12:	Violet Triangle	*Pinus albicaulis/Arctostaphylos uva-ursi* association

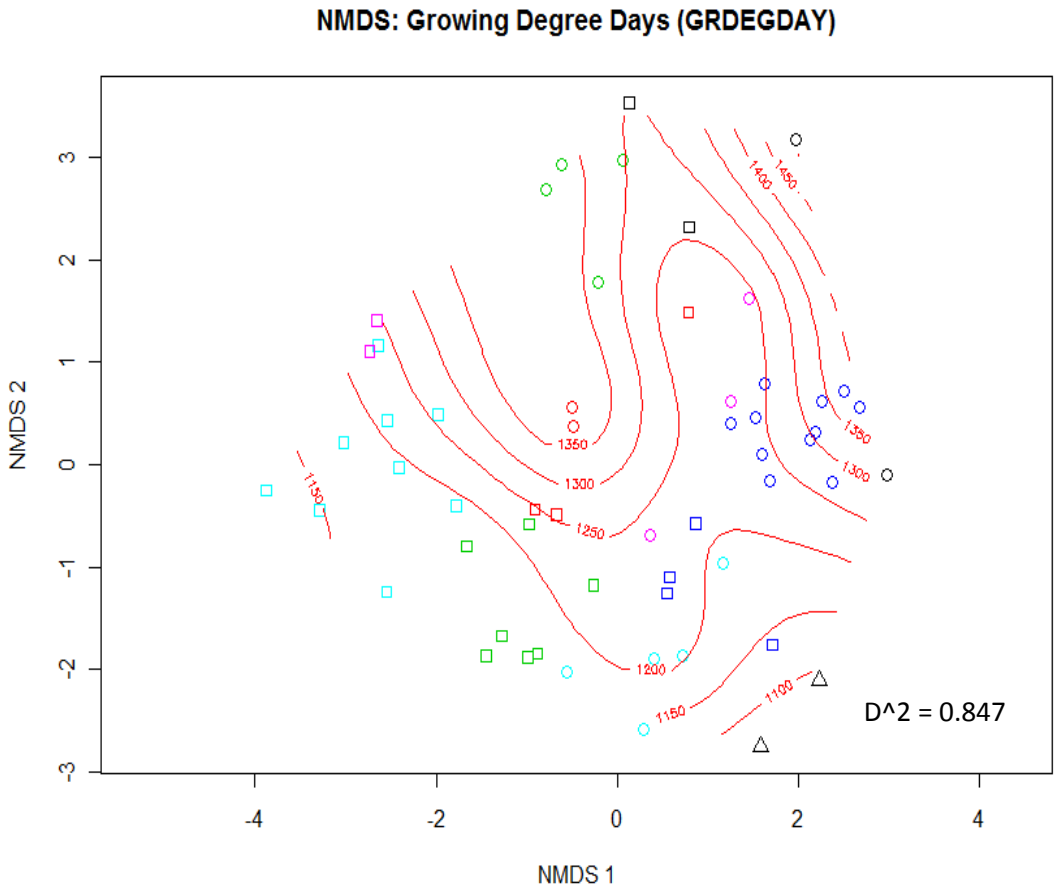


Figure 3.19. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.847 for smooth of growing degree days (GRDEGDAY) on all three dimensions.

Cluster 1:	Black Circle	*Pinus flexilis/Symphoricarpos albus* association
Cluster 2:	Red Circle	*Pseudotsuga menziesii/Arnica cordifolia* association
Cluster 3:	Green Circle	*Pinus flexilis/Artemisia frigida* association
Cluster 4:	Blue Circle	*Pinus flexilis/Agoseris glauca* association
Cluster 5:	Cyan Circle	*Pinus contorta* var. *latifolia/Ceanothus velutinus* association
Cluster 6:	Violet Circle	*Pseudotsuga menziesii*/mixed xeric shrub association
Cluster 7:	Black Triangle	*Pinus contorta* var. *latifolia/Spiraea betulifolia* association
Cluster 8:	Red Triangle	*Pseudotsuga menziesii/Juniperus communis* var. *depressa* association
Cluster 9:	Green Triangle	*Abies lasiocarpa/Arnica cordifolia* association
Cluster 10:	Blue Triangle	*Picea engelmannii/Minuartia obtusiloba* association
Cluster 11:	Cyan Triangle	*Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association
Cluster 12:	Violet Triangle	*Pinus albicaulis/Arctostaphylos uva-ursi* association

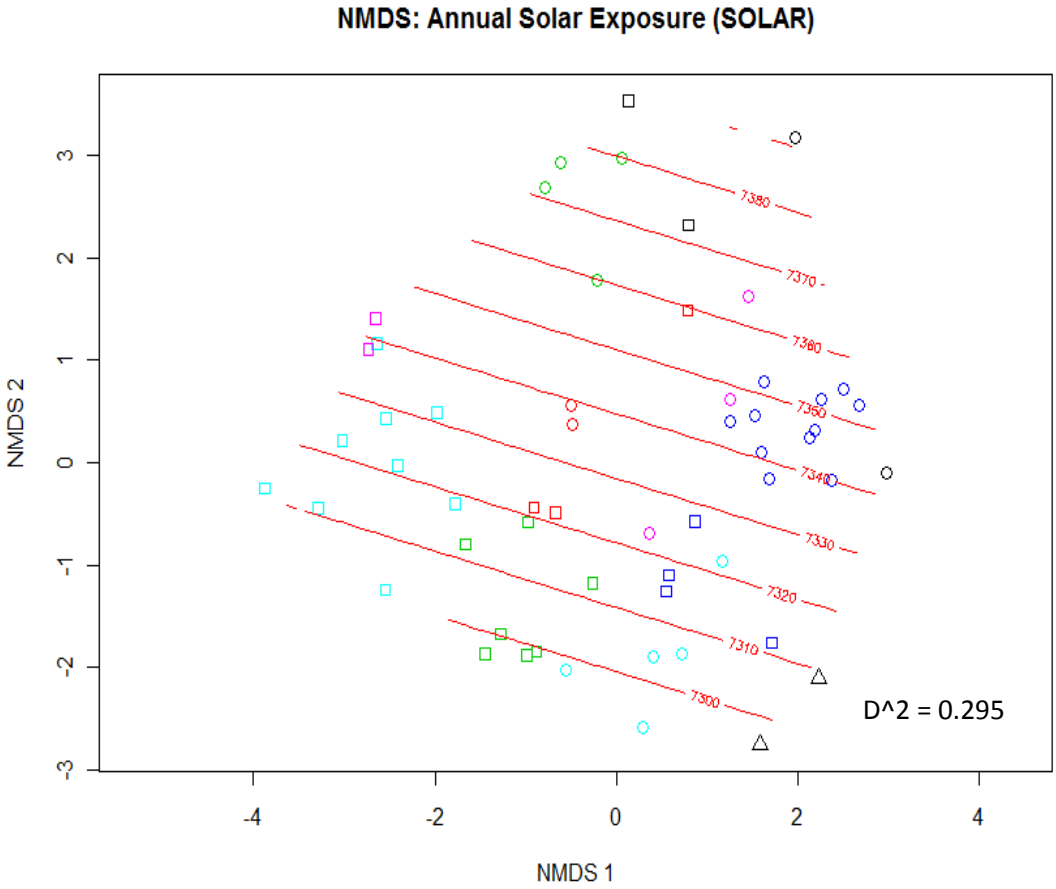


Figure 3.20. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.295 for smooth of annual solar exposure (SOLAR) on all three dimensions.

Cluster 1:	Black Circle	*Pinus flexilis/Symphoricarpos albus* association
Cluster 2:	Red Circle	*Pseudotsuga menziesii/Arnica cordifolia* association
Cluster 3:	Green Circle	*Pinus flexilis/Artemisia frigida* association
Cluster 4:	Blue Circle	*Pinus flexilis/Agoseris glauca* association
Cluster 5:	Cyan Circle	*Pinus contorta* var. *latifolia/Ceanothus velutinus* association
Cluster 6:	Violet Circle	*Pseudotsuga menziesii*/mixed xeric shrub association
Cluster 7:	Black Triangle	*Pinus contorta* var. *latifolia/Spiraea betulifolia* association
Cluster 8:	Red Triangle	*Pseudotsuga menziesii/Juniperus communis* var. *depressa* association
Cluster 9:	Green Triangle	*Abies lasiocarpa/Arnica cordifolia* association
Cluster 10:	Blue Triangle	*Picea engelmannii/Minuartia obtusiloba* association
Cluster 11:	Cyan Triangle	*Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association
Cluster 12:	Violet Triangle	*Pinus albicaulis/Arctostaphylos uva-ursi* association

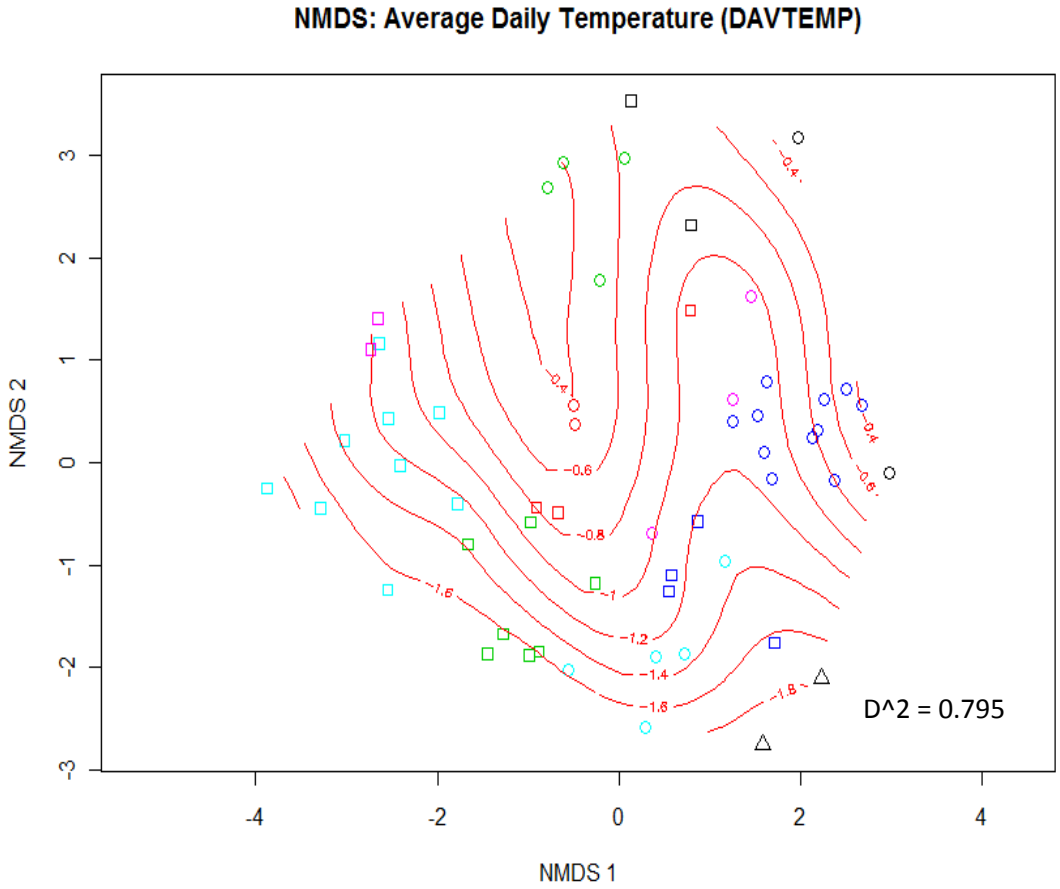


Figure 3.21. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.795 for smooth of average daily temperature (DAVTEMP) on all three dimensions.

Cluster 1:	Black Circle	*Pinus flexilis/Symphoricarpos albus* association
Cluster 2:	Red Circle	*Pseudotsuga menziesii*/*Arnica cordifolia* association
Cluster 3:	Green Circle	*Pinus flexilis/Artemisia frigida* association
Cluster 4:	Blue Circle	*Pinus flexilis/Agoseris glauca* association
Cluster 5:	Cyan Circle	*Pinus contorta* var. *latifolia/Ceanothus velutinus* association
Cluster 6:	Violet Circle	*Pseudotsuga menziesii*/mixed xeric shrub association
Cluster 7:	Black Triangle	*Pinus contorta* var. *latifolia/Spiraea betulifolia* association
Cluster 8:	Red Triangle	*Pseudotsuga menziesii/Juniperus communis* var. *depressa* association
Cluster 9:	Green Triangle	*Abies lasiocarpa/Arnica cordifolia* association
Cluster 10:	Blue Triangle	*Picea engelmannii/Minuartia obtusiloba* association
Cluster 11:	Cyan Triangle	*Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association
Cluster 12:	Violet Triangle	*Pinus albicaulis/Arctostaphylos uva-ursi* association

Table 3.4. D^2 values of GAMs fit to continuous environmental variables, based on the three dimensional NMDS ordination. All models are Gaussian.
$D^2 > 0.5$ are in bold.

VARIABLE	GAM D^2
Northing Coordinate (UTM)	0.149
Easting Coordinate (UTM)	0.399
Elevation (m)	**0.879**
Slope Percent (%)	0.254
Relative effective annual precipitation (REAP)	**0.692**
Total precipitation (TOTPRCP)	**0.739**
Growing degree days (GRDEGDAY)	**0.847**
Annual solar exposure (SOLAR)	0.295
Average daily temperature (DAVTEMP)	**0.795**

Table 3.5. P-values and chi-squared values from Kruskal-Wallis Rank Sum Test for each of the continuous environmental variables. P-values < 0.1 are bolded.
d.f. = 11

VARIABLE	p-value	Chi-squared value
Northing Coordinate (UTM)	0.584	9.4113
Easting Coordinate (UTM)	**0.003077**	28.1442
Elevation (m)	**6.314e-11**	71.506
Slope Percent (%)	**0.0003420**	34.1483
Relative effective annual precipitation (REAP)	**2.865e-11**	73.3028
Total precipitation (TOTPRCP)	**8.239e-11**	70.8993
Growing degree day (GRDEGDAY)	**2.544e-11**	73.5726
Annual solar exposure (SOLAR)	**5.566e-05**	38.8736
Average daily temperature (DAVTEMP)	**8.075e-10**	65.6658

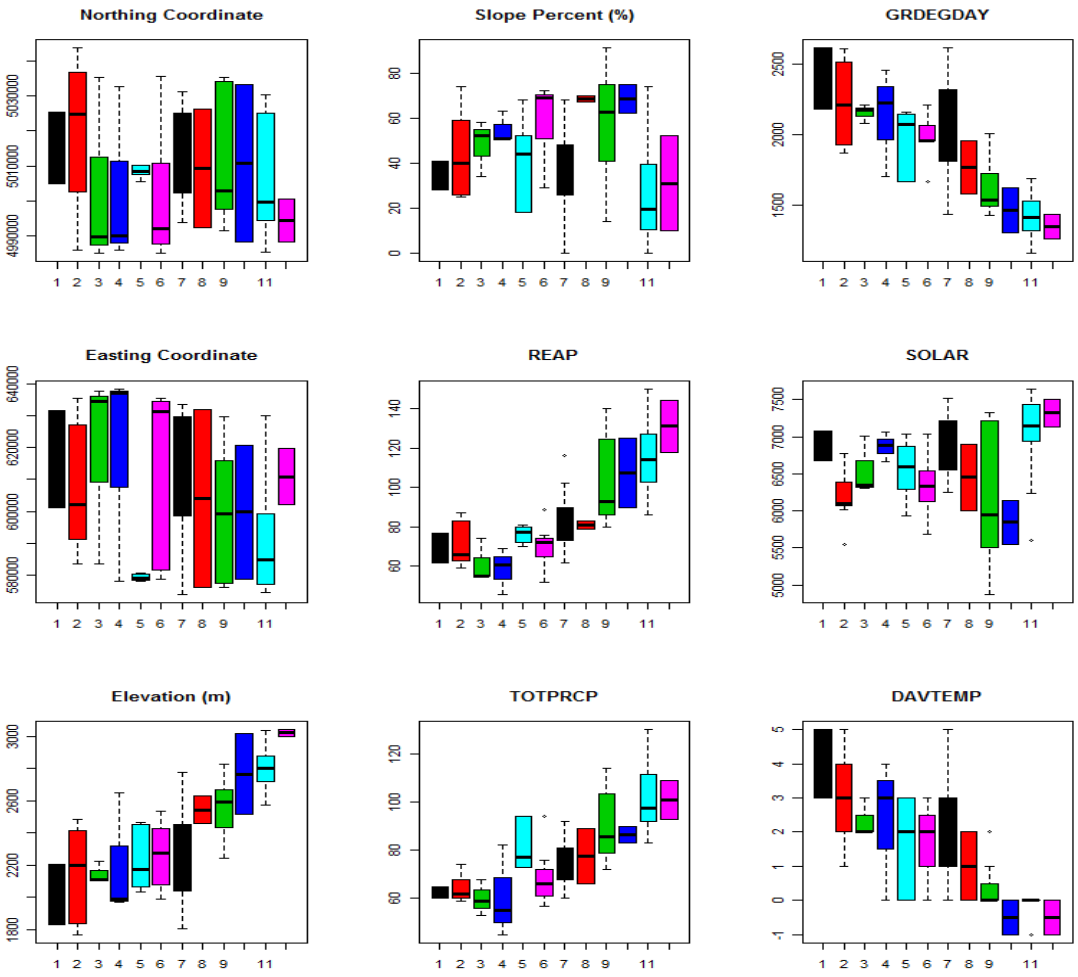


Figure 3.22. Boxplots of continuous environmental variables Northing coordinate, Eaasting coordinate, elevation (m), slope percent (%), aspect degree, relative effective annual precipitation (REAP), total annual precipitation (TOTPRCP), growing degree days (GRDEGDAY), units solar loading (SOLAR) and average daily temperature (DAVTEMP).

Cluster 1: *Pinus flexilis/Symphoricarpos albus* association
Cluster 2: *Pseudotsuga menziesii*/*Arnica cordifolia* association
Cluster 3: *Pinus flexilis/Artemisia frigida* association
Cluster 4: *Pinus flexilis/Agoseris glauca* association
Cluster 5: *Pinus contorta* var. *latifolia/Ceanothus velutinus* association
Cluster 6: *Pseudotsuga menziesii*/mixed xeric shrub association
Cluster 7: *Pinus contorta* var. *latifolia/Spiraea betulifolia* association
Cluster 8: *Pseudotsuga menziesii/Juniperus communis* var. *depressa* association
Cluster 9: *Abies lasiocarpa/Arnica cordifolia* association
Cluster 10: *Picea engelmannii/Minuartia obtusiloba* association
Cluster 11: *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association
Cluster 12: *Pinus albicaulis/Arctostaphylos uva-ursi* association

Categorical environmental variables were tested for significance to cluster membership using ORDTEST (library labdsv, R statistical software). Each factor within categorical environmental variables was tested for significance as well. Tables 3.6 through 3.9 show the resultant ORDTEST p-values, as well as, the number of times each variable and factor occurred in each cluster. Primary landform, soil temperature regime (STR), soil moisture regime (SMR), soil moisture subclass (SMSC), soil depth, disturbance, habitat type, soil particle size and soil subgroup are all significant (p=0.001, 0.001, 0.001, 0.004, 0.044, 0.001, 0.001, 0.016 and 0.001 respectively). Ground moraines, recessional moraines, scarp slopes and U-shaped valleys are the significant landform factors of the primary landform variable (p=0.012, 0.091, 0.001, and 0.01 respectively). Cryic and frigid are the significant factors within the variable soil temperature regime (STR) (p=0.001 for both). Aridic, typic and ustic are the significant factors within the variable soil moisture regime (SMR) (p=0.006, 0.002 and 0.027, respectively).

Table 3.6. Ordtest p-values for topographic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level.

	PIFL / SYAL	PSME / ARCO9	PIFL / ARFR4	PIFL / AGGL	PICO / CEVE	PSME / Xeric shrub	PICO / SPBE2	ABLA / ARCO9	PSME / JUCOD	PIEN / MIOB2	ABLA – PIAL / VASC	PIAL / ARUV	p-val
Topographic Position													0.309
Backslope	1	8	3	2	4	7	20	9	2	2	17	0	0.251
Footslope	1	1	0	0	2	0	0	3	0	0	4	0	0.121
Shoulder	0	0	0	1	0	0	4	0	0	0	5	2	0.286
Summit	0	0	0	0	0	0	1	0	0	0	6	0	0.913
Toeslope	0	0	0	0	0	0	0	0	0	0	0	0	1
Primary Landform													**0.001**
Cirque	0	0	0	0	0	0	0	0	0	0	0	1	0.18
Dipslope	0	2	0	0	0	1	0	3	0	1	0	0	0.284
Disintegration Moraine	0	0	0	0	0	0	3	0	0	0	0	0	0.236
Glacial-valley Floor	0	0	0	0	1	0	0	0	0	0	1	0	0.436
Glacial-valley Wall	0	0	0	0	0	0	0	0	0	1	2	0	0.212
Ground Moraine	0	0	0	0	0	0	0	0	0	0	0	1	**0.012**
Hillslope	0	0	1	1	0	0	0	0	0	0	0	0	0.794
Knob	0	0	0	0	0	0	0	0	0	0	3	0	0.897
Lateral Moraine	0	0	0	0	0	0	4	0	0	0	0	0	0.895
Mountain Slope	0	5	0	0	0	0	12	3	0	0	8	0	0.747
Pediment	0	1	0	0	0	0	1	0	0	0	0	0	0.392
Plateau	0	0	0	0	0	0	0	0	0	0	3	0	0.666
Recessional Moraine	0	0	0	0	0	0	0	0	0	0	1	0	0.601
Ridge	0	1	0	1	0	0	0	0	0	0	2	0	**0.091**
Saddle	0	0	0	0	0	0	0	0	0	0	1	0	0.849
Scarp Slope	1	0	2	1	0	2	0	0	0	0	0	0	**0.001**
U-shaped Valley	0	0	0	0	5	2	0	6	0	0	8	0	**0.01**
V-shaped Valley	0	0	0	0	0	2	2	0	2	0	3	0	0.964

Table 3.6. Ordtest p-values for topographic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level (continued).

	PIFL / SYAL	PSME / ARCO9	PIFL / ARFR4	PIFL / AGGL	PICO / CEVE	PSME / Xeric shrub	PICO / SPBE2	ABLA / ARCO9	PSME / JUCOD	PIEN / MIOB2	ABLA – PIAL / VASC	PIAL / ARUV	p-val
Slope Complex													0.562
Complex Broken	0	0	1	0	0	0	0	2	0	0	3	0	0.5
Complex Undulating	0	0	0	0	0	0	2	2	0	0	7	0	0.654
Simple Concave	2	4	0	0	1	0	3	1	0	1	0	0	0.26
Simple Convex	0	2	0	0	0	0	13	3	0	0	6	0	0.855
Simple Linear	0	3	2	3	5	7	7	4	2	1	16	2	**0.059**
Slope Complexity													.368
Complex	0	0	1	0	0	0	2	4	0	0	10	0	0.361
Simple	2	9	2	3	6	7	23	8	2	2	22	2	0.392
Verticle Slope Shape													0.127
Broken	0	0	1	0	0	0	0	1	0	0	0	0	0.299
Concave	1	4	1	0	1	0	4	3	0	1	1	0	0.352
Convex	0	2	0	0	3	0	10	6	1	0	13	2	0.306
Linear	0	2	1	2	1	6	6	1	1	1	12	0	0.175
Undulating	1	1	0	1	1	0	5	1	0	0	6	0	0.691
Horizontal Slope Shape													0.546
Broken	0	0	1	0	0	0	0	2	0	0	3	0	0.497
Concave	2	4	0	0	1	0	3	1	0	1	0	0	0.295
Convex	0	2	0	0	0	0	13	3	0	0	6	0	0.855
Linear	0	3	2	3	5	7	7	4	2	1	16	2	**0.054**
Undulating	0	0	0	0	0	0	2	2	0	0	7	0	0.643

Table 3.7. Ordtest p-values for climatic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level.

	PIFL / SYAL	PSME / ARCO9	PIFL / ARFR4	PIFL / AGGL	PICO / CEVE	PSME / mixed xeric shrub	PICO / SPBE2	ABLA / ARCO9	PSME / JUCOD	PIEN / MIOB2	ABLA - PIAL / VASC	PIAL / ARUV	p-val
Soil Temperature Regime (STR)													**0.001**
Cryic	1	6	3	1	6	5	22	2	12	2	32	2	**0.001**
Frigid	1	3	0	2	0	2	3	0	0	0	0	0	**0.001**
Gelic	0	0	0	0	0	0	0	0	0	0	0	0	1
Soil Moisture Regime (SMR)													**0.001**
Aquic	0	0	0	0	0	0	0	0	0	0	0	0	1
Udic	1	6	3	1	6	5	22	2	12	2	32	2	**0.001**
Ustic	1	3	0	2	0	2	3	0	0	0	0	0	**0.001**
Soil Moisture Sub Class (SMSC)													**0.004**
Aquic	0	0	0	0	0	0	0	0	0	0	0	0	1
Aridic	0	0	0	1	0	0	0	0	0	0	0	0	**0.006**
Oxyaquic	0	0	0	0	1	0	0	0	1	0	2	0	0.29
Typic	0	9	1	2	5	6	25	1	11	2	30	2	**0.002**
Udic	1	0	0	0	0	0	0	0	0	0	0	0	0.088
Ustic	1	0	2	0	0	1	0	0	0	0	0	0	**0.027**
Aspect Class													0.633
E	1	0	1	0	0	0	1	0	0	0	1	1	0.491
ENE	0	0	0	0	1	1	1	0	0	0	3	0	0.701
ESE	0	0	1	0	1	1	1	0	1	0	2	0	**0.074**
N	0	1	0	0	0	0	3	0	1	0	5	0	0.23
NE	0	2	0	0	0	0	2	0	3	1	2	0	0.545
NNE	0	2	0	0	0	0	1	0	3	0	1	0	0.619
NNW	0	1	0	0	0	0	1	0	1	1	1	0	0.487
NW	0	1	0	0	0	0	1	0	0	0	2	0	0.551

Table 3.7. Ordtest p-values for climatic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level (continued).

	PIFL / SYAL	PSME / ARCO9	PIFL / ARFR4	PIFL / AGGL	PICO / CEVE	PSME / mixed xeric shrub	PICO / SPBE2	ABLA / ARCO9	PSME / JUCOD	PIEN / MIOB2	ABLA - PIAL / VASC	PIAL / ARUV	p-val
Aspect Class													0.633
S	0	0	1	1	0	0	3	0	0	0	1	0	0.482
SE	0	0	0	0	1	1	6	0	1	0	0	0	0.791
SSE	0	0	0	0	1	2	0	1	1	0	0	0	0.628
SSW	0	1	0	1	0	0	0	0	0	0	4	1	0.874
SW	1	1	0	0	0	0	2	0	0	0	1	0	0.358
W	0	0	0	0	2	1	1	1	0	0	3	0	**0.071**
WNW	0	0	0	0	0	0	0	0	1	0	2	0	0.706
WSW	0	0	0	1	0	1	1	0	0	0	3	0	0.53

Table 3.8. Ordtest p-values for geologic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level.

	PIFL / SYAL	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**	**PICO / SPBE2**	**ABLA / ARCO9**	**PSME / JUCOD**	**PIEN / MIOB2**	**ABLA - PIAL / VASC**	**PIAL / ARUV**	**p-val**
Soil Depth													**0.044**
Deep	2	9	2	2	3	6	23	2	9	1	20	1	**0.06**
Moderate	0	0	0	1	1	1	2	0	1	1	6	1	0.262
Shallow	0	0	1	0	1	0	0	0	1	0	6	0	0.439
Soil Particle Size													**0.016**
clayey skeletal	1	0	0	0	0	0	0	0	0	0	0	0	1
coarse loamy	0	0	0	0	0	0	1	0	0	0	1	0	1
fine loamy	1	2	1	0	0	0	0	0	1	0	1	0	1
Fragmental	0	0	1	0	0	0	0	0	1	0	0	0	1
Loamy	0	0	0	0	0	0	0	0	1	0	2	0	1
loamy skeletal	0	6	1	3	2	7	13	1	7	2	23	2	1
Sandy	0	0	0	0	0	0	0	0	0	0	1	0	1
sandy skeletal	0	1	0	0	4	0	9	1	1	0	4	0	1
Soil SubGroup													**0.001**
Aridic Haplustepts	0	0	0	1	0	0	0	0	0	0	0	0	1
Calcic Haplocryepts	0	1	0	1	0	0	0	0	1	0	0	0	1
Calcic Haplocryolls	0	0	0	0	0	1	0	0	0	0	0	0	1
Calcic Pachic Haplocryolls	0	0	1	0	0	0	0	0	0	1	0	0	1
Eutric Haplocryalfs	0	0	0	0	0	0	1	0	0	0	0	0	1
Inceptic Haplustalfs	0	0	0	1	0	0	0	0	0	0	0	0	1
Lithic Cryorthents	0	0	0	0	0	0	0	0	0	0	1	0	1
Lithic Dystrocryepts	0	0	0	0	0	0	0	0	0	0	2	0	1
Lithic Haplocryalfs	0	0	1	0	0	0	0	0	0	0	0	0	1

Table 3.8. Ordtest p-values for geologic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level (continued).

	PIFL / SYAL	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**	**PICO / SPBE2**	**ABLA / ARCO9**	**PSME / JUCOD**	**PIEN / MIOB2**	**ABLA - PIAL / VASC**	**PIAL / ARUV**	**p-val**
Lithic Haplocryepts	0	0	0	0	0	0	0	0	0	0	2	0	1
Lithic Humicryepts	0	0	0	0	0	0	0	0	1	0	1	0	1
Oxyaquic Haplocryalfs	0	0	0	0	0	0	0	0	1	0	0	0	1
Oxyaquic Haplocryepts	0	0	0	0	1	0	0	0	0	0	2	0	1
Pachic Argicryolls	1	0	0	0	0	0	0	0	0	0	0	0	1
Pachic Argiustolls	0	1	0	0	0	0	0	0	0	0	0	0	1
Pachic Haplocryolls	0	1	0	0	0	0	0	0	0	0	0	0	1
Pachic Haplustolls	0	0	0	0	0	1	0	0	0	0	0	0	1
Typic Calcicryepts	0	0	0	0	0	0	0	0	2	0	0	0	1
Typic Cryorthents	0	1	1	0	2	0	7	1	1	0	1	0	1
Typic Cryothents	0	0	0	0	0	0	2	0	0	0	0	0	1
Typic Dystrocryepts	0	0	0	0	0	0	1	0	1	0	8	0	1
Typic Haplocryalfs	0	0	0	0	0	0	0	1	0	0	3	0	1
Typic Haplocryepts	0	3	0	0	3	4	10	0	3	0	12	2	1
Typic Haplocryolls	0	0	0	0	0	0	0	0	1	0	0	0	1
Typic Haplustalfs	0	2	0	0	0	0	0	0	0	0	0	0	1
Typic Haplustepts	0	0	0	0	0	1	3	0	0	0	0	0	1
Typic Humicryepts	0	0	0	0	0	0	0	0	0	1	0	0	1
Udic Haplustalfs	1	0	0	0	0	0	0	0	0	0	0	0	1

Table 3.9. Ortest p-values for the categorical variable, disturbance, based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level.

	PIFL / SYAL	PSME / ARCO9	PIFL / ARFR4	PIFL / AGGL	PICO / CEVE	PSME / mixed xeric shrub	PICO / SPBE2	ABLA / ARCO9	PSME / JUCOD	PIEN / MIOB2	ABLA - PIAL / VASC	PIAL / ARUV	p-val
Disturbance													**0.001**
Avalanche	0	0	0	0	0	0	0	1	0	1	0	0	**0.021**
Blister rust	1	1	0	1	0	5	0	1	0	0	5	0	0.965
Erosion	0	0	2	1	1	0	0	0	0	0	0	0	**0.001**
Fire	0	2	0	0	2	1	1	1	0	5	2	0	**0.004**
Foliage disease	0	0	0	0	0	0	0	0	0	0	1	0	0.548
Insect	0	1	0	0	0	0	0	1	0	0	1	0	0.279
Mistletoe	0	0	0	0	0	1	0	0	0	0	1	0	0.894
None	0	4	1	1	3	8	1	5	2	0	20	1	0.28
Rockfall	0	0	0	0	0	0	0	2	0	0	0	0	0.633
Snow accumulation	0	0	0	0	0	0	0	0	0	0	1	0	0.564
Snow mold	0	0	0	0	0	0	0	0	0	0	0	1	0.218
Windthrow	1	1	0	0	1	10	1	1	0	0	1	0	0.367
Habitat Type													**0.001**
ABLA/ALSI	0	0	0	0	0	0	0	1	0	0	0	0	0.33
ABLA/ARCO9	0	1	0	0	0	0	0	1	0	0	0	0	0.566
ABLA/ARLA8	0	0	0	0	0	0	0	1	0	0	0	0	0.137
ABLA/JUCOD	0	1	0	0	1	3	0	0	0	0	0	0	0.968
ABLA/SPBE	0	0	0	0	0	0	0	1	0	0	0	0	0.473
ABLA/SYAL	1	0	0	0	0	0	0	0	0	0	0	0	0.694
ABLA/VACE	0	0	0	0	0	0	0	1	0	0	0	0	0.608
ABLA/VAME	0	0	0	0	0	2	0	3	0	0	0	0	0.986
ABLA/VASC-PIAL	0	0	0	0	0	2	0	1	0	0	23	0	**0.042**
ABLA/VASC-VASC	0	0	0	0	1	0	0	2	0	0	4	0	0.88

Table 3.9. Ortest p-values for the categorical variable, disturbance, based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level (continued).

	PIFL / SYAL	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**	**PICO / SPBE2**	**ABLA / ARCO9**	**PSME / JUCOD**	**PIEN / MIOB2**	**ABLA - PIAL / VASC**	**PIAL / ARUV**	**p-val**
PIAL/CARO2-PICO	0	0	0	0	0	1	0	0	0	0	0	0	0.713
PIAL/JUCOD	0	0	0	0	0	2	0	0	0	0	0	0	0.908
PIAL timberline	0	0	0	0	0	0	0	1	1	0	2	1	0.149
PIAL/VASC	0	0	0	0	0	3	0	0	0	0	3	1	0.863
PICO/SHCA	0	0	0	0	0	1	0	0	0	0	0	0	0.681
PICO/SPBE	0	0	0	0	0	7	0	0	0	4	0	0	**0.002**
PICO/VAME	0	0	0	0	0	0	0	0	0	2	0	0	**0.054**
PIEN/JUCOD	0	0	0	0	0	0	0	0	1	0	0	0	0.243
PIFL/FEID	0	0	1	0	0	0	0	0	0	0	0	0	0.186
PIFL/JUCOD	0	1	0	1	1	1	1	0	0	0	0	0	0.041
PIFL/PSSPS	1	0	2	2	1	0	0	0	0	0	0	0	**0.001**
PSME/ARCO9	0	1	0	0	0	0	0	0	0	0	0	0	0.132
PSME/JUCOD	0	0	0	0	2	1	1	0	0	0	0	0	0.173
PSME/PHMA5	0	2	0	0	0	0	0	0	0	0	0	0	0.143
PSME/SPBE	0	1	0	0	1	2	0	0	0	0	0	0	0.213
PSME/SYAL	0	2	0	0	0	0	0	0	0	0	0	0	0.242

Woodland and Forested Association Descriptions

Cluster 1: *Abies lasiocarpa/Symphoricarpos albus* Association (n=2)

Vegetation. This community is not characterized by the dominant presence of a single tree species in the overstory, but rather by the regeneration of *Pinus flexilis* in the understory, the presence and abundance of *Symphoricarpos albus* (> 20%) and consistent presence of *Amelanchier alnifolia* and *Prunus virginiana* var. *melanocarpa* in the shrub layer, and the consistent presence and occasional abundance (~5%) of *Lupinus argenteus*, *Achillea millefolium* var. *lanata, Arnica cordifolia, Balsamorhiza sagittata, Cerastium arvense, Chamerion angustifolium, Frigaria virginiana, Galium boreale, Geranium viscosissimum, Taraxacum officionale* and *Campanula rotundifolia* in the forb layer. *Abies lasiocarpa*, *Pinus contorta* var. *latifolia, Pinus flexilis* and *Pseudotsuga menziesii* var. *glauca* were all observed in the overstory. *Carex rossii* is the only consistently associated graminoid species. *Vaccinium scoparium* is conspicuously absent from this type.

Environment. This association occurs in the foothills on erosion remnants and scarp slopes at elevations between 1,800 and 2,220 m on moderate slopes (20-40%) with simple concave local topography. Concave local topography should indicate slightly moister conditions than would be found on adjacent linear slopes. The soil temperature regime is cryic or frigid, the soil moisture regime is udic or ustic and the soil moisture subclass is either ustic or udic. Soils are deep, formed from limestone and mixed till and

colluvium. Soil particle size is fine loamy or clayey skeletal. Soils were classified as Pachic Argicryolls and Udic Haplustalfs.

Other Classifications. Habitat types represented in this association include: *Abies lasiocarpa/Symphoricarpos albus* and *Pinus flexilis/Elymus spicatus*. The *Abies lasiocarpa/Symphoricarpos albus* h.t. was described for eastern Idaho and western Wyoming (Steele et al., 1983), but not for westerm Montana (Pfister et al., 1977). *Abies lasiocarpa/Symphoricarpos albus* is a minor habitat type that occupies benches, lower slopes and well-drained alluvial terraces at low elevations of the *Abies lasiocarpa* series.

The *Pinus flexilis/Elymus spicatus* h.t. was described for western Montana (Pfister et al., 1977), but not for eastern Idaho and western Wyoming (Steele et al., 1983). The *Pinus flexilis/Elymus spicatus* h.t. (Pfister et al., 1977) is widely distributed east of the Continental Divide on dry, rocky sites adjacent to or within the forested zone. *Pinus flexilis* is the dominant climax tree, often occurring with *Juniperus scopulorum* and *Pseudotsuga menziesii* var. *glauca* in lesser amounts. The *Pinus flexilis/Elymus spicatus* h.t. (Pfister et al., 1977) typically occurs on rocky, broken terrain on sedimentary parent materials, primarily limestone and sandstone, and calcareous soils with higher pH's (7.1).

The *Abies lasiocarpa/Symphoricarpos albus* association is composed of only two samples. Both samples have regenerating *Pinus flexilis*, abundant *Symphoricarpos albus* and higher consistency and average cover of *Achillea millefolium, Arnica cordifolia, Balsamorhiza sagittata, Campanula rotundifolia, Cerastuim arvense, Fragaria virginiana, Galium boreale, Geranium viscosissimum, Lupinus argenteus, Amelanchiar alnifolia* and *Prunus virginiana* var. *melanocarpa* than was observed in other

woodland/forested associations identified in this analysis. While samples included in the *Abies lasiocarpa/Symphoricarpos albus* association share a number of similarities in vegetation composition, there are obvious differences in the overall structure and successional trajectory of the two samples. One sample clearly represented a forested association, occurring at low elevations of the *Abies lasiocarpa* series, while the other was a much more open woodland association, most similar to a species rich version of the *Pinus flexilis/Elymus spicatus* h.t.. Based on these differences, I do not believe these two samples constitute a true association. The similarities in vegetation composition are likely due to the fact that the two samples occupy similar environments. Both are found along the northeastern margin of the study area in soils derived from sedimentary parent materials and with high clay content. The mean annual solar exposure (SOLAR) of this cluster is higher than for the *Pseudotsuga menziesii/Arnica cordifolia* and *Pinus flexilis/Artemisia frigida* associations but similar to that of the *Pinus flexilis/Agoseris glauca* association. Samples of this cluster experienced the highest average daily temperatures (DAVTEMP) and growing degree days of any association, indicating longer, warmer growing seasons. Relative effective annual precipitation (REAP) and total annual precipitation (TOTPRCP) of this cluster an the *Pseudotsuga menziesii/Arnica cordifolia* association are similar and somewhat higher than observed in the other *Pinus flexilis* associations.

Cluster 2: TO_*Pseudotsuga menziesii* var. *glauca*/*Arnica cordifolia* Association (n=9)

Vegetation. In this association, *Pseudotsuga menziesii* var. *glauca* dominates the overstory and generally occurs with > 30% cover. *Symphoricarpos albus* is the most frequent and abundant shrub species, though it rarely occurs with cover greater than 5%. *Juniperus communis* var. *depressa* is somewhat frequent (55%), but has consistently low cover in this association. *Spiraea betulifolia* and *Physocarpus malvaceus* occur with 44% frequency and only occasionally become well represented. *Arnica cordifolia* and *Galium boreale* are the most frequently associated forb species, both occurring with 77% frequency. *Arnica cordifolia* is frequently well represented (>5%). *Poa wheeleri* is the most frequently (66%) associated graminoid species. *Carex rossii* is also commonly present.

Environment. This association occurs in the foothills and at low elevations (1,750-2,500 m) in the mountains. Commmon landforms include: mountain slopes, dipslopes, ridges and pediments. Sites generally have a slope of 20-60% and occur on northerly aspects. However, two samples occurring near 2,500 m were on southwest-facing slopes with > 70% slope. Local topography is variable. The soil temperature regime is either frigid or cryic, the soil moisture regime is either ustic or udic and the soil moisture subclass is typic. Soils are deep and formed from granite, limestone, metamorphic or mixed colluvium, till and alluvium. Soil particle size is generally loamy skeletal. Fine loamy and sandy skeletal soil particle sizes were also observed. Soils represented in this association were diverse and include: Typic Hapustalfs, Typic

Cryorthents, Typic Haplocryepts, Pachic Argiustolls, Calcic Haplocryepts and Pachic Haplocryolls. This association receives the lowest annual solar exposure (SOLAR) of the low elevation associations and slightly higher relative effective annual precipitation (REAP) and annual total precipitation (TOTPRCP) than the *Pinus flexilis/Artemisia frigida* and *Pinus flexilis/Agoseris glauca* associations.

Other Classifications. Habitat types represented in this association primarily fell into the *Pseudotsuga menziesii* var. *glauca* series and include: *Pseudotsuga menziesii* var. *glauca/Spiraea betulifolia, Pseudotsuga menziesii* var. *glauca/Symphoricarpos albus, Pseudotsuga menziesii* var. *glauca/Arnica cordifolia, Pseudotsuga menziesii* var. *glauca/Physocarpus malvaceus, Abies lasiocarpa/Juniperus communis* var. *depressa, Abies lasiocarpa/Arnica cordifolia* and *Pinus flexilis/Juniperus communis* var. *depressa.* Samples classified as belonging the the *Abies lasiocarpa* and *Pinus flexilis* series were dominated by *Pseudotsuga menziesii* var. *glauca* at the time of sampling.

Pseudotsuga menziesii var. *glauca/Physocarpus malvaceus, Pseudotsuga menziesii* var. *glauca/Symphoricarpos albus* and *Pseudotsuga menziesii* var. *glauca/Spiraea betulifolia* are all minor habitat types that occur from Alpine, WY northward and into Montana (Steele et al., 1983). The *Pseudotsuga menziesii* var. *glauca/Physocarpus malvaceus* h.t. occurs mainly on steep northerly aspects and other moist, protected slopes. It represents moderate environments at low to mid elevations of the forested zone and occurs at the highest elevations in south central Montana (Steele et al., 1983). *Symphoricarpos albus, Spiraea betulifolia, Calamagrostis rubescens, Arnica*

cordifolia and *Carex geyerii* are commonly present and well represented in this habitat type.

The *Pseudotsuga menziesii* var. *glauca/Symphoricarpos albus* h.t. occupies low elevation slopes and benches having relatively mild climates and moist deep soils (Steele et al., 1983). Parent materials of this type are mainly limestone, sandstone and/or basic volcanics. This is one of the more common habitat types in Montana, occurring near the lower limit of the *Pseudotsuga menziesii* var. *glauca* series in the foothills of drier mountain ranges, such as the Beartooth Mountains (Pfister et al., 1977). *Pinus contorta* var. *latifolia* is the most common seral species and *Pseudotsuga menziesii* var. *glauca* dominates at upper elevations of this habitat type.

The *Pseudotsuga menziesii* var. *glauca/Spiraea betulifolia* h.t. represents mid-elevations of the *Pseudotsuga menziesii* var. *glauca* series (Steele et al., 1983) and is a minor h.t. in Montana (Pfister et al., 1977). Steele et al. (1983) found this h.t. on upper slopes and ridges in Wyoming. Pfister et al. (1977) generally found it on south and west facing slopes, but occasionally on north facing slopes at low elevations or on limestone substrates. *Arnica cordifolia, Eurybia conspicua, Frigaria virginiana, Allium cernuum* and *Mahonia repens* are commonly associated species. The h.t. is too dry for *Calamagrostis rubescens, Carex geyerii* and *Symphoricarpos albus*.

Pseudotsuga menziesii var. *glauca/Arnica cordifolia* is a cool, dry habitat type (Pfister et al., 1977) that occupies a variety of dry aspects at low to mid-elevations of the forested zone (Steele et al., 1983). In Wyoming, the *Pseudotsuga menziesii* var. *glauca /Arnica cordifolia* h.t. occurs in the Wind River Range and the east flank of the Absaroka

Range in Wyoming (Steele et al., 1983). In Montana, this h.t. occupies relatively gentle slopes at elevations between 5,900 and 7,000 ft. Juniperus *communis* var. *depressa, Fragaria virginiana, Arnica cordifolia, Antennaria racemosa* and *Astragalus miser* are commonly associated understory species (Pfister et al., 1977).

The *Abies lasiocarpa/Arnica cordifolia, Abies lasiocarpa/Juniperus communis* var. *depressa* and *Pinus flexilis/Juniperus communis* h.t.'s all occurred only on the eastern slopes of the Wind River Range and Absaroka Ranges in Wyoming (Steele et al., 1983).

Abies lasiocarpa/Arnica cordifolia is a major h.t. that represents low to mid-elevations of the *Abies lasiocarpa* series. Steele et al. (1983) found that *Pseudotsuga menziesii* var. *glauca* is occasionally the dominant seral species where sites occur on limestone. Pfister et al. (1977) refer to the *Abies lasiocarpa/Arnica cordifolia* h.t. as a relatively cool, moist habitat type and noted that it is primarily found in semi-arid mountains east of the Continental Divide, also often on limestone parent materials, on benchlike uplands and north-facing slopes and is typically absent elsewhere.

The *Abies lasiocarpa/Juniperus communis* var. *depressa* h.t. occurs primarily on gentle slopes between 2,408 and 2,865 m elevation and occasionally in cold air drainages at elevations as low as 1,981 (Steele et al., 1983). The *Pinus flexilis/Juniperus communis* var. *communis* h.t. occurs at low to mid elevations of the forested zone and represents a moister type in the *Pinus flexilis* series. Pfister et al. (1977) did not describe an *Abies lasiocarpa/Juniperus communis* var. *depressa* h.t. in Montana.

Lesica (1993) described a *Pseudotsuga menziesii* var. *glauca/Physocarpus malvaceus* habitat type that occurred in the foothills between 1,980 and 2,130 m (6,500 and 7,000 ft) on the north and east sides of the Line Creek Plateau study area. This forested habitat type was dominated by *Pseudotsuga menziesii* var. *glauca* and *Pinus contorta* var. *latifolia*. The understory was dominated by *Physocarpus malvaceus* and *Juniperus communis* var. *depressa*. Other common shrubs included *Spiraea betulifolia, Rosa acicularis* and *Shepherdia canadensis*. Common forbs were *Eurybia conspicua, Arnica cordifolia, Antennaria racemosa, Clematis columbiana,* and *Viola canadensis*. He noted that this habitat type is common on limestone-derived soils on the east side of the Line Creek Plateau but is rare on the crystalline-derived soils found on the north side of the Line Creek Plateau.

Cluster 3: *Pinus flexilis/Artemisia frigida* Association (n=3)

Vegetation. This community is dominated by *Pinus flexilis* in the overstory. *Pseudotsuga menziesii* var. *glauca* is often present and well represented in the overstory and understory. *Tragapogon dubius* is consistently present in low abundance (<1%). *Elymus spicatus* and *Leucopoa kingii* are the most consistently present and often well represented graminoids. *Ribes cernuum* var. *pedicillare*, *Symphoricarpos albus* and *Artemisia frigida* are commonly associated shrubs, though all occur in relatively low abundance. The shrub species *Artemisia frigida* and forb species *Cryptantha celosioides* and *Packera cana* are also commonly associated with the *Pinus flexilis/Agoseris glauca* association, though all were identified as indicator species for the *Pinus flexilis/Artemisia*

frigida association. *Macranthera grindelioides* is a commonly associated forb species that occurs only in samples of this association. *Eremegone congesta* and *Castilleja miniata* are forb species commonly associated with the *Pinus flexilis/Artemisia frigida* association and absent from the *Pinus flexilis/Agoseris glauca* association.

Environment. This association occurs in the foothills, typically on the backslope portion of scarp slopes and hillslopes, at slightly higher elevations (2,100-2,250 m) than the *Pseudotsuga menziesii* var*. glauca/Arnica cordifolia* association. Slopes are moderate to steep (30-60%) and generally south or east facing. The soil temperature regime is cryic, the soil moisture regime is udic and the soil moisture subclass is either ustic or typic. Soils are deep, formed from limestone colluvium and till or shallow and formed from shale residuum. Soil particle size can be fine loamy, loamy skeletal or fragmental. Soils were classified as Lithic Haplocralfs, Calcic Pachic Haplocryolls and Typic Cryorthents. The *Pinus flexilis/Artemisia frigida* association appears to occur on slightly more moderate slopes that receive less annual solar radiation (SOLAR) than sites occupied by the *Pinus flexilis/Agoseris glauca* association.

Other Classifications. The habitat types represented in this association include: *Pinus flexilis/Elymus spicatus* and *Pinus flexilis/Festuca idahoensis.* The *Pinus flexilis/Elymus spicatus* h.t. (Pfister et al., 1977) is widely distributed east of the Continental Divide on dry, rocky sites adjacent to or within the forested zone. *Pinus flexilis* is the dominant climax tree, often occurring with *Juniperus scopulorum* and *Pseudotsuga menziesii* var. *glauca* in lesser amounts. The *Pinus flexilis/Elymus spicatus*

h.t. typically occurs on rocky, broken terrain on sedimentary parent materials, primarily limestone and sandstone, and calcareous soils with higher pH's (7.1).

The *Pinus flexilis/Festuca idahoensis* h.t. is a minor h.t. described by both Pfister et al. (1977) and Steele et al. (1983). It is found primarily east of the Continental Divide on dry wind-exposed slopes and is better developed in south-central Montana than western Wyoming and eastern Idaho (Steele et al., 1983). At the dry extreme, the *Pinus flexilis/Festuca idahoensis* h.t. borders nonforest communities and at the moist extreme it borders the driest h.t.'s of the *Pseudotsuga menziesii* var. *glauca* and *Picea engelmannii* series.

Cluster 4: TO_*Pinus flexilis/Agoseris glauca* Association (n=3)

Vegetation. This community is dominated by *Pinus flexilis* in the overstory. *Pseudotsuga menziesii* var. *glauca* is absent from the overstory and infrequently and poorly represented in the understory. *Tragopogon dubius* is consistently absent. *Chaenactis douglasii, Phacelia linearis, Agoseris glauca* and *Astragalus miser* are commonly associated forb species. *Pinus flexilis, Phacelia linearis* and *Phlox hoodii* are indicator species. While this association is similar to the *Pinus flexilis/Artemisia frigida* association, also identified in this analysis, *Agoseris glauca* and *Phacelia linearis* are consistently present in the *Pinus flexilis/Agoseris glauca* association and consistently absent from the *Pinus flexilis/Artemisia frigida* association. Similarily, overstory *Pseudotsuga menziesii* var. *glauca* and understory *Tragapogon dubius* and *Ribes cereum* var. *pedicillare* are characteristic of the *Pinus flexilis/Artemisia frigida* association but are

absent from the *Pinus flexilis/Agoseris glauca* association. *Juniperus scopulorum*, *Juniperus communis* var. *depressa* and *Artemisia tridentata* var. *vaseyana* are shrubs commonly associated with both types. *Phacelia linearis* has 66% frequency in the *Pinus flexilis/Agoseris glauca* type and 33% frequency in the *Pinus flexilis/Artemisia frigida* association. In a further analysis, these two associations should be considered for merger.

Environment. This association occurs in the foothills around 2,000 m elevation (one sample occurred in the mountains at 2,650 m) on south and southwest-facing backslopes of scarp slope, ridge and hillslope landforms with > 50% slope. The soil temperature regime is cryic or frigid, the soil moisture regime is udic or ustic and the soil moisture subclass is typic or aridic. Soils are moderate or deep and formed from limestone and conglomerate colluvium and residuum. The soil particle size is loamy skeletal. Soils were classified as Calcic Haplocryepts, Aridic Haplustepts and Inceptic Haplustalfs.

Other Classifications. Habitat types represented in this association include: *Pinus flexilis/Juniperus communis* var. *depressa* and *Pinus flexilis/Elymus spicatus*. The two samples classified as the *Pinus flexilis/Elymus spicatus* h.t. using Pfister et al. (1977) were classified as *Pinus flexilis/Leucopoa kingii* h.t. using Steele et al. (1983).

One sample included in this association was identified to the *Pinus flexilis/Juniperus communis* var. *depressa* h.t. using both Steele et al. (1983) and Pfister et al. (1977). The *Pinus flexilis/Juniperus communis* var. *depressa* h.t occurs at low to mid elevations of the forested zone and represents a moister type in the *Pinus flexilis*

series. The *Pinus flexilis/Juniperus communis* var. *depressa* h.t. is widespread in dry mountains east of the Continental Divide, especially common near Red Lodge, Montana (Pfister et al., 1977). This type is restricted to limestone or other calcareous parent material on severe south to southwest exposures and ridges from 1,219 to 1,829 m (Pfister et al., 1977). *Pinus flexilis* often shares climax status with *Pseudotsuga menziesii* var. *glauca* and *Pinus albicaulis* is occassionally a minor component in the overstory. *Juniperus communis* var. *depressa, Juniperus horizontalis, Arnica cordifolia, Eurybia consipicua, Carex rossii, Galium boreale* and *Astragalus miser* are common understory species.

The *Pinus flexilis/Elymus spicatus* h.t. (Pfister et al., 1977) is widely distributed east of the Continental Divide on dry, rocky sites adjacent to or within the forested zone. *Pinus flexilis* is the dominant climax tree, often occurring with *Juniperus scopulorum* and *Pseudotsuga menziesii* var. *glauca* in lesser amounts. The *Pinus flexilis/Elymus spicatus* h.t. (Pfister et al., 1977) typically occurs on rocky, broken terrain on sedimentary parent materials, primarily limestone and sandstone, and calcareous soils with higher pH's (7.1).

The *Pinus flexilis/Leucopoa kingii* h.t. described by Steele et al. (1983) is the most common h.t in the *Pinus flexilis* series. It occurs in the Absaroka, Wind River, and Medicine Bow ranges in Wyoming and in small amounts in southern Montana. The *Pinus flexilis/Leucopoa kingii* type occupies severe, drougty sites on southeast and southwest exposures. *Pinus flexilis* are widely spaced, often accompanied by *Pseudotsuga menziesii* var. *glauca* and create a savanna-like aspect. *Juniperus*

scopulorum is a minor component of the tree layer and *Leucopoa kingii* and *Elymus spicatus* codominate the undergrowth.

Lesica (1993) described a similar *Pinus flexilis/Festuca idahoensis* habitat type that occurs in the foothills along the east slope of the Line Creek Plateau between 1,890 and 2,195 m on soils derived from limestone. This woodland habitat type is dominated by *Pinus flexilis*. *Juniperus scopulorum* and *Pseudotsuga menziesii* var. *glauca* were present in some stands. *Artemisia tridentata* var. *vaseyana* and *Juniperus horizontalis* were the common shrubs. *Festuca idahoensis, Elymus spicatus* and *Koeleria cristata* were abundant graminoids. *Balsamorhiza incana, Cerastium arvense* and *Antennaria microphylla* were some of the many common forbs present in this type.

Cluster 5: *Pinus contorta* var. *latifolia/*
Ceanothus velutinus Association (n=6)

Vegetation. This is an early seral community dominated by regenerating *Pinus contorta* var. *latifolia. Ceanothus velutinus, Spiraea betulifolia, Vaccinium membranaceum, Ribes viscosissimum, Rubus parviflora, Shepherdia canadensis* and *Mahonia repens* are consistently associated shrub species with cover ranging from well represented to abundant. *Epilobium angustifolium*, *Eurybia conspicua, Chamerion angustifolium* and *Anaphalis margaritacea* are consistently associated forb species. *Carex geyeri* is the most consistently associated graminoid species.

Environment. This association occurs only in the Stillwater River basin, a large U-shaped valley, on backslope and footslope positions that burned in the Stillwater Fire

(1988). Elevation ranges from 2,000 to 2,500 m and slope percent and aspect range widely. Local topography is generally simple and linear. The soil temperature regime is cryic, the soil moisture regime is udic and the soil moisture subclass is typic. Soils range from shallow to deep and are formed from granitic colluvium and residuum. The soil particle size is loamy skeletal or sandy skeletal. Soils were classificed as Typic Haplocryepts and Typic Cryorthents, indicating they are relatively young. This association occurs at similar elevations as the *Pseudotsuga menziesii* var. *glauca*/mixed xeric shrub and *Pinus contorta* var. *latifolia/Spiraea betulifolia* associations, but receives substantially more total annual precipitation than both types. The relative effective annual precipitation (REAP) is similar to the *Pinus contorta* var. *latifolia/Spiraea betulifolia* association and greater than the *Pseudotsuga menziesii* var. *glauca*/mixed xeric shrub association.

Other Classifications. The *Pinus contorta* var. *latifolia/Spiraea betulifolia* h.t. and *Pinus contorta* var. *latifolia Vaccinium membranaceum (Vaccinium globulare)* c.t. (Steele et al., 1983) are both represented in this association, though the *Pinus contorta* var. *latifolia/Vaccinium membranaceum* h.t. is much more common. The *Pinus contorta* var. *latifolia/Vaccinium membranaceum* c.t. occurs from Yellowstone National Park south to Utah, but is absent from the Wind River range, the southern end of the Absaroka range and the east slope of the Wyoming range (Steele et al., 1983). Steele et al. (1983) thought this to be a relatively rare community type, since associated sites favor reproduction of *Pseudotsuga*, *Picea* and *Abies* and occur only in the earliest stages of secondary succession following widespread wildfire. Fittingly, the *Pinus contorta* var.

latifolia/*Ceanothus velutinus* association occurred only in the Stillwater Basin, which is located in the northwestern portion of the study area and burned extensively in 1988. Pfister et al. (1977) did not describe a similar habitat or community type in the *Pinus contorta* var.*latifolia* series.

The two samples classified as *Pinus contorta* var. *latifolia/Spiraea betulifolia* were both very early seral stands and most likely belong to the *Calamagrostis canadensis* and *Carex geyerii* habitat types of the *Abies lasiocarpa* series, though no *Abies lasiocarpa* was observed in or near the sampled stands. These samples represented wetter conditions than samples classified to the *Pinus contorta* var. *latifolia/Vaccinium membranaceum* association.

The *Abies lasiocarpa/Carex geyerii* community type identified by Steele et al. (1983) occured from Yellowstone National Park to the Bear River range in southeastern Idaho. Pfister et al. (1977) also identified this type in Montana. The *Abies lasiocarpa/Calamagrostis canadensis* c.t. occurs on broad wet benches in the Wind River Range and *Picea engelmannii* eventually dominates the overstory. The *Calamagrostis canadensis* phase is one of the wettest sites in the *Abies lasiocarpa* series. Since *Abies lasiocarpa* was totally absent from these and adjacent sites, the site was classified as a *Pinus contorta* var. *latifolia /Spiraea betulifolia* habitat type. The *Pinus contorta* var. *latifolia /Spiraea betulifolia* community type occurs from the Palisades Reservoir northward to Yellowstone National Park (Steele et al., 1983). This type was also identified as being scarce and representing the early stages of secondary succession in the

Abies lasiocarpa/Spiraea betulifolia and *Pseudotsuga menziesii* var. *glauca/Spiraea betulifolia* habitat types.

The *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* and *Pseudotsuga menziesii* var. *glauca*/mixed xeric shrub associations also occur in the Stillwater River basin. Most samples in the *Pseudotsuga menziesii* var. *glauca*/mixed xeric shrub association occur along the northeastern and eastern margins of the study area in the transition zone between gneissic/granitic and sedimentary parent materials. Those occurring in the Stillwater River basin are the centralmost occurrences of the *Pseudotsuga menziesii* var. *glauca*/mixed xeric shrub association in the Beartooth Mountains study area.

Cluster 6: *Pseudotsuga menziesii* var. *glauca*/mixed xeric shrub Association (n=7)

Vegetation. This association is dominated by *Pseudotsuga menziesii* var. *glauca* occurring with < 30% cover. *Pseudotsuga menziesii* var. *glauca* is also the most common tree species reproducing in the understory. The shrub species *Juniperus communis* var. *depressa*, *Spiraea betulifolia*, *Ribes cernuum* var. *pedicillare* and *Juniperus scopulorum* consistently occur in low abundance (<5%), but have the highest frequencies of occurrence (100%, 71%, 42% and 42% respectively). *Campanula rotundifolia* occurs in low abundance and is the most frequently associated (71%) forb species. *Boechera nuttallii* and *Fragaria vesca* are the next most commonly associated forb species. Each occur with 42% frequency and have low abundance. *Carex rossii* is the most commonly associated graminoid species (71% frequency), followed by *Elymus*

spicatus (56% frequency). Both occur with low abundance (<2%). No indicator species were identified for the *Pseudotsuga menziesii* var. *glauca/*mixed xeric shrub association.

Environment. This association occurs in the foothills and at low and moderate elevations in the mountains (approximately 1,990 m to 2,500 m) on moderate to steep (30-75%), southerly-facing backslopes with simple, linear local topography. The soil temperature regime and soil moisture regime are either jointly frigid and ustic or cryic and udic and the soil moisture subclass is typic. Soils are deep, formed from limestone or granite colluvium and have a loamy skeletal soil particle size. Soils were classified as Typic Haplustepts, Typic Haplocryepts, Calcic Haplocryolls and Pachic Hapustolls.

The *Pseudotstuga menziesii* var. *glauca*/mixed xeric shrub association generally occurs on steeper slopes and in shallower soils. It seems to be transitional between the *Pseudotsuga menziesii* var. *glauca/Arnica cordifolia* association and the *Pseudotsuga menziesii* var. *glauca/Juniperus communis* var. *depressa* association. . The *Pseudotsuga menziesii* var. *glauca*/mixed xeric shrub association is drier, colder, and has a shorter growing season than the *Pseudotsuga menziesii/Arnica cordifolia* association. It has lower cover of *Juniperus communis* var. *depressa* and a characteristically more depauperate understory than the *Pseudotsuga menziesii* var. *glauca/Juniperus communis* var. *depressa* association.

Other Classifications. The *Pinus flexilis* var. *glauca/Elymus spicatus* h.t., *Pseudotsuga menziesii* var. *glauca/Juniperus communis* var. *depressa* h.t. and *Abies lasiocarpa/Vaccinium scoparium* h.t. *Vaccinium scoparium* phase are represented in the

Pseudotstuga menziesii var. *glauca*/mixed xeric shrub association, but not in the *Pseudotsuga menziesii* var. *glauca/Arnica cordifolia* association. Conversly, the *Abies lasiocarpa/Arnica cordifolia* h.t., *Pseudotsuga menziesii* var. *glauca/Arnica cordifolia* h.t., *Pseudotsuga menziesii* var. *glauca/Physocarpus malvaceus* h.t. and *Pseudotsuga menziesii* var. *glauca*/*Symphoricarpos albus* h.t. are not represented in the *Pseudotstuga menziesii* var. *glauca*/mixed xeric shrub association as they are in the *Pseudotsuga menziesii* var. *glauca/Arnica cordifolia* association. The *Abies lasiocarpa/Juniperus communis* var. *depressa* h.t., *Pinus flexilis/ Juniperus communis* var. *depressa* h.t and *Pseudotsuga menziesii* var. *glauca /Spiraea betulifolia* habitat types are represented in both associations.

The *Pinus flexilis/Elymus spicatus* h.t. (Pfister et al., 1977) is widely distributed east of the Continental Divide on dry, rocky sites adjacent to or within the forested zone. *Pinus flexilis* is the dominant climax tree, often occurring with *Juniperus scopulorum* and *Pseudotsuga menziesii* var. *glauca* in lesser amounts. The *Pinus flexilis/Elymus spicatus* h.t. (Pfister et al., 1977) typically occurs on rocky, broken terrain of sedimentary parent materials, primarily limestone and sandstone, and calcareous soils with higher pH's (7.1). Steele et al. (1983) did not describe the same type in Wyoming. The *Pinus flexilis/Leucopoa kingii* h.t. identified by Steele et al. (1983) is similar to this association, though no samples were classified to this habitat type. The *Pinus flexilis/Leucopoa kingii* h.t. occurs on severe, droughty sites, most extensively on southeast and southwest exposures anywhere from lower to upper treeline as long as slopes are dry.

The *Pseudotsuga menziesii* var. *glauca/Juniperus communis* var. *depressa* h.t. occupies extensive areas on the east slope of the Wind River and Absaroka ranges in Wyoming (Steele et al., 1983) and is locally abundant in central and southwestern Montana between 1,615 and 2,073 m elevation (Pfister et al., 1977). It is generally considered to be a cool and dry or excessively well-drained habitat type that occurs on exposed rocky slopes at low to mid elevations of the forest zone. In Montana, it is most common on steep, south- facing exposures and limestone substrates. This is one of the driest habitat types in the *Pseudotsuga menziesii* var. *glauca* series (Pfister et al., 1977). *Pinus contorta* var. *latifolia* often codominates in granitics. In these instances, progression to a *Pseudotsuga menziesii* var. *glauca*-dominated stand is slow.

The *Abies lasiocarpa/Vaccinium scoparium* h.t.-*Vaccinium scoparium* phase is extensive throughout much of western Wyoming and Yellowstone National Park (Steele et al., 1983) at mid- to upper elevations of the *Abies lasiocarpa* series. In the *Vaccinium scoparium* phase, *Pinus contorta* var. *latifolia* dominates most seral stands and is eventually replaced by *Abies lasiocarpa* and *Picea engelmannii*. In Montana, the *Abies lasiocarpa/Vaccinium scoparium* h.t. is most abundant east of the Continental Divide, where it occurs on broad ridges, gentleslopes and benches with well drained soils between 2,134 and 2,590 m elevation (Pfister et al., 1977).

The *Abies lasiocarpa/Juniperus communis* var. *depressa* h.t. occurs primarily on gentle slopes between 2,408 and 2,865 m elevation and occasionally in cold air drainages at elevations as low as 1,981 (Steele et al., 1983). Pfister et al. (1977) did not describe an *Abies lasiocarpa/Juniperus communis* var. *depressa* h.t. in Montana.

The *Pinus flexilis/Juniperus communis* var. *communis* h.t. occurs at low to mid elevations of the forested zone and represents a moister type in the *Pinus flexilis* series that is widespread in dry mountains east of the Continental Divide, especially common near Red Lodge, Montana (Pfister et al., 1977). This type is restricted to limestone or other calcareous parent material on severe south to southwest exposures and ridges from 1,219 to 1,829 m (Pfister et al., 1977). *Pinus flexilis* often shares climax status with *Pseudotsuga menziesii* var. *glauca* and *Pinus albicaulis* is occasionally a minor component in the overstory. *Juniperus communis* var. *depressa, Juniperus horizontalis, Arnica cordifolia, Eurybia consipicua, Carex rossii, Galium boreale* and *Astragalus miser* are common understory species.

The *Pseudotsuga menziesii* var. *glauca /Spiraea betulifolia* h.t. occurs on upper slopes and ridges and represents a mid-elevation segment of the *Pseudotsuga menziesii* var. *glauca* series (Steele et al., 1983). In Montana, *Pseudotsuga menziesii* var. *glauca /Spiraea betulifolia* is a minor h.t. that occurs on warm, dry slopes at lower elevations east of the Continental Divide (Pfister et al., 1977). This type generally occurs on south and west facing exposures, but generally occurs on northerly aspects at the lowest elevations of the habitat type or on limestone (Pfister et al., 1977).

Cluster 7: *Pinus contorta* var. *latifolia* / *Spiraea betulifolia* Association (n=25)

Vegetation. This association is dominated by *Pinus contorta* var. *latifolia* in the overstory. *Pinus albicaulis, Abies lasiocarpa, Pseudotsuga menziesii* var. *glauca* and *Pinus flexilis* may be present in the overstory, but occur with 36%, 28%, 20% and 8%

frequency (respectively) and always have less cover than *Pinus contorta* var. *latifolia*. *Spiraea betulifolia* (88% frequency) and *Juniperus communis* var. *depressa* (68% frequency) are the most common shrub species and occasionally become well represented. *Arctostaphylos uva-ursi* and *Vaccinium scoparium* occur with 28% frequency and are generally well represented where they occur. *Campanula rotundifolia* is the most frequent forb species (52% frequency), followed by *Hedysarum sulphurescens* (24% frequency) and *Arnica cordifolia* (20% frequency). *Carex rossii* is the most frequent graminoid species (72% frequency) followed by *Poa wheeleri* (20% frequency). Unless already noted, graminoid and forb species generally occur with low abundance in this association. *Ceanothus veultinus, Mahonia repens* and *Epilobium angustifolium,* are generally absent.

Environment. Due to the broad ecological amplitude of *Pinus contorta* var. *latifolia*, this is one of the most common forested community associations. It occurs in the mountains from moderately low to high elevations (1,800 m - 2,800 m) on the backslopes, shoulders and summits of mountain slopes, erosion remnants, disintegration moraines, lateral moraines, V-shaped valleys and one pediment. Slope percent and slope aspect are variable. Local topography is most commonly simple convex, but simple linear and complex undulating topography are also likely. The soil temperature regime is generally cryic and occasionally frigid, the soil moisture regime is generally udic and occasionally ustic and the soil moisture subclass is always typic. Soils are moderate to deep and formed from granite and mixed colluvium and till. The soil particle size is either sandy skeletal or loamy skeletal. Soils were most commonly classified as Typic

Haplocryepts and Typic Orthocryents. Typic Haplustepts, Eutric Haplocryalfs and Typic Dystrocryepts also occurred. Windthrow and blister rust were very common disturbances observed in this association.

Other Classifications. The habitat types represented in this association include: *Pinus contorta* var. *latifolia*/S*piraea betulifolia, Pinus contorta* var. *latifolia/Shepherdia canadensis, Pseudotsuga menziesii* var*. glauca /Spiraea betulifolia, Pseudotsuga menziesii* var*. glauca /Juniperus communis* var. *depressa, Pinus flexilis/Juniperus communis* var. *depressa, Abies lasiocarpa/Juniperus communis* var. *depressa, Abies lasiocarpa/Vaccinium membranaceum, Abies lasiocarpa/Vaccinium-Pinus albicaulis* phase*, Pinus albicaulis/Carex rossii-Pinus contorta* var. *latifolia* phase*, Pinus albicaulis/Vaccinium scoparium* and *Pinus albicaulis/Juniperus communis* var. *depressa.* The number of habitat types represented in this association primarily reflects the broad ecological amplitude of *Pinus contorta* var. *latifolia* and its tendancy to dominate a range of habitat types during early successional stages.

Cluster 8: *Pseudotsuga menziesii* var*. glauca /*
Juniperus communis var. *depressa* association (n=2)

Vegetation. This community is dominated by *Pseudotsuga menziesii* var*. glauca*, which occurs with relatively low abundance (<30%) in the overstory and is commonly present and reproducing successfully in the understory. *Pinus flexilis* and *Pinus albicaulis* are often well-represented in the overstory and occasionally become codominant with *Pseudotsuga menziesii* var*. glauca*. Total overstory tree cover is less

than 30%. *Juniperus communis* var. *depressa* is consistently present (100% frequency) and abundant (>20% cover). *Arctostaphylos uva~ursi* and *Rosa sayi* also occur with 100% frequency, but in low abundance. *Juniperus scopulorum* is absent from the shrub layer. *Sedum lanceolatum, Trifolium haydenii* and *Erigeron compositus* var. *discoideus* are consistently associated forb species that were also identified as indicator species for this cluster. *Campanula rotundifolia, Heuchera cylindrica* var. *suksdorfii, Saxifraga bronchialis* var. *austromontana* and *Solidago multiradiata* var. *scopulorum* are consistently asscociated forb species (100% frequency) that in low abundance. *Carex rossii* occurs in low abundance, and is the only graminoid to occur with 100% frequency.

Environment. This association occurs in the foothills and at mid elevations in the mountains (approximately 2,050 m to 2,650 m) on moderate to steep (30-70%) south, southeast and west facing slopes with simple, linear topography. It is common on the backslopes of V-shaped and U-shaped valleys and scarp slopes. The soil temperature regime is cryic, the soil moisture reguime is udic and the soil moisture subclass is typic. Soils are deep, formed from limestone, granite or metasedimentary colluvium and have a loamy skeletal soil particle size. Soils were classified as Typic Haplocryepts and Typic Cryorthent. This association has much lower relative effective annual precipitation (REAP) and total annual precipitation (TOTPRCP) and higher average daily temperatures (DAVTEMP) than the *Abies lasiocarpa/Arnica cordifolia* association, which occupies similar elevations.

Other Classifications. The *Pinus flexilis/Juniperus communis* var. *depressa* and *Pseudotsuga menziesii* var. *glauca /Juniperus communis* var. *depressa* habitat types are represented in this association, both of which were described by both Steele et al. (1983) and Pfister et al. (1977). *Juniperus communis* var. *depressa* is commonly well represented in the understory and *Pinus flexilis* commonly well represented in the overstory of both habitat types. *Pinus flexilis* was present with moderate abundance (15%) in the sample classified to the *Pinus flexilis/Juniperus communis* var. *depressa* h.t., but *Pseudotsuga menziesii* var. *glauca* was also present and dominant in the overstory.

The *Pseudotsuga menziesii* var. *glauca/Juniperus communis* var. *depressa* h.t. occupies extensive areas on the east slope of the Wind River and Absaroka Ranges in Wyoming (Steele et al., 1983) and is locally abundant in central and southwestern Montana between 1,615 and 2,073 m elevation (Pfister et al., 1977). It is generally considered to be a cool and dry or excessively well-drained habitat type (Pfister et al., 1977). In Wyoming, the *Pseudotsuga menziesii* var. *glauca/Juniperus communis* var. *depressa* h.t. occupies exposed, rocky slopes at low to mid elevations of the forest zone. In Montana, it is most common on steep, south- facing exposures and limestone substrates (Pfister et al., 1977). This is one of the driest habitat types in the *Pseudotsuga menziesii* var. *glauca* series. *Pinus contorta* var. *latifolia* codominates at lower elevations and in granitics. In such instances, progression to a *Pseudotsuga menziesii* var. *glauca*-dominated stand is slow.

In Montana, the *Pinus flexilis/Juniperus communis* var. *depressa* h.t. is widespread in dry mountains east of the Continental Divide, especially near Red Lodge

(Pfister et al., 1977). It is restricted to limestone or other calcareous parent materials on severe south to southwest exposures and ridges from 1,219 to 1,829 m (Pfister et al., 1977). *Pinus flexilis* often shares climax status with *Pseudotsuga menziesii* var. *glauca*. *Pinus albicaulis* is occassionally a minor component of the overstory. *Juniperus communis* var. *depressa, Juniperus horizontalis, Arnica cordifolia, Eurybia consipicua, Carex rossii, Galium boreale* and *Astragalus miser* are common understory species of the *Pinus flexilis/Juniperus communis* var. *depressa* h.t..

Lesica (1993) described a *Pseudotsuga menziesii* var. *glauca/Juniperus communis* var. *depressa* community that occurs on cool and warm slopes between 1,981-2,560 m on the north and east sides of the Line Creek Plateau. His type is dominated by *Pseudotsuga menziesii* var. *glauca* and *Pinus contorta* var. *latifolia*. *Pinus flexilis* is common in seral stands at lower elevations on the east side of the study area. The shrub layer is dominated by *Juniperus communis* var. *depressa* with minor amounts of *Spiraea betulifolia*. *Arnica cordifolia* and *Antennaria racemosa* are common ground layer species. Low-elevation seral stands often have many components of *the Pinus flexilis/Festuca idahoensis* type, but *Pseudotsuga menziesii* var. *glauca* is the indicated climax. This was the most common lower montane habitat Lesica described in the Line Creek Plateau study area.

Cluster 9: *Abies lasiocarpa/Arnica cordifolia* Association (n=12)

Vegetation. This community is dominated by *Abies lasiocarpa* in the overstory, which generally occurs with > 40% cover. *Abies lasiocarpa* is also present and reproducing in the understory. *Picea engelmannii* is the second most commonly

associated species in the overstory and understory. *Pinus albicaulis* is absent from or poorly represented in the overstory (<5%). *Pseudotsuga menziesii* var. *glauca, Pinus contorta* var. *latifolia* and *Pinus flexilis* are occasionally present in the overstory in very low abundance. *Ribes lacustre* is consistently represented in the shrub layer and *Arnica cordifolia* is consistently present in the forb layer. Both occasionally become well represented. At least one of the following species is generally present and well represented: *Alnus sinuata, Vaccinium membranaceum, Thalictrum occidentale* and/or *Chamerion angustifolium*. *Alnus sinuata* was generally observed in the isolated wetter portions of sites where either a seep or irregular, broken topography has caused interstitial soil patches to accumulate more seasonal moisture.

Environment. This association occurs in the mountains at mid to upper elevations (2,200-2,850 m) on the toeslopes and backslopes of U-shaped valleys, mountain slopes and dipslopes. Slope percent, slope aspect and local topography are all variable. North and east-facing slopes predominate, but this association also occurred on southeast-facing slopes. Similarly, steep slopes (>50%) predominate, but occasionally slopes are more moderate (~20%). The soil temperature regime is cryic, the soil moisture regime is udic and the soil moisture subclass is typic. Soils are generally deep and formed from granite and limestone colluvium and residuum or mixed till. A wide range of soil classifications were represented in this association, including: Typic Haplocryepts, Typic Calcicryepts, Typic Cryorthents, Typic Calcicryepts, Calcic Haplocryepts, Oxyaquic Haplocryalfs, Typic Dystrocryepts, Typic Haplocryolls and Lithic Humicryepts.

Other Classifications. The habitat types represented in this association include: *Abies lasiocarpa/Vaccinium membranaceum, Abies lasiocarpa/Alnus sinuata, Abies lasiocarpa/Arnica cordifolia, Abies lasiocarpa/Spiraea betulifolia, Abies lasiocarpa/Vaccinium cespitosum, Abies lasiocarpa/Vaccinium scoparium-Vaccinium scoparium* phase*, Abies lasiocarpa/Vaccinium scoparium-Pinus albicaulis* phase*, Abies lasiocarpa/Arnica latifolia* and *Pinus albicaulis* timberline*,*.

Each of the habitat types represented in this association is characteristic of low- to mid, and very occasionally upper, elevations of the *Abies lasiocarpa* series. The *Abies lasiocarpa/Vaccinium membranaceum* occurs mainly on northerly to easterly aspects and represents low to mid-elevations of the *Abies lasiocarpa* series. The *Abies lasiocarpa/Alnus sinuata* was described for western Montana by Pfister et al. (1977), but not for eastern Idaho and western Wyoming (Steele et al., 1983). It is considered to be a relatively cool and moist upland habitat type within the lower subalpine forest, generally occurring on north-facing slopes. The *Abies lasiocarpa/Arnica cordifolia* h.t. was described by both Pfister et al. (1977) and Steele et al. (1983). It is a relatively cool, moist habitat type found in semi-arid mountains east of the Continental Divide and represents low to mid-elevations of the *Abies lasiocarpa* series. The *Abies lasiocarpa/Arnica cordifolia* h.t. is associated with benchlike upland and north-facing slopes and often occurs on limestone substrates. *Abies lasiocarpa/Spiraea betulifolia* is a minor habitat type described only by Steele et al. (1983). It represents low- to mid elevations of the *Abies lasiocarpa* series and generally occurs on westerly to southerly aspects. The *Abies lasiocarpa/Vaccinium cespitosum* h.t. was described by Pfister et al.

(1977) but not by Steele et al. (1983). It is confined to well-drained sites on benchlands and in frosty basins where cold air accumulates at moderate elevations of the *Abies lasiocarpa* series.

The *Abies lasiocarpa/Vaccinium scoparium* habitat type *Vaccinium scoparium* phase, *Abies lasiocarpa/Vaccinium scoparium* habitat type *Pinus albicaulis* phase, *Abies lasiocarpa/Arnica latifolia* h.t. and *Pinus albicaulis* timberline all represent habitat types found at upper elevations of the *Abies lasiocarpa* series. Samples classified to these habitat types but included in this association are generally early seral and dominated by *Pinus contorta* var. *latifolia*, or have much lower abundance of *Pinus albicaulis* than *Pinus contorta* var. *latifolia*.

Lesica (1993) described an *Abies lasiocarpa/Arnica cordifolia* community type that occurs on north and east-facing slopes between 2,134 m and 2,438 m on the Line Creek Plateau. This forest community type is dominated by *Pinus contorta* var. *latifolia, Pseudotsuga menziesii* var. *glauca, Abies lasiocarpa* and *Picea engelmannii*. *Juniperus communis* var. *depressa, Shepherdia canadensis* and *Physocarpus malvaceus* are common shrubs. *Arnica cordifolia* and *Antennaria racemosa* are common components of the sparse understory. Lesica (1993) noted that *Abies lasiocarpa/Vaccinium scoparium* usually occur upslope from and along drainage courses.

Lesica (1993) also described an *Abies lasiocarpa*/*Vaccinium scoparium* community type that occurs along and upslope from drainage courses between 7,600 and 9,200 ft. on the north side of Line Creek Plateau. His type is dominated by *Pinus contorta* var.*latifolia* and *Abies lasiocarpa*. *Pinus albicaulis* is common in more exposed

positions and *Pseudotsuga menziesii* var. *glauca* in warmer, more protected positions. These successional stands generally have a dense shrub layer of *Vaccinium scoparium* and much sparser representation of *Juniperus communis* and *Shepherdia canadensis*. He noted that *Alnus sinuata* occasionally persisted in seep areas. *Arnica cordifolia* and *Antennaria racemosa* are the most common forb species.

Cluster 10: *Picea engelmannii/Minuartia obtusiloba* Association (n=2)

Vegetation. This is a minor, high elevation community dominated by *Picea engelmannii* in the overstory. *Pinus albicaulis* was present where the community occurred on granitic substrate and *Pinus flexilis* where the community occurred on calcareous substrates. Vegetation composition is highly variable in this type. *Minuartia obtusiloba* and *Sedum lanceolatum* are commonly associated forbs. *Carex rossii* and *Trisetum spicatum are* the most commonly associated graminoid species. Other cushion plant, forb and graminoid species common to the alpine zone may be variously represented.

Environment. This association occurs in the mountains at mid to high elevations (2,500- 3,000 m) on the backslopes of dipslopes and glacial valley walls. Sites typically have linear and concave local topography, steep slopes (60-80%) and occur on northerly aspects. The soil temperature regime is cryic, the soil moisture regime is udic and the soil moisture subclass is typic. Soils are moderate to deep and formed from granite and

limestone colluvium. The soil particle size is loamy skeletal. Soils were classified as Calcic Pachic Haplocryolls and Typic Humicryepts.

Other Classifications. Habitat types represented in this association include: *Picea engelmannii/Juniperus communis* var. *depressa* and *Pinus albicaulis* timberline. *Picea engelmannii/Juniperus communis* var. *depressa* is a major h.t. in southern portions of the Absaroka Mountains and the eastern flank of the Wind River Range in Wyoming (Steele et al., 1983). It occurs from approximately 2,255 to 3,139 m on cool, generally northwest to east facing exposures. At higher elevations this association is more likely to occur on calcareous substrates (Steele et al., 1983). *Picea engelmannii/Juniperus communis* var. *depressa* may border *Abies lasiocarpa/Arnica cordifolia, Picea engelmannii/Arnica cordifolia, Pinus flexilis/Juniperus communis* and/or nonforest communities. In the Wind River Range, it usually borders *Pseudotsuga menziesii* var. *glauca /Juniperus communis* var. *depressa* on sedimentaries and *Picea engelmannii/Vaccinium scoparium* or *Pinus albicaulis/Vaccinium scoparium* on granitics (Steele et al., 1983). Steele et al. (1983) note that tree composition of seral stands is strongly dependent upon parent material. *Pseudotsuga menziesii* var. *glauca, Picea engelmannii* and *Pinus flexilis* are the primary seral species on calcareous substrates. In this study, the sample with *Pinus flexilis* as a codominant species occurred on limestone and the sample with *Pinus albicaulis* as a codominant species occurred on granitics.

The sample identified as *Pinus albicaulis* timberline h.t. is most similar to the *Pinus albicaulis/Carex rossii* h.t. described by Steele et al. (1983) and the *Pinus albicaulis-Abies lasiocarpa* h.t.'s described by Pfister et al. (1977). The *Pinus albicaulis-*

Abies lasiocarpa h.t.'s include most timberline sites in Montana and the Northern Rockies and encompass more variation in vegetational composition and tree life-forms than forest habitat types of lower elevations (Pfister et al., 1977). *Pinus albicaulis*, *Abies lasiocarpa* and *Picea engelmannii* occur in varying amounts, though *Abies lasiocarpa* is generally stunted, wind-deformed and shrublike.

Cluster 11: *Abies lasiocarpa-Pinus albicaulis/ Vaccinium scoparium* Association (n=32)

Vegetation. *Pinus albicaulis* is typically the dominant overstory tree species of this association. *Abies lasiocarpa* and *Picea engelmannii* are frequently codominants in the overstory and occasionally become more abundant than *Pinus albicaulis*. When *Abies lasiocarpa* is the dominant tree, *Vaccinium scoparium* is commonly well represented or abundant. When *Pinus albicaulis* is the dominant tree in the overstory, *Vaccinium scoparium* representation is variable. *Vaccinium scoparium* occurs with 93% frequency and an average of 27% cover. *Arnica latifolia* is the most commonly associated forb species (75% frequency) and generally occurs with < 10% cover. *Campanula rotundifolia, Chamerion angustifolium, Potentilla diversifolia* and *Solidago multiradiata* var. *scopulorum* are the only other forb and *Carex rossii* the only other graminoid species to occur with > 50% frequency. *Abies lasiocarpa* is frequently dominant at lower elevations and more moderate environments of this type, while *Pinus albicaulis* is frequently dominant at the higher elevations and harsher environments spanned by this association. *Vaccinium scoparium* is commonly sparse and occasionally absent at the highest elevations of this type.

Environment. This is the most common forested association in the Beartooth Mountains study area. It occurs from mid to high elevations (2,550 to 3,050 m) in the mountains on a wide range of landforms, including: mountain slopes, U-shaped and V-shaped valleys, knobs, recessional moraines, ridges, saddles and on the plateau. As such, the aspect and slope percents of sites included in this community are highly variable. Local topography may be simple linear, convex, complex undulating or complex broken but was never observed to be concave. The soil temperature regime is cryic, the soil moisture regime is udic and the soil moisture subclass is generally typic and very occasionally oxyaquic. Soils are generally deep, though both moderate and shallow soils were observed, and derived from granite and/or gabbro and diorite volcanic colluvium, residuum and till. Soil particle size is most commonly loamy skeletal. Sandy skeletal, loamy, sandy, fine loamy and coarse loamy soil particle sizes were also observed. Typic Haplocryepts, Typic Dystrocryepts, Typic Cryorthents, Typic Haplocryalfs, Lithic Haplocryepts, Lithic Dystrocryepts, Lithic Humicryepts, Lithic Cryorthents and Oxyaquic Haplocryepts are all represented in this associaton.

Other Classifications. Habitat types represented in this association include: *Abies lasiocarpa/Vaccinium scoparium-Pinus albicaulis* phase, *Abies lasiocarpa/Vaccinium scoparium-Vaccinium scoparium* phase, *Pinus albicaulis/Vaccinium scoparium* and *Pinus albicaulis* timberline. The majority of samples were classified as the *Abies lasiocarpa/Vaccinium scoparium* habitat type *Pinus albicaulis* phase.

The *Abies lasiocarpa/Vaccinium scoparium* habitat type *Pinus albicaulis* phase represents the cold, upper elevations of the *Abies lasiocarpa/Vaccinium scoparium* h.t.

and a transition between the *Abies lasiocarpa/Vaccinium scoparium* h.t and the *Pinus albicaulis/Vaccinium scoparium* h.t.. At higher elevations and in harsher environments, such as those represented by the *Pinus albicaulis/Vaccinium scoparium* h.t. and *Pinus albicaulis* timberline h.t., *Pinus albicaulis* dominates the overstory and *Pinus contorta* var. *latifolia*, *Abies lasiocarpa* and *Picea engelmannii* are less frequent and/or stunted. Several samples were classified as the *Abies lasiocarpa/Vaccinium scoparium* h.t. *Vaccinium scoparium* phase because *Pinus albicaulis* cover was lower than 5% and *Vaccinium scoparium* cover was greater than 5%. These samples could have just as easily been classified to the *Abies lasiocarpa/Vaccinium scoparium* h.t. *Pinus albicaulis* phase.

In Montana, the *Abies lasiocarpa/Vaccinium scoparium* habitat type *Pinus albicaulis* phase represents a majority of the highest elevation forests east of the Continental Divide (Pfister et al., 1977). *Pinus albicaulis* and *Picea engelmannii* generally dominate the overstory. *Abies lasiocarpa* may be present in the overstory but is commonly stunted and deformed and remains in the understory. *Vaccinium scoparium* is consistently present and abundant in the shrub layer.

Pinus albicaulis habitat types occur at higher elevations than the *Abies lasiocarpa/Vaccinium scoparium* habitat type *Pinus albicaulis* phase. In Montana, they are most common atop drier mountain ranges east of the Continental Divide on sites too dry for *Abies lasiocarpa* and near or above the cold limits *of Pseudotsuga menziesii* var. *glauca* and *Pinus flexilis* (Pfister et al., 1977). Understories of pure *Vaccinium*

scoparium are common on the highest and least droughty sites. *Festuca idahoensis* and dry-site subalpine and alpine forbs occur on the most arid sites.

Pfister et al. (1977) lumped timberline forested sites into the *Pinus albicaulis/Abies lasiocarpa* habitat types. These represent most timberline sites in Montana and the northern Rockies. *Juncus parryi, Carex rossii, Festuca idahoensis, Eremegone congesta, Arnica latifolia, Vaccinium scoparium* and *Hieracium triste* var. *gracile* are species commonly associated with this type east of the Continental Divide.

The *Abies lasiocarpa-Pinus albicaulis*/*Vaccinium scoparium* association described by Lesica (1993) occurred on cool slopes near timberline on the north side of the Line Creek Plateau. His community is dominated by *Abies lasiocarpa, Pinus albicaulis, Pinus contorta* var. *latifolia* and *Picea engelmannii*, with *Pinus contorta* var. *latifolia* becoming more common at the lower elevations and *Picea engelmannii* more common at higher elevations of the community type. *Vaccinium scoparium* is the dominant shrub, although *Spiraea betulifolia* and *Shepherdia canadensis* are common, especially at lower elevations. The ground cover layer is generally sparse. *Arnica cordifolia, Arnica latifolia* and *Potentilla diversifolia* are the most common forb species. Lesica (1993) noted that this type merged into the *Abies lasiocarpa/Vaccinium scoparium* habitat type below and that the two may be difficult to distinguish over large portions of the study area.

Lesica (1993) also described a *Pinus albicaulis* community type that occurs on ridge crests, warm slopes and other exposed sites near timberline (2,590-2,896 m) on the Line Creek Plateau. It is dominated by *Pinus albicaulis* and *Picea engelmannii* and *Abies*

lasiocarpa are generally scarce and of small stature. The ground layer is dominated by *Festuca idahoensis, Carex phaeochephala, Lupinus argenteus* and *Trifolium parryi*. Numerous other species of forbs are common but had low cover and consistency.

Cluster 12: *Pinus albicaulis/*
Arctostaphylos uva-ursi Association (n=2)

Vegetation. This is a minor high elevation community dominated by extremely stunted *Pinus albicaulis* in the tree layer. Stunted *Abies lasiocarpa* and *Picea engelmannii* also occur in the tree layer, but in lesser abundance. *Arctostaphylos uva-ursi* occurs with 100% frequency and is generally well represented. *Juniperus communis* var. *depressa* occurs with 100% frequency and is generally poorly represented. *Luzula spicata* and *Carex paysonis* occur with 100% frequency in the graminoid layer, along with *Sibbaldia procumbens, Minuartia obtusiloba, Potentilla diversifolia* and *Sedum lanceolatum* in the forb layer. *Silene acaulis* var. *subacaulescens* and *Carex phaeochephala* are indicator species because they occur only in this association and the *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association and they occur in this type with greater frequency.

Environment. This association occurs at high elevations (> 3,000 m) on the shoulders of ground moraines and cirques where the vertical slope shape is convex and the horizontal slope shape is linear. Slope percent and aspect are variable. The soil temperature regime is cryic, the soil moisture regime is udic and the soil moisture

subclass is typic. Soils are moderate to deep and formed from granite colluvium and till. Soils were classified as Typic Haplocryepts.

Other Classifications. The habitat types represented in this association include: *Pinus albicaulis/Vaccinium scoparium* and *Pinus albicaulis* timberline, though both should probably have been classified as *Pinus albicaulis* timberline due to the scarcity of *Vaccinium scoparium* and stuntedness of *Pinus albicaulis* in the sample classified as a *Pinus albicaulis/Vaccinium scoparium* h.t.. *Pinus albicaulis* h.t.'s extend downslope from upper timberline on dry, exposed ridges and are best developed on southern to western aspects, though they may occur on any aspect. At cold extremes this series borders alpine communities commonly dominated by *Carex*. spp., *Festuca idahoensis* or *Festuca ovina* (Steele et al., 1983).

This *Pinus albicaulis/Arctostaphylos uva~ursi* association is unlike any community type currently described for eastern Idaho and western Wyoming (Steele et al., 1983), western Montana (Pfister et al., 1977) or the Beartooth Mountains (Lesica, 1993) and may represent a currently undescribed community type association. The *Pinus albicaulis/Arctostaphylos uva~ursi* association occurs at the highest elevations and harshest environments of the forested zone. Like other high timberline *Pinus albicaulis* community types, alpine cushion and sedge species are common in the understory. However, the presence of *Arctostaphylos uva~ursi* at the highest elevations, being a species much more common to lower elevations and warmer environments, is very interesting.

Discussion

Twelve forested associations were identified using cluster analysis performed on vegetation composition data from 105 forested samples. The newly classified and described forested associations include: two *Pinus flexilis*- dominated woodland associations, three *Pseudotsuga menziesii* var. *glauca*- dominated woodland/forested associations, two *Pinus contorta* var. *latifolia*-dominated forested associations, one low elevation association where *Abies lasiocarpa* is the indicated climax species and *Pinus flexilis* is frequent in the understory, two high elevation *Abies lasiocarpa*- dominated forested associations and two high treeline associations, one that is *Pinus albicaulis*-dominated and one that is *Picea engelmannii*- dominated.

The forested associations classified and described here make reasonable ecological sense, especially at mid to high elevations. It was considerably more difficult to tease out the ecological factors potentially driving observed differences in vegetation composition between the *Pinus flexilis*- and *Pseudotsuga menziesii*- dominated associations and the *Abies lasiocarpa/Symphoricarpos albus* association. Differences in low elevation forest and woodland vegetation associations seem to correspond with very slight differences in total annual precipitation, relative effective annual precipitation, annual solar exposure and average daily temperature and more obvious differences in the parent materials on which associations occur.

All twelve associations were represented by a somewhat unique ensemble of habitat types, the ranges of which provide useful insight for characterizing the nature of vegetation association distribution across larger landscapes. In general, forest habitat

types more common to wetter mountain ranges of Montana were better described by Pfister et al. (1977) and forest habitat types more common to drier mountain ranges of Montana, such as the Beartooth Mountains, were better described by Steele et al. (1983). Moderate habitat types were generally adequately described by both.

The five woodland and forested associations occurring at the lowest elevations of the forested zone and are dominated by P*inus flexilis*, *Pseudotsuga menziesii* var. *glauca* or, in the *Abies lasiocarpa/Symphoricarpos albus* association, *Abies lasiocarpa* in the overstory and *Pinus flexilis* in the understory. The *Pseudotsuga menziesii* var. *glauca*/*Arnica cordifolia* and *Abies lasiocarpa/Symphoricarpos albus* associations extend to the lowest elevations and represent the highest ranges of relative effective annual precipitation observed in low elevation associations, though the range represented by the *Pseudotsuga menziesii* var. *glauca*/*Arnica cordifolia* association is slightly higher. The range of relative effective annual precipitation represented by the *Pseudotsuga menziesii* var. *glauca*/mixed xeric shrub association is only slightly lower than that of the *Pseudotsuga menziesii* var. *glauca*/*Arnica cordifolia* and *Abies lasiocarpa/Symphoricarpos albus* associations. *Symphoricarpos albus* is the most frequent and abundant shrub species in both the *Abies lasiocarpa/Symphoricarpos albus* and *Pseudotsuga menziesii* var. *glauca/Arnica cordifolia* associations. The main difference between the two is the *Abies lasiocarpa/Symphoricarpos albus* association occupies sites with slightly higher average daily temperatures, greater annual solar exposure and is consistently associated with soils formed from limestone parent materials. The *Abies lasiocarpa/Symphoricarpos albus* association may represent a

unique association specific to warm sites with moist, deep, limestone-derived soils where *Abies lasiocarpa* is the indicated climax and grassland/shrubland associations occur nearby, but this cluster is not ecologically or compositionally well-resolved. In further analysis, the *Abies lasiocarpa/Symphoricarpos albus* and *Pseudotsuga menziesii* var. *glauca/Arnica cordifolia* associations associations could possibly be considered for merger.

The *Pinus flexilis/Agoseris glauca* association stretches to the highest elevations of the *Pinus flexilis and Pseudotsuga menziesii* var. *glauca* dominated types but occupies the same general elevation range as the *Pseudotsuga menziesii* var. *glauca*/*Arnica cordifolia* and *Pseudotsuga menziesii* var. *glauca*/mixed xeric shrub associations. Though the *Pinus flexilis/Agoseris glauca* association occurs at higher elevations than other *Pseudotsuga menziesii* var. *glauca* and *Pinus flexilis*-dominated associations, it does so only on limestone parent materials, steep slopes and sites with low total annual precipitation, low relative effective annual precipitation and high annual solar exposure. *Pseudotsuga menziesii* var. *glauca* is characteristically absent from the overstory and understory of this association.

The *Pinus flexilis/Artemisia frigida* association is similar to the *Pinus flexilis/Agoseris glauca* association, but *Pseudotsuga menziesii* var. *glauca* is present in the overstory and *Ribes cernuum* var. *pedicillare* and *Tragapogon dubius* are present in the understory. These differences in vegetation compostion between the *Pinus flexilis/Artemisia frigida* association and the *Pinus flexilis/Agoseris glauca* association could be attributable to the slight increase in annual solar exposure represented by the

Pinus flexilis/Agoseris glauca association, which may make conditions too dry for *Pseudotsuga menziesii* var. *glauca*. The *Pinus flexilis/Artemisia frigida* association restricted to a very narrow elevation range, ~2,100 m, which overlaps with elevation ranges of the other four *Pseudotsuga menziesii* var. *glauca* and *Pinus flexilis*-dominated associations.

The *Pseudotstuga menziesii* var. *glauca/*mixed xeric shrub association also occurs on steep slopes with shallow soils. These sites tend to be wetter and colder than the *Pinus flexilis/Agoseris glauca* association and are drier, colder and have shorter growing seasons than the *Pseudotsuga menziesii* var*. glauca/Arnica cordifolia* association.

The *Pinus contorta* var. *latifolia/Spiraea betulifolia* association is a convoluted representation of low to high elevation habitat types that reflect the broad ecological amplitude of *Pinus contorta* var. *latifolia* as a seral, and occasionally climax, species. The most prominent feature of this association is the consistent presence and dominance of *Pinus contorta* var. *latifolia*. The other *Pinus contorta* var. *latifolia* dominated association, the *Pinus contorta* var. *latifolia*/*Ceanothus velutinus* association, occurred at slightly lower elevations than the *Pinus contorta* var. *latifolia/Spiraea betulifolia* association and only in the Stillwater Basin, which burned extensively in 1988. Both of the habitat types represented in the *Pinus contorta* var. *latifolia*/*Ceanothus velutinus* association are considered to represent early stages of secondary succession of the *Abies lasiocarpa* and *Pseudotsuga menziesii* var. *glauca* series.

The next highest elevation band is occupied by the *Abies lasiocarpa/Arnica cordifolia* association on wetter, cooler sites and the *Pseudotsuga menziesii* var.

glauca/Juniperus communis var. *depressa* association on drier, warmer sites. The *Pseudotsuga menziesii* var. *glauca/Juniperus communis* var. *depressa* association occurred at the lowest relative effective annual precipitation values recorded for samples of both associations. Sites were south, southeast and west-facing and moderate to steep in slope. The *Abies lasiocarpa/Arnica cordifolia* association spanned a very large range of slope percents and annual solar exposure budgets, a slightly smaller range of relative effective annual precipitation values and occurred primarily on north and east facing aspects. The range of relative effective annual precipitation is similar to that of the *Picea engelmannii/Minuartia obtusiloba* and *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* associations.

The *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association occurs at the next highest elevations. For being such a well represented association (n=32), a relatively narrow range of elevation, average daily temperature and growing degree days is represented. The ranges of slope percent, relative effective annual precipitation and total annual precipitation represented are broader. Average daily temperatures are typically some of the lowest observed in the forested zone, after the two high timberline associations. The range of total annual precipitation represented in this association is similar to, though broader in both directions, than the *Pinus albicaulis/Arctostaphylos uva~ursi* association. However, the range of relative effective annual precipitation represented is, on average, slightly lower in the *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association.

The two high treeline associations represent very minor forested associations and share vegetation composition traits with the alpine and forested communities they border. The *Pinus albicaulis/Arctostaphylos uva~ursi* association is unlike any community type currently described for eastern Idaho and western Wyoming (Steele et al., 1983), western Montana (Pfister et al., 1977) or the Beartooth Mountains (Lesica, 1993) in south central Montana. Like other high timberline *Pinus albicaulis* community types, alpine cushion and sedge species are common in the understory. The *Pinus albicaulis/Arctostaphylos uva~ursi* association is interesting because it occurs at the highest elevations of the forested zone and is characterized by the presence of *Arctostaphylos uva~ursi*, a shrub species typically associated with lower elevations and warmer environments, in the understory. While this association occurs strictly on the convex shoulders of moraines and cirques in soils classified as Typic Haplocryepts, slope percent and aspect were highly variable. Soils are likely to be well-drained, as they are primarily derived from granitic colluvium and till. The *Pinus albicaulis /Arctostaphylos uva~ursi* association also occurs on the sites receiving the highest annual solar exposure budget, which likely explains the presence of *Arctostaphylos uva~ursi* at such high and seemingly cool elevations, and spans the highest values of relative effective annual precipitation.

The *Picea engelmannii/Minuartia obtusiloba* association, which also occurs at some of the highest elevations observed in the study area and shares vegetation characteristics with adjacent alpine communities, occupies sites with the lowest annual solar exposure budget while spanning similar average daily temperature and growing degree days ranges as the *Pinus albicaulis/Arctostaphylos uva~ursi* association. The

Picea engelmannii/Minuartia obtusiloba association occurs on characteristically steeper slopes and spans lower average ranges of relative effective annual precipitation and total precipitation than the *Pinus albicaulis/Arctostaphylos uva~ursi* association, indicating it may be characteristic of colder and drier high timberline sites.

Conclusion

The goal of this chapter was to classify and describe the woodland and forested associations of the Beartooth Mountains study area and to compare newly derived woodland and forested associations with existing habitat type classifications for similar ranges in Montana, Wyoming and Idaho. Samples were well classified as was evidenced by optimization of geometric criteria, the identification of indicator species with meaningful ecological value and the represention of habitat types similar to newly classified associations in both vegetation composition and environments occuppied. Further attention should be paid to the arrangement of forested and woodland associations at low elevations as potentially related to time since and nature of disturbance.

Literature Cited

Arno, S.F. and Gruell, G.E. fire history at the forest-grassland ecotone in southwestern Montana. Accepted for publication by J. of Range Management.

Bray, J.R. and Curtis J.T. 1957. An ordination of the upland forest communities of Southern Wisconsin. Ecological Monopraphs. 27:325-349.

Cleland, D.T., Avers, P.E., McNab, W.H., Jensen, M.E., Bailey, R.G., King, T. and Russell. W.F. 1997. Chapter Nine: National Hierarchical Framework of Ecological Units. *Ecosystem Management: Applications for Sustainable Forest and Wildlife Resources.* Library of Congress Cataloging-in-Publication Data. Yale University, USA.

Daubenmire, R. F. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecological Monographs 22: 301-330.

Daubenmire, R. 1966. Vegetation:identification of typal communities. Science 151(3708): 291-298.

Dorn, R.D. 1977. *Manual of the vascular plants of Wyoming*. Garland Publishing, NY.

Dorn, R. D. 1984. Vascular plants of Montana. Mountain West Publishing, Cheyenne, WY.

Dufrêne, M. and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67: 345-366.

Fischer, W.C. and Clayton, B.C. 1983. Fire ecology of Montana forest habitat types east of the Continental Divide. Gen. Tech. Rep. INT-141. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 83 p.

Gordon, A.D. 1999. Classification. 2nd Edition. Chapman & Hall/CRC, Boca Raton, FL.

Haskins, D.M., Correll, Cynthia, S., Foster, R.A., Chatoian, J.M., Fincher, J.M., Strenger, S., Keys, J.E., Maxwell, J.R. and King, T. 1998. A Geomorphic Classification System. USDA Forest Service Department of Agriculture. Version 1.4.

Hitchcock, C.L., and Cronquist, A. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle, WA.

Jennings, Michael D., Faber-Langendoen, D., Loucks, O.L., Peet, R.K., Roberts, D. 2009. Standards for associations and alliances of the U.S. National Vegetation Classification. Ecological Monographs, 79(2): 173-199.

Johnson, P.L. and Billings, W.D. 1962. The alpine vegetation of the Beartooth Plateau in relation to Cryopedogenic processes and patterns. Ecological Monographs 32: 105-135.

Kaufman, L. and Rousseeuw, P.J. 1990. Finding groups in data: an introduction to cluster analysis. John Wiley & Sons, Inc, NY.

Kenkel, N.C., Juhasz-N.P., Podani, J. 1989. On sampling procedures in population and community ecology. Vegetatio. 83: 195-207.

Kruskal, J.B. and Wish, M. 1978. Multidimensional Scaling. Sage University Paper series on Quantitative Applications in the Social Sciences, number 07-011. Sage Publications, Newbury Park, CA.

Kruskal, W.H. and Wallis, A. 1952. Use of ranks in one-criterion analysis of variance. Journal of the American Statistical Association 47(260): 583-621.

Lavin, M. and Seibert, C. 2011. Grasses of Montana. Montana State University Herbarium. Department of Olant Sciences and Plant Pathology. Bozeman, MT.

Lesica, P. 1993. Vegetation and flora of the Line Creek Plateau Area, Carbon County, Montana. Unpublished report to U.S. Forest Service. Montana Natural Heritage Program. Helena. 30 pp.

Maechler, M., Rousseeuw, P., Struyf, A. and Hubert, M. 2005. cluster: Cluster Analysis Basics and Extensions. R package version 2.11.1.

Mueggler, W.F. and W.L. Steward. 1980. Grassland and Shrubland Habitat Types of Western Montana. USDA Forest Service General Technical Report INT-66, Odgen, Utah.

Pfister, R.D., and Arno, S.F. 1980. Classifying forest habitat types based on potential climax vegetation. Forest Science 26: 52-70

Pfister, R.D. , Kovalchik, B.L., Arno, S.F. and Presby, R.C.. 1977. Forest Habitat Types of Montana. USDA Forest Service General Technical Report INT-34, Ogden, Utah.

R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Roberts, D.W. 2007. labdsv: Ordination and Multivariate Analysis for Ecology. R package version 2.11.1.

Roberts, D.W. 2011. optpart: Optimal partitioning of similarity relations. R package version 2.11.1.

Shoeneberger , P.J., Wysocki, D.A., Benham, E.C., Broderson, W.D. (ed.). 2002. Field book for describing and sampling soils. Version 2.0. USDA-NRCS, National Soil Survey Center. Lincoln, NE.

Spribille, T., Stroh, H.G. & Triepke, F.J. 2001. Are habitat types compatible with floristically-derived associations? Journal of Vegetation Science. 12: 791-796.

Steele, R., Cooper, S.V., Ondov, D.M., Roberts, D.W. & Pfister, R.D. 1983. Forest Habitat Types of Eastern Idaho-Western Wyoming. USDA Forest Service Intermountain Research Station General Technical Report INT-144, Ogden, UT.

Stride, labdsv package for R; Roberts, 2010.

Vaseth, R. and C. Montagne. 1980. Geologic parent materials of Montana Soils. Montana Agricultural Experiment Station Bulletim 721, Bozeman, MT.

Venables, W. N. & Ripley, B. D. 2002. Modern Applied Statistics with S. Fourth Edition. Springer, New York.

Wells, A. 1998. Custer National Forest National Cooperative Soil Survey and Terrestrial Ecological Unit Inventory: Pre-Mapping, Preliminary Data Analysis, and Study Design Development. Unpublished document.

Wilson, J.B. 1991. Does vegetation science exist? J. Veg. Sci. 2: 289-290.

Winthers, E., Fallon, D., Haglund, J., DeMeo, T., Nowacki, G., Tart, D., Ferwerda, M., Robertson, G., Gallegos, A., Rorick, A., Cleland, D.T., Robbie, W. 2005. Terrestrial Ecological Unit Inventory technical guide. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington, DC: U.S. Department of Agriculture. Forest Service. Washington Office, Ecosystem Management Coordination Staff. 245p.

Wood, 2004. mgcv: GAMs with GCV/AIC/REML smoothness estimation and GAMMs by PQL. R package version 2.7-10.

CHAPTER 4

CLASSIFICATION OF THE ALPINE VEGETATION ASSOCIATIONS OF THE BEARTOOTH MOUNTAINS STUDY AREA

Contribution of Authors and Co-Authors

Manuscripts in Chapters 2, 3, 4

Chapter 4:

Author: Kristin L. Williams

Contributions: Supervised and conducted field data collection activities, managed and analyzed data and wrote the manuscript.

Co-author: Dave W. Roberts

Contributions: Obtained funding, supervised project, provided statistical consultation and edited text at all stages of manuscript development.
Journal to be submitted to: *Western North American Naturalist*

Manuscript Information Page

- Kristin L. Williams and Dave W. Roberts
- *Western North American Naturalist*
- Status of manuscript (check one)
  _x_Prepared for submission to peer-reviewed journal
  ___Officially submitted to peer-reviewed journal
  ___Accepted by a peer-reviewed journal
  ___Published in a peer-reviewed journal

Abstract

The purpose of this chapter was to create an alpine vegetation association classification for the Custer National Forest portion of the Beartooth Mountains in southcentral Montana. Johnson and Billings (1962) and Lesica (1993) previously described alpine community types for those portions of the Beartooth Mountains occurring along the Beartooth Highway (Johnson and Billings, 1962) and on the Line Creek Plateau (Lesica, 1993). Prior to this thesis, no comprehensive vegetation association classification of the alpine region of the Beartooth Mountains, the highest, largest and easternmost alpine region in Montana, has been conducted. Thirteen alpine associations were classified and described in this analysis. Many were similar to turf, cushion, snowbed, grassland and wetland alpine vegetation associations previously described for the Beartooth Mountains by Johnson and Billings (1962), Lesica (1993) and Bamberg (1961) and for the alpine ranges of the Beaverhead National Forest in southwest Montana (Cooper et al., 1997), Glacier National Park in northwestern Montana (Choate and Habeck, 1963; Bamberg and Major, 1968), the Big Snowy and Flint Creek ranges in central and western Montana (Bamberg and Major, 1968) and the Wind River Range in northwestern Wyoming (Potkin and Munn, 1987; Wells, 2008). Finally, I created a dichotomous key to the alpine associations identified in this analysis for use in the field and thoroughly described the vegetation and environment of each association.

Introduction

Vegetation ecologists commonly seek to characterize plant species distributions across the landscape. The recurrence of similar plant assemblages wherever the net influence of climate, soil, animal, disturbance and time factors have provided roughly equivalent environments was recognized early in vegetation studies (Daubenmire, 1966). Due to changing climate regimes and increasing demands placed on natural resources, the documentation and classification of vegetation, as tools for organizing and interpreting ecological information and context, are integral to biological conservation, resource management and scientific research (Pfister and Arno, 1980; Jennings et al., 2009).

Classification is the art and science of grouping objects considered to be similar in some respect (Kaufman and Rousseeuw, 1990; Gordon, 1999). In vegetation studies, researchers generally classify samples based on some aspect of floristic composition. Habitat types and community type associations are the most commonly used basic hierarchical units of floristic composition analysis (Spribille et al., 2001) in the western United States. Habitat types seek to classify land based on the vegetation composition sites are capable of supporting in late succession (Daubenmire, 1952; Pfister and Arno, 1980). The late succession association of plants characteristic of a habitat is referred to as the potential natural vegetation (PNV). Community types and associations seek to classify vegetation based on existing species composition, regardless of a sites potential to support a particular late seral or climax association. As such, a single community type may include samples classified to multiple habitat types, depending on the nature, frequency and distribution of stand-altering disturbances in the landscape. The recent

resurgence of interest in vegetation classification and adoption of U.S. National Vegetation Classification (NVC) standards for associations and alliances (Jennings et al., 2009) has renewed interest in the theory behind and relative ecological usefulness of both frameworks.

The habitat type classification system is based on plant succession theory, a basic tenet of which states that the most shade tolerant or "climax" species present in a stand will eventually dominate in the absence of disturbance. Samples are first divided into 'series' comprised of stands with the same indicated climax tree species (Daubenmire, 1952, Pfister and Arno, 1980, Steele et al., 1981). Even if the indicated climax tree species occurs in low abundance, its presence alone is indicative of the successional trajectory of the stand. Series represent major environmental differences reflected by the distributions of climax tree species. Habitat types are subdivisions of series that represent environmental differences represented by total vegetation composition (Pfister and Arno, 1980). While a given habitat type should reflect all land areas capable of supporting the same potential natural vegetation association in late succession, it is not necessarily a reflection of similarities in existing vegetation between samples (Pfister and Arno, 1980).

Classification by community type association uses the floristic characteristics of species assemblage and abundance to group samples with similar composition and physiognomy into clusters that are consistently recognizable using diagnostic features (Jennings et al., 2009). NVC defines plant associations as "a vegetation classification unit defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions, and physiognomy (Jennings et al., 2009)."

Alliances are conceptually similar to 'series' and are defined by NVC (Jennings et al., 2009) as "a vegetation classification unit containing one or more associations, and defined by a characteristic range of species composition, habitat conditions, physiognomy, and diagnostic species, typically at least one of which is found in the uppermost or dominant stratum of the vegetation."

The habitat type concept emphasizes the diagnostic potential of climax-dominant species and uses the presumed climax development to assign samples to series (and land to habitat types) regardless of existing vegetation. The association/alliance concept emphasizes the composition of existing vegetation (Jennings et al., 2009; Pfister and Arno, 1980). NVC associations and habitat types are likely similar in stands where the potential climax species have attained dominance. In stands where the climax species remains subordinate to a seral species, ecologically interesting discrepancies between NVC associations and habitat types are bound to emerge (Jennings et al., 2009).

The primary objective of this chapter was to classify the high-elevation alpine vegetation of the Beartooth Mountains study area into compositionally and ecologically distinct associations. The absence of vegetation altering disturbance in the alpine ecosystem renders the differentiation between existing (community type/association) and potential natural vegetation (habitat type) unnecessary. Theoretically, the classification I created for alpine associations should be similar to, or the same as, a classification created to emphasize habitat types. In order to be able to use this classification in the field, I created a dichotomous key to the association classification and provided a brief description of each identified association. Finally, I compared my results with

community types/associations identified for alpine regions of the Beaverhead National Forest in southwest Montana (Cooper et al., 1997), Glacier National Park (Bamberg and Major, 1968; Choate and Habeck, 1967), the Big Snowy Mountains and Flint Creek Mountains (Bamberg and Major, 1968), the Beartooth Plateau (Johnson and Billings, 1962) and Line Creek Plateau (Lesica, 1993) of the Beartooth Mountain Range and the Wind River Range in northwestern Wyoming (Potkin and Munn, 1987; Wells, 2008).

Study Area

The Beartooth Mountains study area is primarily composed of the largest expanse of alpine plateau in the lower 48 states. The Beartooth Plateau is dissected by six large, glacially-scoured waterways that drain from higher elevations in the south and southwest to lower elevations in the north and northeast (Chapter One, Figure 1.2). Remnant fingers of plateau occur between major drainages (Chapter One, Figure 1.2). Alpine vegetation is generally restricted to the plateau and mountain slopes rising above the plateau.

Soils on the plateaus are predominantly derived from hard coarse-grained metamorphic rocks (Chapter One, Figure 1.3; Vaseth and Montagne, 1980). Portions of Line Creek Plateau, in the southeast, Fishtail Plateau, in the northwest, and several other smaller portions of plateau along the northwest margin, have soils weathered from limestone, dolomite, moderately hard green-gray shales and a basal deposit of sandstone (Chapter One, Figure 1.3; Vaseth and Montagne, 1980).

The Beartooth Mountains experience a continental climate regime that is characterized by hot, dry summers and cold, wet winters. Winds are predominantly from

the west, resulting in both large and fine-scale precipitation gradients (Johnson and Billing, 1962, Lesica, 1993). On a large scale, the western portion of the study area receives more precipitation than the eastern portion due to orographic effects. On a smaller scale, windward west-facing slopes are often blown free of snow while lee east-facing slopes often receive additional snow accumulation (Johnson and Billing, 1962, Lesica, 1993). This dynamic of moisture distribution plays a critical role in structuring the mosaic of plant communities in the alpine zone. The timing and form in which precipitation is received also changes along a gradient trending from north to south. The northern portion of the study receives the majority of annual precipitation during the months of March, April, May and June in the forms of snow and rain, while the southern portion of the study area receives precipitation during the months of November, December, and January primarily in the form of snow (Wells, 2008).

Alpine vegetation occurs in a mosaic of turf, cushion, grassland, snowbed and wetland associations (Johnson and Billings, 1962; Lesica, 1993). Wind exposure, moisture and timing of snow release have generally been considered to be the most important environmental factors determining the arrangement of vegetation above treeline (Bliss 1963; Johnson and Billings 1962). Cooper et al. (1997) found supporting evidence for the role of these factors in the alpine regions of the Beaverhead National Forest, MT. They proposed soil depth as an additional determining environmental factor and noted that wind exposure and soil depth are often correlated. Wind often results in soil and snow removal on windward sites and soil and snow accumulation, along with increased soil development, on lee sites (Cooper et al., 1997).

Cooper et al. (1997) defined turf as "vegetation dominated by dwarf, fibrous-rooted graminoids." Turf communities generally occur on gentle terrain (ridgetops and slope shoulders) with appreciable soil development (Cooper et al., 1997). Turf vegetation grades into cushion plant vegetation where wind exposure increases and/or soil development decreases (Cooper et al., 1997). Cushion plant communities are most likely to occur on ridgetops and saddles. Their compact growth form allows them to persist despite dry, windy, cold conditions and shallow, stony, nutrient-poor soils (Cooper et al., 1997). These sites are often blown free of winter snow and exposed to increased direct solar insolation. This makes such sites the most xeric high-elevation sites and earns them the distinction of being labeled "alpine deserts." Unlike other alpine communities, including turf communities, graminoids are generally less abundant than forbs in cushion plant communities (Cooper et al., 1997). Snowbed communities occur where prevalent wind patterns result in increased snow accumulation behind small ridges, on upper lee slopes and in depressions (Cooper et al., 1997). Plants occurring in these microsites receive more moisture and experience shorter growing seasons, due to later snow-release, than adjacent communities (Cooper et al., 1997). Grassland communities generally occur in the lower reaches of the alpine zone on both gentle and steep slopes with deep soils and relatively warm climates (Cooper et al., 1997). Alpine grasslands can be compositionally similar and even grade into high-elevation grasslands and sagebrush steppe (Cooper et al., 1997). Grassland communities are similar to turf communities in that they are both graminoid dominated. However, alpine turf communities tend to occur on more wind-exposed slopes than grassland communities and are dominated by sedges

and forbs of shorter stature than the more robust grasses characteristic of alpine grasslands (Cooper et al., 1997). Alpine riparian and wetland communities occur in extremely wet sites, such as basins and local depressions.

Methods

Study Design

The data were collected for the purposes of a United States Forest Service (USFS) and Natural Resource Conservation Service (NRCS) collaborative inventory/mapping project called a Terrestrial Ecological Unit Inventory (TEUI). TEUI's are an attempt to produce large scale, consistent and integrated ecosystem inventory, classification and mapping management tools for all public lands nationwide. The TEUI approach to land classification and mapping is based on a National Hierarchy of Ecological Units, a hierarchical land unit classification system within which soil and vegetation map units are nested (Cleland, 1997). The National Hierarchy classification system begins by grouping land areas into broad classes based on large-scale climatic and physiographic factors. More detailed, nested categories are then classified based on systematically smaller-scale climatic, geological, geomorphic, vegetative, and topographic factors (Winthers et al., 2005). The lowest nested category is called an 'ecological unit'. Each ecological unit represents a unique combination of geologic, climatic, geomorphologic and topographic characteristics.

Field seasons were restricted to the weeks between mid June and late August due to persistent spring snowpack and early snowfall in the late summer/early fall. The study

area was pre-stratified into ecological units using TEUI protocol, vegetation data were collected according to TEUI protocol and soil samples were collected according to NRCS standards and protocol.

Plot locations were selected to reflect all dominant and characteristic vegetation types of each ecological unit prior to sampling. Dominant associations within each unit were estimated using aerial photos, satellite imagery and topographic maps. Plots were distributed within each ecological unit to represent the diversity of slopes, elevations, aspects and dominant plant associations in each ecological unit. Special attention was also paid to the distribution of sample plots across larger environmental gradients, such as the prevalent west to east moisture gradient, within each ecological unit.

This extensive stratification process reflects the ongoing efforts of ecologists to standardize protocol and satisfy the principles and procedures of classical sampling theory. While many of the fundamental principles (e.g. randomization) underlie all sampling decisions, it is also important to recognize that the objectives of an ecological study may differ considerably from objectives studied using classical theory (Kenkel et al., 1989). Specifically, classical theory is concerned with the estimation of population parameters of discrete, recognizable units while vegetation ecology is concerned with the recognition of patterns in community assemblage and distribution where the sampling unit (i.e. a plot) is arbitrarily defined (Kenkel et al., 1989).

Plot Selection

Once arriving at the target plot coordinates, field researchers confirmed that the plot position represented uniformity of environment, was large enough to include normal

species composition and had homogenous vegetation throughout. Obvious ecotones were not sampled. Within the stratified sampling protocol, characteristics were identified for each target sample plot, including: desired slope percent, aspect and vegetation association. If the site was not representative of the dominant association, slope percent and/or aspect value specified, sample plots were moved to the closest plot center reflecting target parameters. If a plot reflecting the target parameters could not be found, the sample plot was either not collected or an alternate plot was chosen to reflect the dominant vegetation observed at or close to the target sample plot position.

Vegetation Data

Vegetation data of grassland/shrubland samples were collected using circular fixed-radius macroplots with a radius of 11.35 m, resulting in a 405 m^2 ($1/10^{th}$ of an acre) area plot. All species occurring within the perimeter of the community macroplot were recorded and their abundance estimated. Since plants show huge plasticity between individuals and it is often impossible to define an individual, abundance of each species can be effectively and efficiently characterized using aboveground canopy cover estimates (Wilson, 1991). Canopy cover is defined as the percentage of ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage of plants where small openings within the canopy are included in the cover estimate (Winthers et al., 2005). Cover was estimated according to the following classes:

- 0.1 = "trace" = species with less than 1 percent cover (1% = 1.1m radius).
- The nearest 1 percent for species with cover between 1 and 10 percent.

• The nearest 5 percent for species with cover between 10 and 30 percent cover.

• The nearest 10 percent for species with cover exceeding 30 percent cover.

Using the same cover classes, cover was recorded separately for each lifeform category. Lifeform categories include: graminoid (GR), forb (FB), shrub (SH), and tree (TR and TO). Tree layer subcategories were defined by height (TR: <=2.0 m, TO: >2.0 m). The possibility of overlap between tree sublayers requires that overstory and regeneration cover for each tree species be estimated or measured directly, not calculated by summing the sublayer cover values.

Plant Taxonomy Considerations

Plants were primarily identified using Plants of Wyoming (Dorn, 1977). Where the collected species could not be identified using Plants of Wyoming (Dorn, 1977), Plants of Montana (Dorn, 1984) was used. For particularly difficult identifications, several floras were consulted, including: Flora of the Pacific Northwest (Hitchcock and Cronquist, 1963), The Intermountain Flora (various authors, various years) and Grasses of Montana (Lavin and Seibert, 2011). NRCS species codes were recorded according to Dorn's taxonomy where possible. Where no NRCS code was available for Dorn's taxonomy, the NRCS synonym code was used. When referencing species belonging to associations, community types or habitat types described by other authors, the taxonomy used in the original publication was retained.

Soil Data Collection

Soil pedon data were collected according to NRCS standards using codes and procedures outlined in the NRCS publication Field Book for Describing and Sampling Soils (Shoeneberger et al., 2002). Geologic information was collected according to the standards in Forest Service Manual 2881. Surficial geology, origin and kind were identified using the terms and definitions listed in the FRIS Terra data dictionary. Geomorphic information was collected to the standards in A Geomorphic Classification System (Haskins et al. 1998).

A soil pit was dug near the center of each macroplot in an area that appeared to be representative of the soils supporting the target vegetation. All soil pits were dug to a depth of 1m where possible. If lithic contact was made prior to reaching 1m, the type of lithic layer contacted and depth to contact was recorded.

Soil horizons were identified and the depth, texture, color (either wet or dry but must be indicated) and pH were recorded for each. Texture modifiers, such as: percent gravel, percent cobble, percent stone and percent boulder were also recorded for each horizon. Additionally, root pore percentage, clay film percentage, calcium carbonate accumulation and redoximorphic features were estimated within each horizon. Where redoximorphic and/or calcium carbonate features were observed, the beginning depth and end depth of that feature were recorded along with color classes specific to the feature. Finally, soil was classified using the NRCS soil classification system.

A soil sample was collected from each soil horizon and the organic horizon. Samples were chosen to be representative of the horizon they were taken from and

included samples of gravel or cobble, calcium carbonate accumulations or redoximorphic features that were encountered. Soil horizon samples were organized into soil profile boxes in order of horizon. A total of ten representative samples was sent to the lab for analysis. These samples were used as quality control to confirm the textures, colors, pHs and soil classifications determined by soil technicians in the field.

Environmental Site Data

In addition to vegetation composition and soil data, descriptive documentation and environmental gradient characteristics were collected at each site. There are no NRCS Snotel stations within the boundaries of the study area. In order to evaluate the distribution of plant community associations with respect to climatic gradients occurring within the study area, climate variables were modeled using climate data from nearby Snotel sites, including: Beartooth Lake, WY, Burnt Mtn., MT and Cole Creek, MT. The Snotel station at Beartooth Lake provides a good approximation of the climate at high elevations and the stations at Burnt Mtn. and Cole Creek provide a good approximation of the climate at lower elevations (Chapter One, Figure 1.2). Modeled variables include: relative effective annual precipitation (REAP), total precipitation (TOTPRCP), growing degree days (GRDEGDAY), average daily temperature (DAVTEMP) and annual solar exposure (SOLAR).

Relative effective annual precipitation (REAP) uses precipitation, slope, aspect and soil properties to indicate the amount of moisture available at a given location. As such, two sites receiving the exact same annual precipitation may have very different effective precipitation due to other site factors. Total annual precipitation (TOTPRCP) is

calculated by summing the inches of precipitation received, either as snow or rain, in a year. Growing degree days (GRDEGDAY) are calculated by subtracting a base temperature (usually 10°C) from the average of the daily maximum and minimum temperatures of a location. The minimum temperature is bounded by the base temperature and the maximum temperature is generally bounded by 30°C, as most plants grow in this range. The annual GRDEGDAY is calculated by summing daily GRDEGDAY. Growing degree days (GRDEGDAY) is an indicator of both the length and warmth of the growing season of a location. Annual average daily temperature (DAVTEMP) is calculated by summing the monthly averages and dividing by 12. Monthly average daily temperatures are calculated by summing the daily maximum temperatures with the daily minimum temperatures and dividing by two. Annual average daily (DAVTEMP) is a rough estimate of the overall annual temperature of a location. The solar loading (SOLAR) variable estimates incoming solar electromagnetic radiation given latitude, slope and aspect information for the summer solstice in watt hours/m².

Measured and modeled environmental variables are identified as continuous and categorical variables and listed below.

Continuous:

- Northing Coordinate (UTM's)
- Easting Coordinate (UTM's)
- Elevation (m)
- Slope Percent (%)
- Aspect (°)
- Relative Effective Annual Precipitation (REAP)
- Total Precipitation (TOTPRCP)
- Growing Daily Degree (GRDEGDAY)
- Annual Solar Exposure (SOLAR)
- Average Daily Temperature (DAVTEMP)

Categorical:

- Topographic Position
- Primary Landform
- Vertical Slope Shape
- Horizontal Slope Shape
- Slope Complexity
- Geologic Parent Material
- Parent Material Kind
- Soil Depth
- Soil Particle Size
- Soil Temperature Regime
- Soil Moisture Regime
- Soil Moisture Sub-Class
- NRCS Soil Classification
- Disturbance History
- Potential Natural Vegetation Classification

Statistical Analysis

Two hundred vegetation community plots with associated soil profile pits were collected during the 2008 and 2009 summer field seasons. These two hundred sample plots were then divided into the following three groups based on physiognomy and elevation: low-elevation grassland/shrubland samples (<10% tree cover, < 2,500 m elevation), mid-elevation woodland and forested samples (>10% tree cover, all elevations), high-elevation alpine samples (<10% tree cover, >2,500 m). The following is the analysis of the 56 samples identified as 'alpine'. The vegetation data were analyzed using several multivariate techniques, including: cluster analysis, nonmetric multidimensional scaling ordinations (NMDS), summaries of the occurrence and significance of both continuous and categorical environmental variables and plant species cover and constancy tables by identified cluster. Multivariate statistics were performed in R (R Development Core Team, 2011).

The Bray-Curtix index (Bray and Curtis, 1957) was used to create a dissimilarity matrix of vegetation composition data for the alpine samples. Vegetation data were not transformed or standardized. Distance analysis (DISANA, labdsv package for R; Roberts, 2011) was used to identify structure in the dissimilarity matrix and to identify plots that were highly dissimilar from all other plots (i.e outliers).

Cluster analysis was performed using OPTBEST (OPTBEST, optpart package for R; Roberts, 2011) a fixed cluster, PARTANA optimizing algorithm and OPTSIL (OPTSIL, optpart package for R; Roberts, 2011), a Silhouette width-maximizing reallocation algorithm performed on original BESTOPT models. STRIDE (STRIDE, optpart package for R; Roberts, 2011) analysis was used to identify cluster number solutions likely to result in the maximization of geometric criteria (PARTANA ratio and Silhouette width).

Dufrêne and Legendre's (1997) indicator value algorithm was used to assess the ecological significance of various clustering solutions. The algorithm determines indicator species by identifying those species exhibiting the highest constancy and fidelity in each cluster. Indicator values were calculated for each species as follows:

$$INDVAL_{ij} = A_{ij} \times B_{ij}$$

Where $INDVAL_{ij}$ is the indicator value of species *i* in sites of *j*, A_{ij} is the relative mean abundance of species *i* in sites of cluster *j*, and B_{ij} is the frequency of occurrence of species *i* in sites of cluster *j*.

Final classifications were chosen based on the characteristics of: 1) high PARTANA ratios, 2) high Silhouette width averages, both within and across clusters, and

3) high ecological significance as determined by species indicator values. Communities were named using the two most abundant significant indicator species in each cluster, unless otherwise described. If only one species was identified as an indicator species, only that species name was used in the cluster name.

The unconstrained ordination technique NMDS (labdsv package, Non-Metric Multidimensional Scaling; Kruskal and Wish, 1978) was applied to a Bray-Curtis dissimilarity matrix of vegetation community abundance data (labdsv package; Roberts, 2007; MASS package; Venables and Ripley, 2002). Environmental variables were evaluated for explanatory value using the D^2 values (defined below) of GAMs (generalized additive models, mgcv package for R; Wood, 2004) fit to the ordination in combination with the p- and chi-squared values obtained from a Kruskal-Wallis rank sum test. The D^2 value of deviance was defined as:

D^2 = (null deviance – residual deviance) / null deviance.

Results

Vegetation Compostion

A total of 250 plant species was recorded from 56 sample plots. Tree species were stunted and occurred only in the tree regeneration (TR) strata. Plot-level species richness ranged from 8 to 46, with an average of 25.67 species/plot (Figure 4.1). Seventy-five species occurred in only one sample, while the species with the highest frequency, *Polygonum bistortoides*, occurred in 37 samples (Figure 4.42). The mean frequency of species in samples is 5.75. *Salix planifolia, Arcostaphylus uva~ursi* and

Helianthela uniflora occur with the highest abundance (Figure 4.3). *Polygonum bistortoides, Potentilla diversifolia* and *Deschampsia cespitosa* are the three most frequently occurring species. The 10 most frequent and 10 most abundant species are listed in Table 4.1.

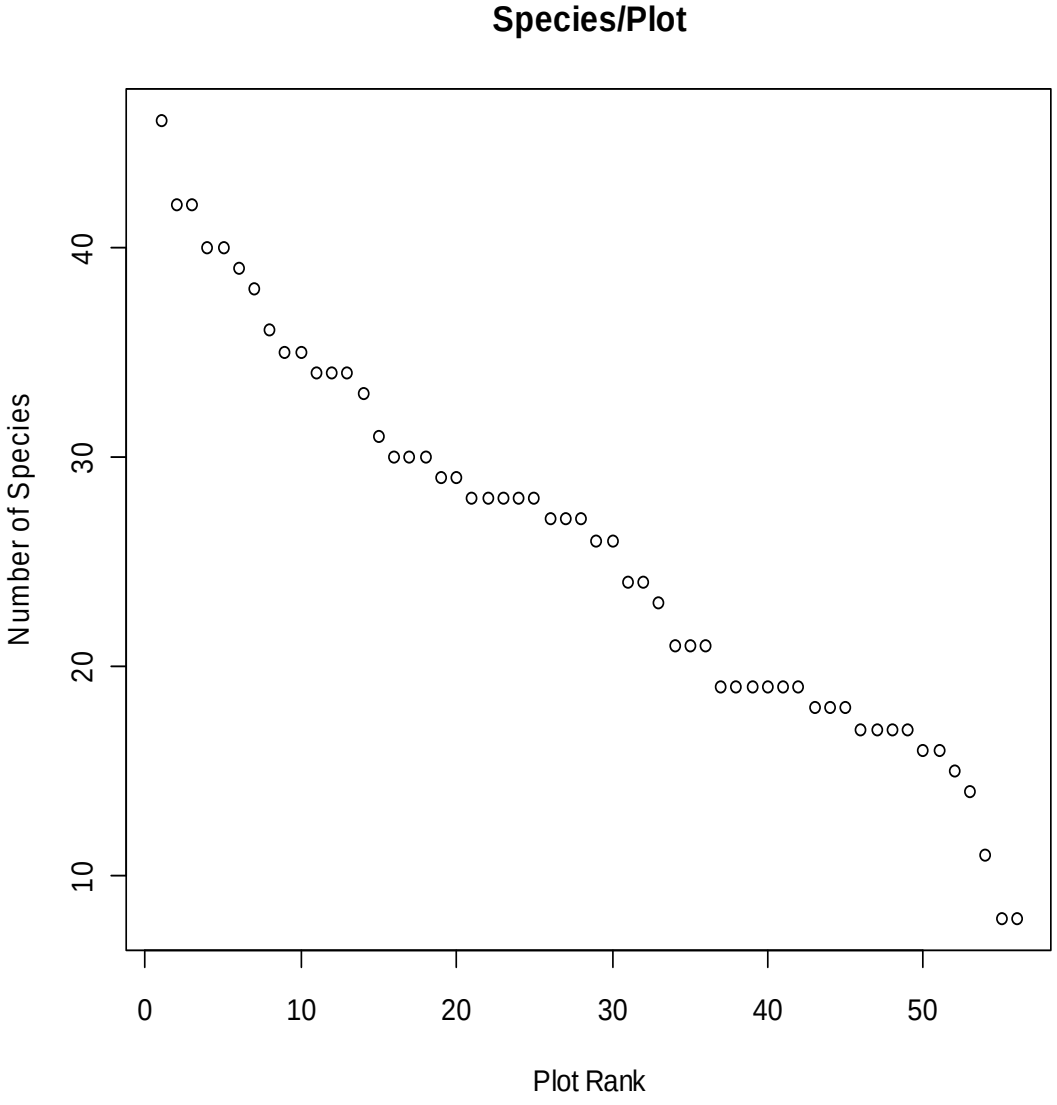


Figure 4.1. Number of species per plot across all plots.

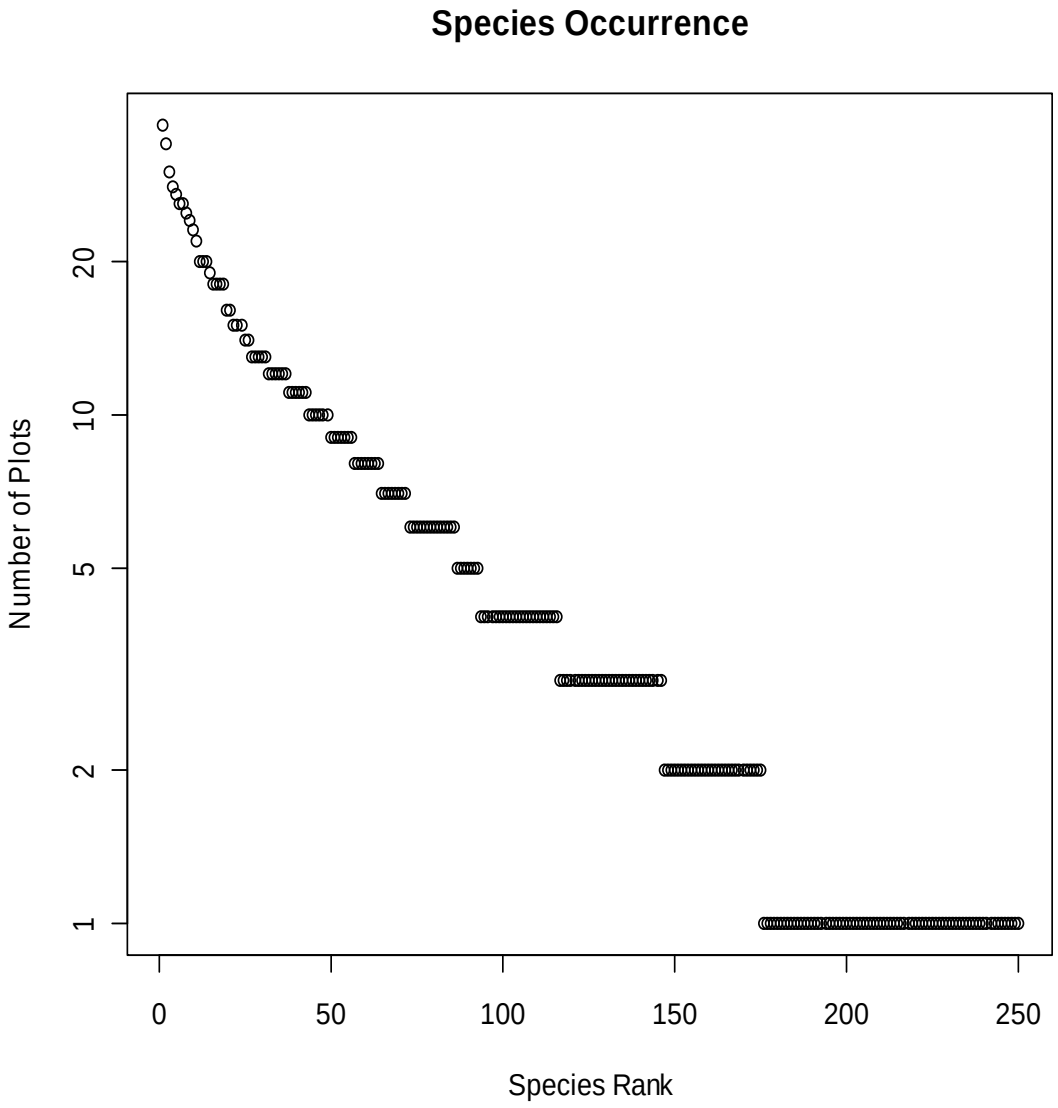


Figure 4.2. Species occurrence on each plot, across all species

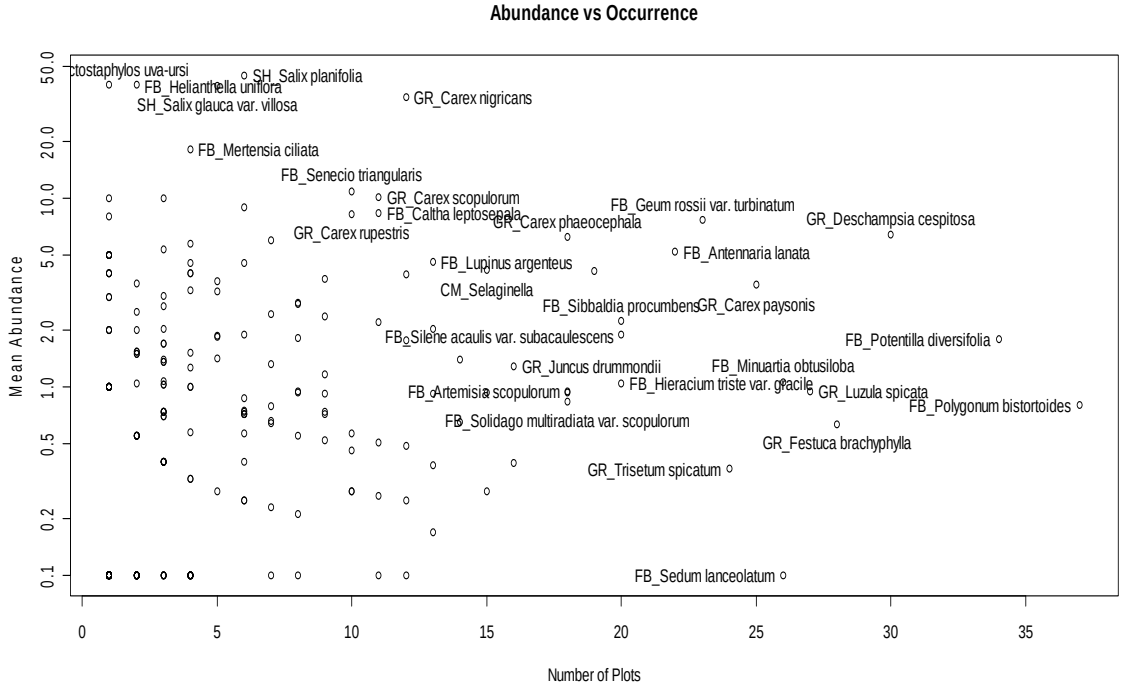


Figure 4.3. Mean species abundance versus number of plots in which the species occurred.

Table 4.1. The 10 most abundant and 10 most frequent species. Mean % cover is rounded to the nearest whole number.

10 Most Abundant Species	**Mean % Cover**	**10 Most Frequent Species**	**Number of Occurrences**
GR_Calamagrostis canadensis	10	FB_Geum rossii var. turbinatum	23
SH_Dryas octopetala var. hookeriana	10	GR_Trisetum spicatum	24
GR_Carex scopulorum	10.	GR_Carex paysonis	25
FB_Senecio triangularis	10	FB_Minuartia obtusiloba	26
FB_Mertensia ciliata	18	FB_Sedum lanceolatum	26
GR_Carex nigricans	34	GR_Luzula spicata	27
SH_Salix glauca var. villosa	39	GR_Festuca brachyphylla	28
FB_Helianthella uniflora	40	GR_Deschampsia cespitosa	30
SH_Arctostaphylos uva-ursi	40	FB_Potentilla diversifolia	34
SH_Salix planifolia	45	FB_Polygonum bistortoides	37

Correlation of Environmental Variables

Correlation between continuous environmental variables was tested using Pearson's correlation coefficient. Values closer to 1 and -1 indicate a strong correlation and values of 0 indicate no correlation. Relative effective annual precipitation (REAP) and total annual precipitation (TOTPRCP) are strongly positively correlated (0.924). Relative effective annual precipitation (REAP) and growing degree days (GRDEGDAY) are strongly negatively correlated (-0.817). Average daily temperature (DAVTEMP) is moderately negatively correlated with elevation, relative effective annual precipitation (REAP) and total annual precipitation (TOTPRCP) (-0.609, -0.621 and -0.0559 respectively) and moderately positively correlated with growing degree days (GRDEGDAY) (0.81). Slope percent and annual solar exposure (SOLAR) are moderately to highly negatively correlated (-0.712). The correlation between relative effective annual precipitation (REAP) and elevation (0.521) is not as strong in the alpine, where the elevation gradient is reduced. Finally, total annual precipitation (TOTPRCP) is moderately negatively correlated with Easting coordinate (-0.589).

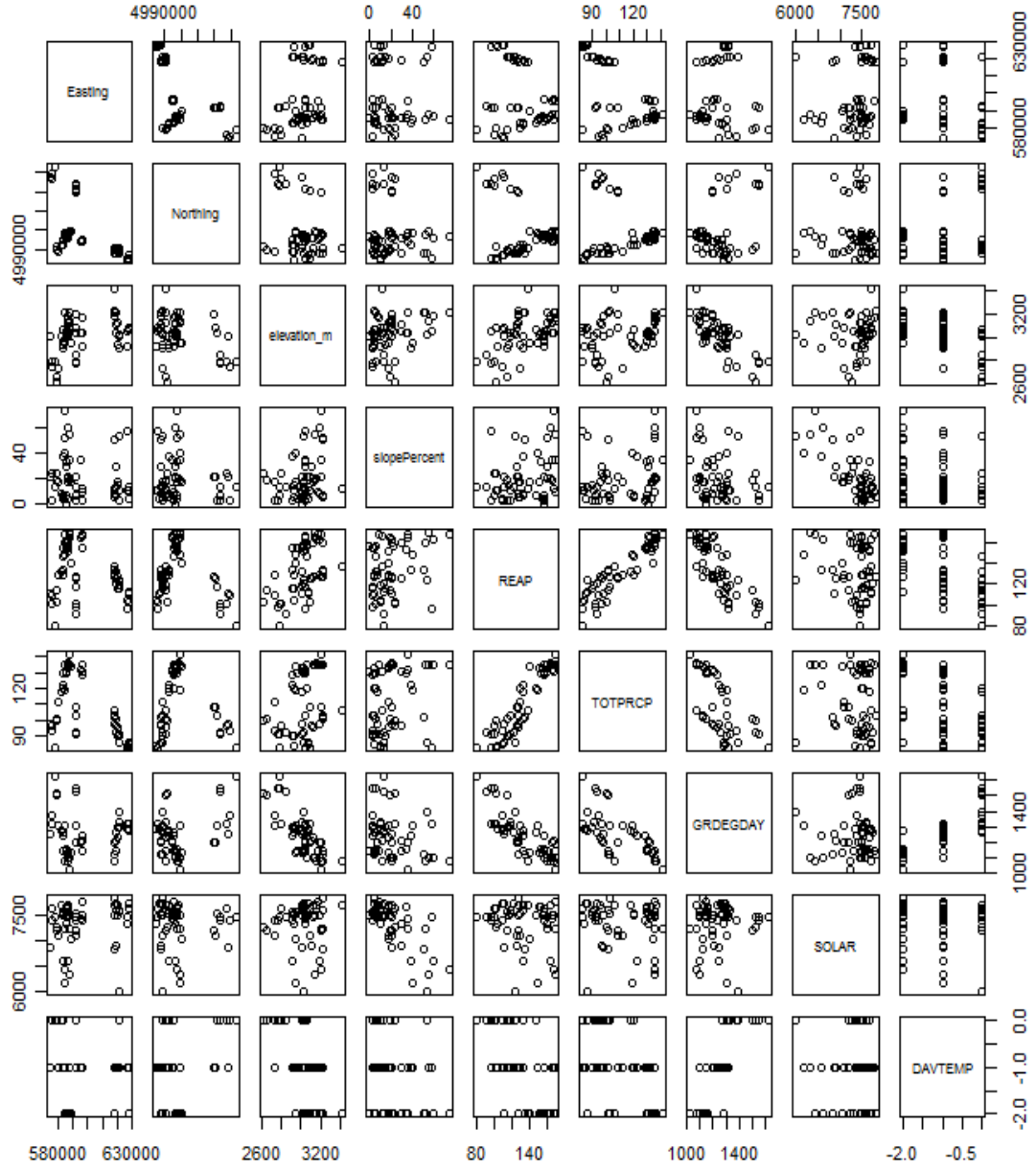


Figure 4.4. Correlations of environmental variables: Easting coordinate, Northing coordinate, elevation (m), slope percent (%), relative effective annual precipitation (REAP), total annual precipitation (TOTPRCP), growing degree days (GRDEGDAY), annual solar exposure (SOLAR), average daily temperature (DAVTEMP).

Table 4.2. Pearson's Correlation Coefficient for joint distribution of continuous environmental variables. Absolute values > 0.5 are in bold.

	Easting	**Northing**	**Elevation**	**Slope Percent**	**REAP**	**TOTPRCP**	**GRDEGDAY**	**SOLAR**	**DAVTEMP**
Easting	1	-0.054	0.361	-0.068	-0.031	**-0.589**	0.0003	0.184	-0.057
Northing		1	-0.032	-0.014	-0.138	0.024	-0.309	-0.095	0.381
Elevation			1	0.272	**0.521**	0.308	**-0.78**	0.016	**-0.609**
Slope Percent				1	0.282	0.229	-0.261	**-0.712**	-0.261
REAP					1	**0.924**	**-0.817**	-0.147	**-0.621**
TOTPRCP						1	**-0.7**	-0.111	**-0.559**
GRDEGDAY							1	0.011	**0.81**
SOLAR								1	-0.023
DAVTEMP									1

Cluster Analysis of Communities

The STRIDE plot (Figure 4.5) indicates that models with 13 and 14 clusters produce the highest PARTANA ratios and Silhoutte widths. BESTOPT models consistently produced the same PARTANA ratios and Silhouette widths as the models returned from performing OPTSIL on them. Models with 14 or more clusters all had clusters containing only one sample. I selected the 13-cluster BESTOPT model to define communities. Clusters are well classified, as is particularly evidenced by a high mean silhouette width (0.31) and the absence of reversals (Figure 4.6). Reversals represent negative Silhouette values and occur when a plot is more similar to another cluster than the cluster to which it belongs. Additionally, all clusters in the 13-cluster model contain more than one sample. The 13-cluster model also has a high degree of within cluster similarity, as is evidenced by a relatively high PARTANA ratio (8.01) (Figure 4.7, Figure 4.8). The 12-cluster model has a PARTANA ratio of 7.884, an average Silhouette width of 0.28, no reversals and no clusters with only one plot. The 14-cluster model has a PARTANA ratio of 8.047, an average Silhouette width of 0.29, no Silhouette reversals and1 cluster containing only one sample. The 13-cluster model had 57 significant indicators, while the 12 and 14-cluster models had only 54 significant indicators. The total deviance of the 13-cluster model is intermediate to the 12 and 14-cluster models (4425.46, 4197.243 and 4707.193, respectively).

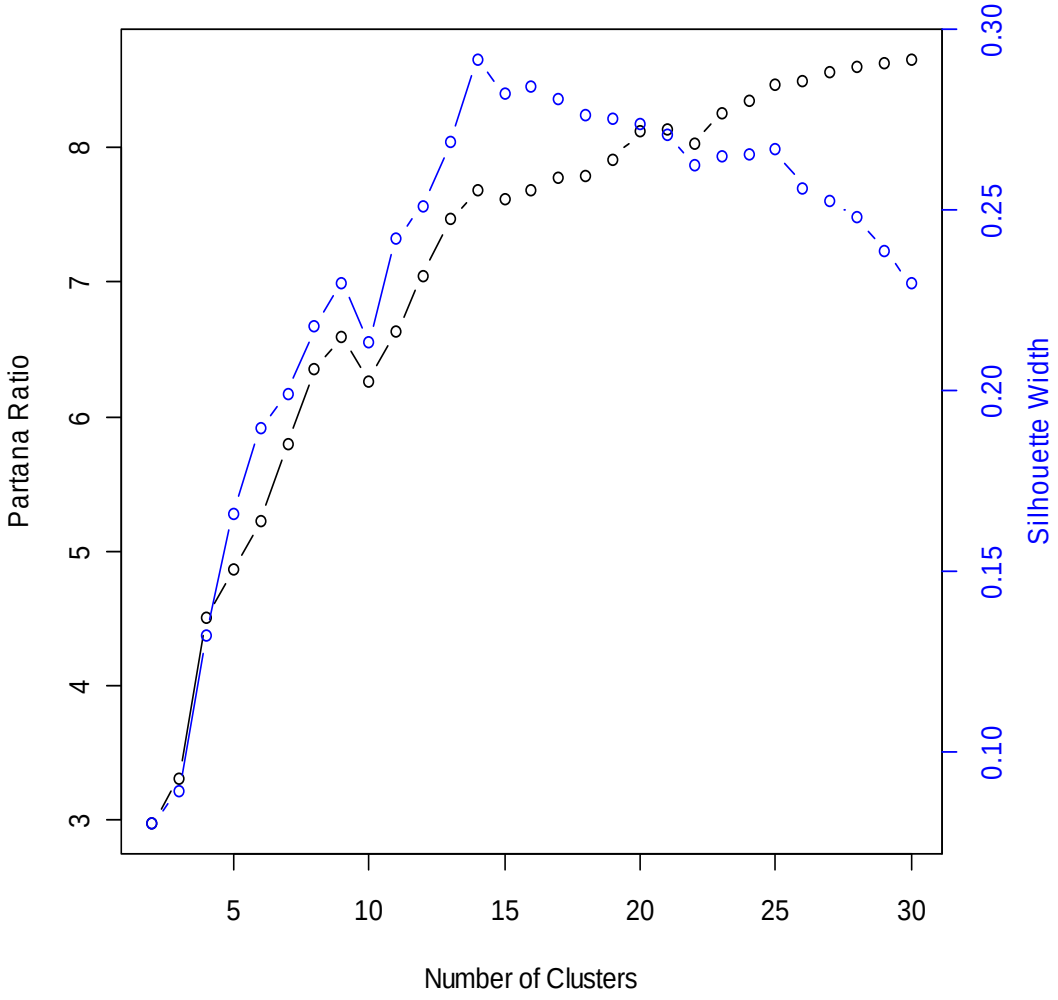


Figure 4.5. STRIDE analysis plot showing the PARTANA ratio and average Silhouette width for models containing 2 to 20 clusters.

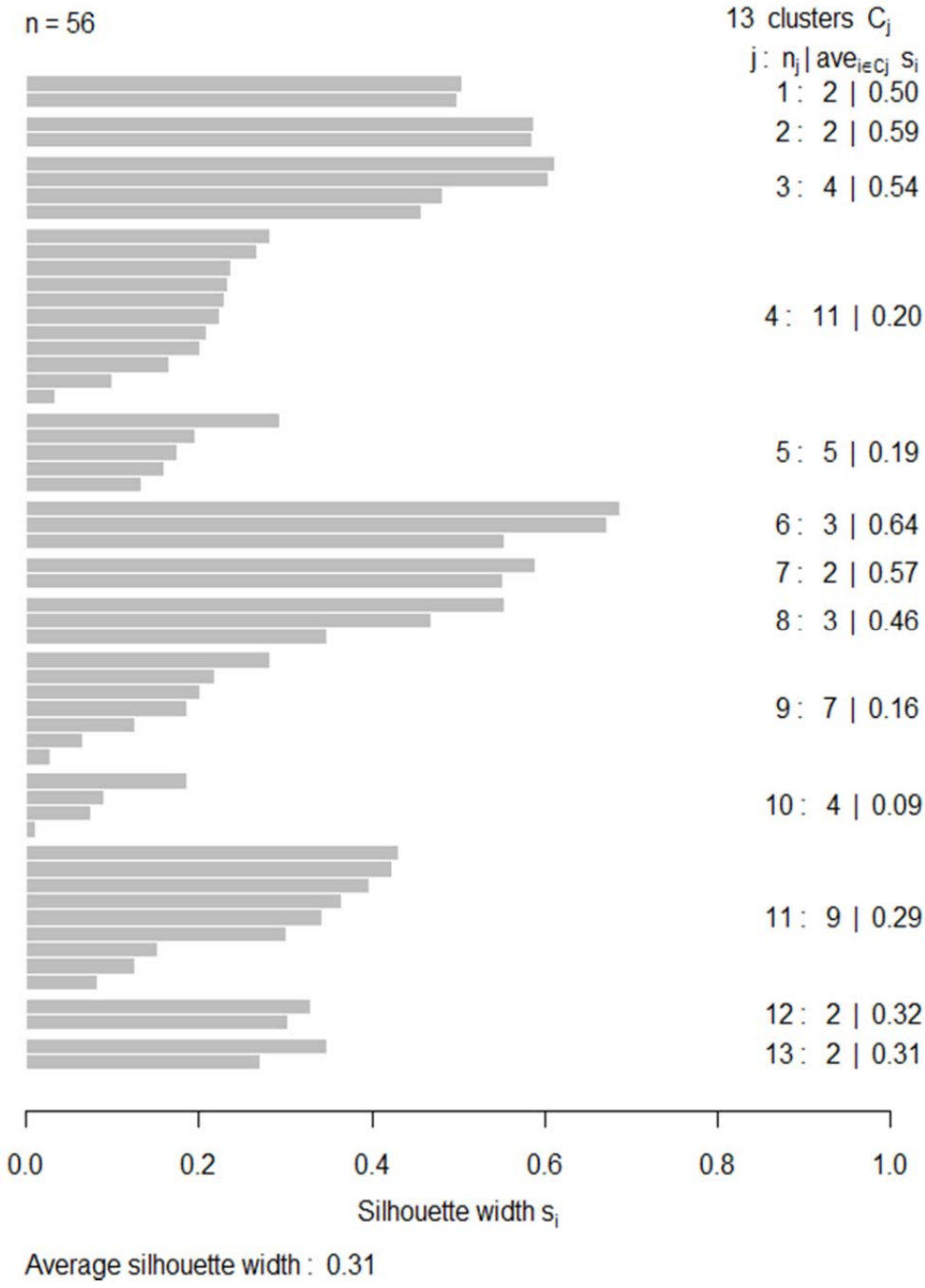


Figure 4.6. Silhouette width plot, indicating within cluster plot similarity for each of 13 clusters. Reversal bars represent negative Silhouette width values which indicate poor similarity of a plot to the cluster in which it belongs. Cluster size and average Silhouette value for each cluster are displayed on right of plot.

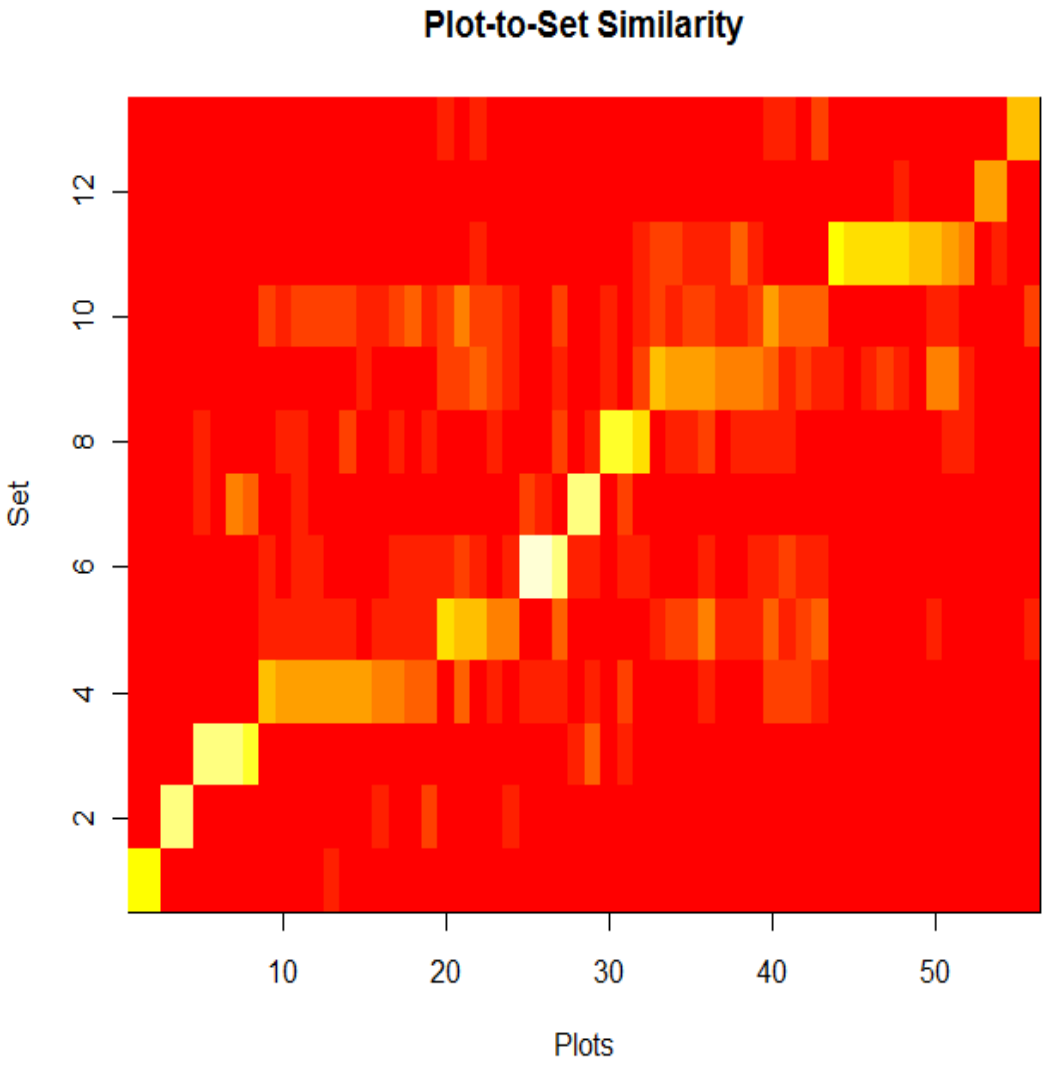


Figure 4.7. PARTANA plot, displaying the similarity of each plot within a cluster to each other plot in other clusters. White indicates high similarity, yellow moderate to high similarity and red a lack of similarity.

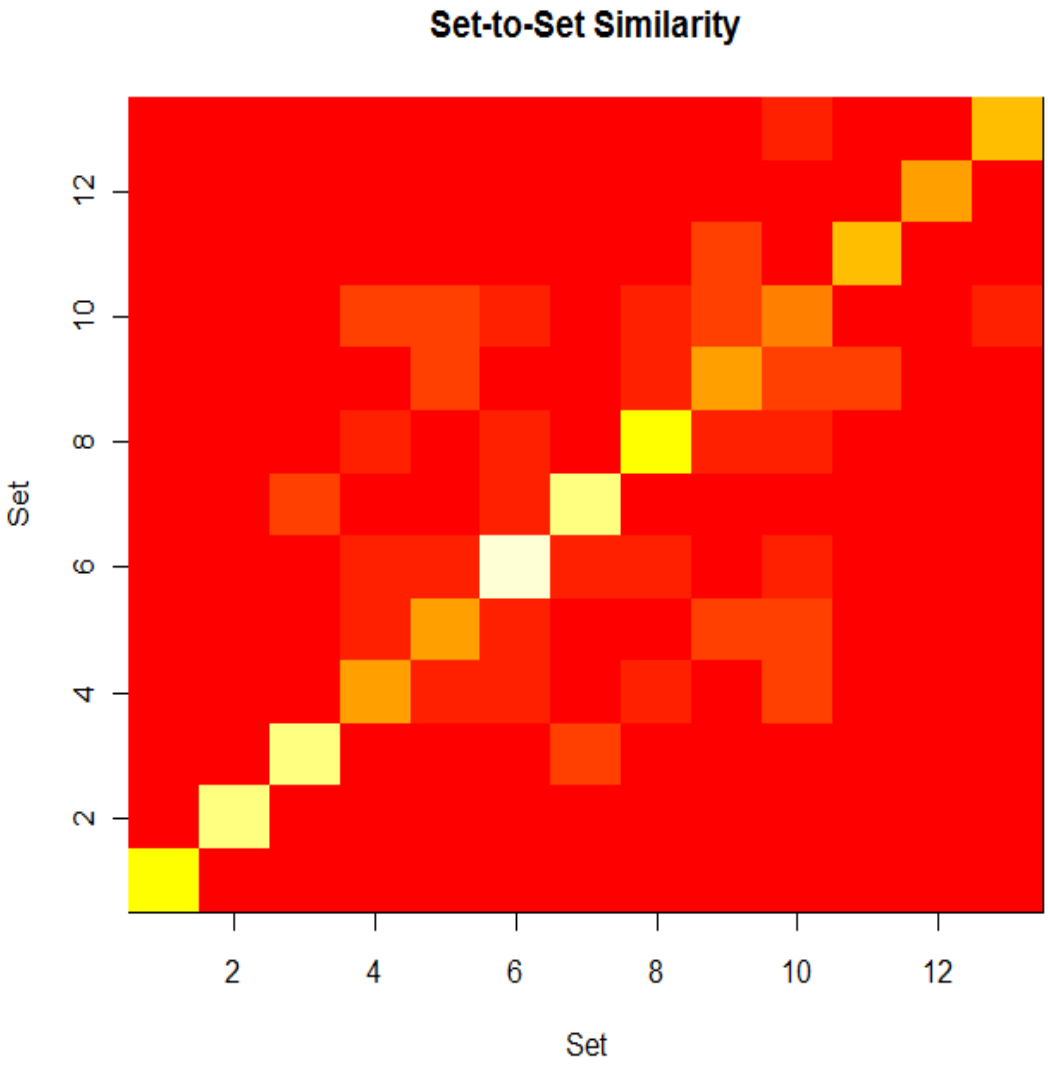


Figure 4.8. PARTANA plot, displaying the similarity of each cluster to each other cluster. White indicates high similarity, yellow moderate to high similarity and red a lack of similarity.

Based on cluster analysis, I identified 1 mid-elevation non-forested and 12 alpine associations. I used the most abundant significant indicators for each cluster (Table 4.3) to name the association, except in cases where only one significant indicator was identified, in which case the most consistent and abundant species in the cluster was

included in the association name. Clusters have been arranged and will be presented in order of increasing mean relative effective annual precipitation (REAP). Cluster 1 was named the *Dryas octopetala* var. *hookeriana*/*Carex rupestris* association. *Dryas octopetala* var. *hookeriana* was identified as an indicator species (Table 4.3) and *Carex rupestris* was the most consistent and abundant species (Appendix H). Cluster 2 is a mid-elevation, forb-dominated meadow association, identified here as the *Helianthella uniflora*/*Astragalus alpinus* association. Both species included in the association name were identified as indicator species for the cluster (Table 4.3). Cluster 3 is a willow-dominated *Salix planifolia*/*Carex scopulorum* association that occurs in basins and drainageways. *Carex scopulorum* was not identified as an indicator species for this cluster, but was the most consistent and abundant species in samples of this cluster (Appendix H). Cluster 4, the *Geum rossii* var. *turbinatum/Silene acaulis* var. *subacaulescens* association, is a cushion plant association. Both species included in the association name were identified as indicator species for this cluster (Table 4.3). Cluster 5 is the *Carex phaeochephala/Sibbaldia procumbens* association, a graminoid-dominated turf association. *Sibbaldia procumbens* was not identified as an indicator species (Table 4.3) but was the most consistently associated and abundant species (Appendix H). Cluster 6 was identified as the *Salix glauca* var. *villosa/Geum rossii var. turbinatum* association. *Geum rossii var. turbinatum* was not identified as an indicator species (Table 4.3) but was the most consistently associated and abundant species (Appendix H). Cluster 7 was named the *Salix reticulata* var. *nana* var. *nana/Polygonum viviparum* association. Both species included in the name were identified as indicator species

(Table 4.3). Cluster 8 is a graminoid-dominated *Deschampsia cespitosa-Carex microptera-Carex macloviana* association. All three species included in the name of the association were identified as indicator species (Table 4.3). Cluster 9 is a snowbed community, named the *Antennaria lanata*/*Hieracium triste* var. *gracile* association. Both species included in the association name were identified as indicator species for this cluster. Cluster 10, the *Pinus engelmannii-Pinus albicaulis/Carex nardina* association, is very similar to the *Carex phaeochephala/Sibbaldia procumbens* association (cluster 5), but *Picea engelmannii* and *Pinus albicaulis* are present in low abundance and the mean species richness is higher. *Picea engelmannii* and *Pinus albicaulis* were not identified as indicator species of Cluster 10, but their presence in stunted form is characteristic of this, and not other, alpine associations. *Carex nardina* was an indicator species for Cluster 10, though it occurs in low abundance and in only two of the three samples in the cluster. Cluster 11 is also a snowbed association and was named the *Carex nigricans*/*Veronica wormskjoldii* association as both species were identified as indicator species (Table 4.3). Cluster 12 occurs around seeps and springs at high elevations and was named the *Senecio triangularis*/*Mertensia ciliata* association. Both species included in the name were identified as indicator species (Table 4.3). Cluster 13 was named the *Senecio fremontii*/*Draba incerta* association. *Draba incerta* was not identified as an indicator species (Table 4.3), but was the most consistently associated species (Appendix H).

Table 4.3. Indicator Species for each of 13 identified clusters.

	cluster	indicator value	probability
SH_Dryas octopetala var. hookeriana	1	0.9983	0.002
FB_Astragalus alpinus	2	1.0000	0.005
FB_Collomia linearis	2	1.0000	0.004
FB_Delphinium glaucum	2	1.0000	0.005
FB_Helianthella uniflora	2	1.0000	0.003
FB_Hydrophyllum capitatum	2	1.0000	0.005
FB_Senecio crassulus	2	1.0000	0.006
FB_Valeriana occidentalis	2	1.0000	0.004
GR_Bromus carinatus var. linearis	2	1.0000	0.005
GR_Melica spectabilis	2	1.0000	0.005
FB_Chamerion angustifolium	2	0.9776	0.007
FB_Pedicularis bracteosa var. paysoniana	2	0.9612	0.004
FB_Erigeron ursinus	2	0.7333	0.009
FB_Boechera angustifolia	2	0.6774	0.010
FB_Lupinus argenteus	2	0.6260	0.008
FB_Solidago multiradiata var. scopulorum	2	0.6036	0.027
GR_Elymus trachycaulus	2	0.4911	0.038
SH_Salix planifolia	3	0.9635	0.001
SH_Betula glandulosa	3	0.7500	0.009
FB_Sedum rhodanthum	3	0.5000	0.016
SH_Pentaphylloides floribunda	3	0.4635	0.045
GR_Carex rupestris	4	0.6773	0.004
FB_Minuartia obtusiloba	4	0.6767	0.001
FB_Phlox pulvinata	4	0.6564	0.002
FB_Eritrichium nanum var. elongatum	4	0.6496	0.034
FB_Trifolium nanum	4	0.6260	0.021
FB_Silene acaulis var. subacaulescens	4	0.6025	0.005
FB_Geum rossii var. turbinatum	4	0.5395	0.006
FB_Bupleurum americanum	4	0.4863	0.043
FB_Erysimum asperum	4	0.3636	0.039
FB_Minuartia rubella	4	0.3636	0.033
GR_Carex elynoides	4	0.3636	0.046
FB_Polemonium viscosum	4	0.3529	0.050
GR_Carex phaeocephala	5	0.5631	0.011
SH_Salix glauca var. villosa	6	0.9767	0.001
FB_Sedum lanceolatum	6	0.1928	0.019
GR_Carex misandra	7	1.0000	0.010
SH_Salix reticulata var. nana	7	0.9524	0.002
FB_Pedicularis oederi	7	0.9425	0.014
FB_Polygonum viviparum	7	0.9360	0.003
GR_Carex scopulorum	7	0.5148	0.045
FB_Potentilla nivea	7	0.4583	0.042
GR_Deschampsia cespitosa	8	0.8545	0.001
GR_Carex macloviana	8	0.6437	0.009
GR_Carex microptera	8	0.6064	0.023
FB_Antennaria lanata	9	0.7575	0.001
FB_Hieracium triste var. gracile	9	0.4763	0.016
FB_Sibbaldia procumbens	9	0.4322	0.002
FB_Boechera lyallii	9	0.4286	0.022
GR_Carex nardina	10	0.4915	0.018
GR_Carex nigricans	11	0.9606	0.001
FB_Veronica wormskjoldii	11	0.7227	0.003

Table 4.3. Indicator Species for each of 13 identified clusters (continued).

cluster	indicator_	value	probability
FB_Senecio triangularis	12	0.9783	0.001
FB_Mertensia ciliata	12	0.9713	0.014
FB_Epilobium hornemannii	12	0.7921	0.009
GR_Poa reflexa	12	0.5313	0.036
GR_Carex spectabilis	12	0.4783	0.025
FB_Senecio fremontii	13	0.6250	0.020
FB_Draba incerta	13	0.4599	0.033

NMDS Ordination and Evaluation of Environmental Variables

The 2-dimensional NMDS ordination of sample plots has a moderate r-value (0.643). The 3-dimensional NMDS ordination of sample plots has a higher r-value (0.713), reflecting a fairly efficient representation of the underlying dissimilarities (Figure 4.9). While both the NMDS ordination and the cluster analysis are based on the Bray-Curtis dissimilarity matrix, their results are independent. Plotting the results of a cluster analysis on an NMDS ordination based on the same dissimilarity matrix (Figure 4.10) helps to confirm that identified clusters are distinct and also provides a tool with which to assess the influence of environmental variables on structuring cluster arrangement in vegetation space.

Continuous environmental variables were tested to determine which variable explained the most deviance in the NMDS ordination using D^2 values obtained by fitting each variable to the ordination coordinates using a GAM on the smooth of all three axes. Gaussian GAM surfaces were fit to the first two dimensions of the 3-dimensional NMDS ordination (Figure 4.12 through 4.19). Of the deviance observed in the ordination, total annual precipitation (TOTPRCP) explains the highest percent (75.2%). Relative effective

annual precipitation (REAP) explained 62% or the deviance, but is correlated with total annual precipitation (TOTPRCP). Elevation is also correlated with both relative effective annual precipitation (REAP) and total annual precipitation (TOTPRCP), but only explained 42.1% of the deviance observed in the NMDS ordination. Growing degree days (GRDEGDAY) explained 50.6% of the deviance observed in the NMDS ordination. All other variables explain less than 50% of the deviance (Table 4.4). The GAM contours indicate that relationships are often non-linear.

While the continuous environmental variables may not be explained well by the NMDS ordination, these variables can further be tested for significance in determining cluster membership using p-values and chi-squared values obtained from a Kruskal-Wallis Rank Sum test (Kruskal and Wallis, 1952). These p-values help to quantify the variation of clusters across continuous environmental variables observed in Figure 4.21. The Easting coordinate was, somewhat surprisingly, the most significant variable ($p=0.002958$), while the Northing coordinate was not significant at all ($p=0.2185$). Relative effective annual precipitation (REAP) and total annual precipitation (TOTPRCP) were the next most significant variables ($p=.003830$ and $p=.004678$ respectively). Elevation, slope percent, growing degree days and average daily temperature were also significant ($p=0.008018$, $p=0.01129$, $p=0.01579$ and $p=0.04632$ respectively). Aspect value and aspect class were not included in this analysis, though these data were collected in the field, since the annual radiation budget is more a result of the net effects of slope and aspect than aspect alone. The annual solar exposure

(SOLAR) model was used to access the effects of slope and aspect together. Annual solar exposure (SOLAR) was not significant to cluster membership (p=0.1602).

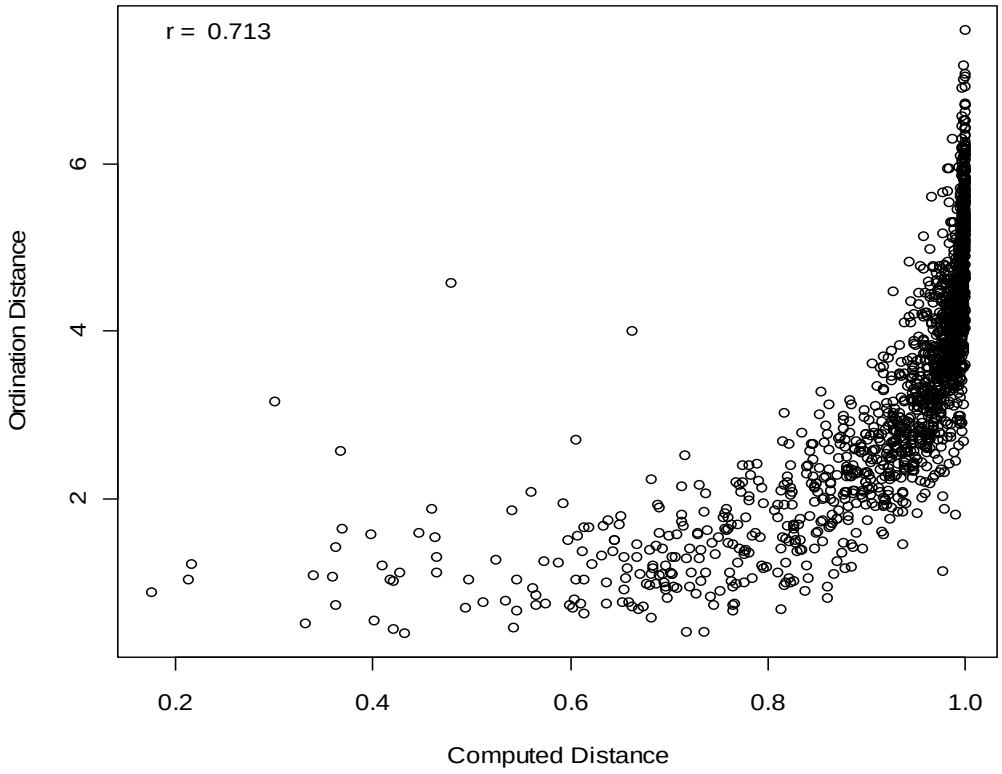


Figure 4.9. Correlation of three-dimensional ordination and computed distances of sample plots, giving an indication of the NMDS ordination quality (r=0.713)

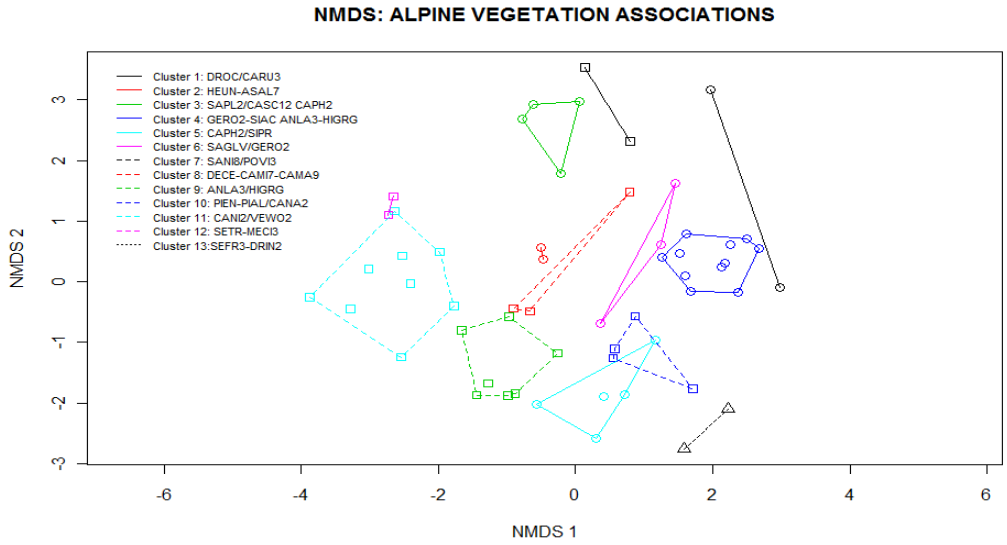


Figure 4.10: First two axes of three-dimensional NMDS ordination with alpine associations outlined.

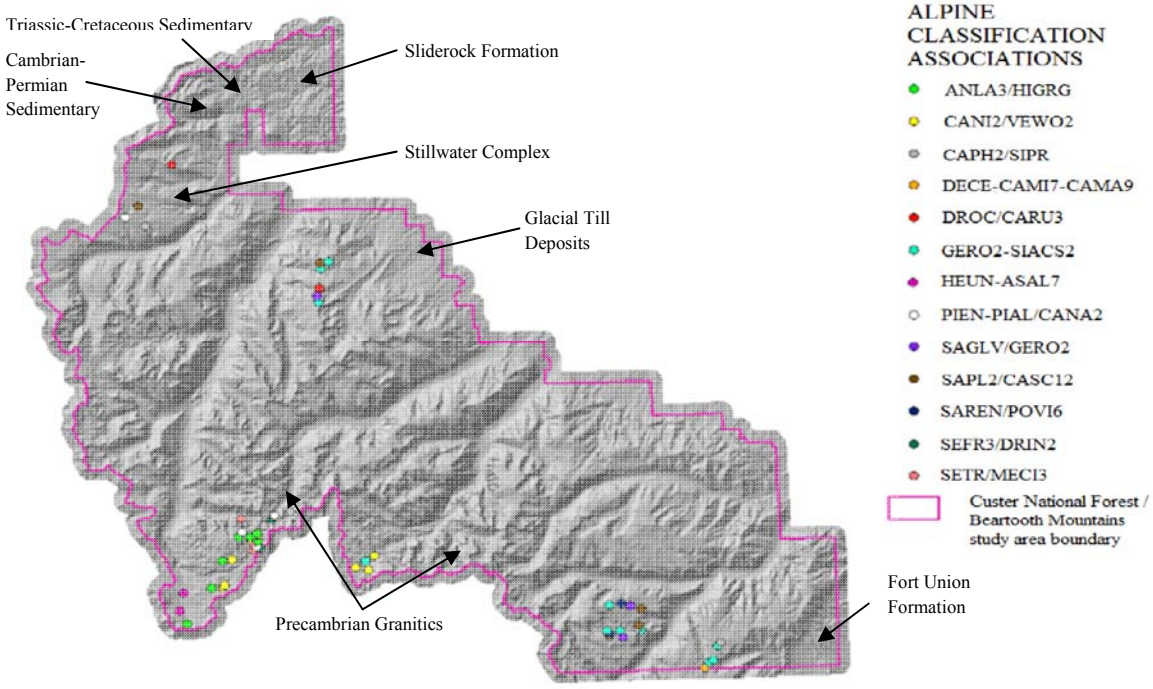


Figure 4.11. Hillshade relief and broad geologic map of study area where membership of alpine samples to alpine association is indicated by differently colored points.

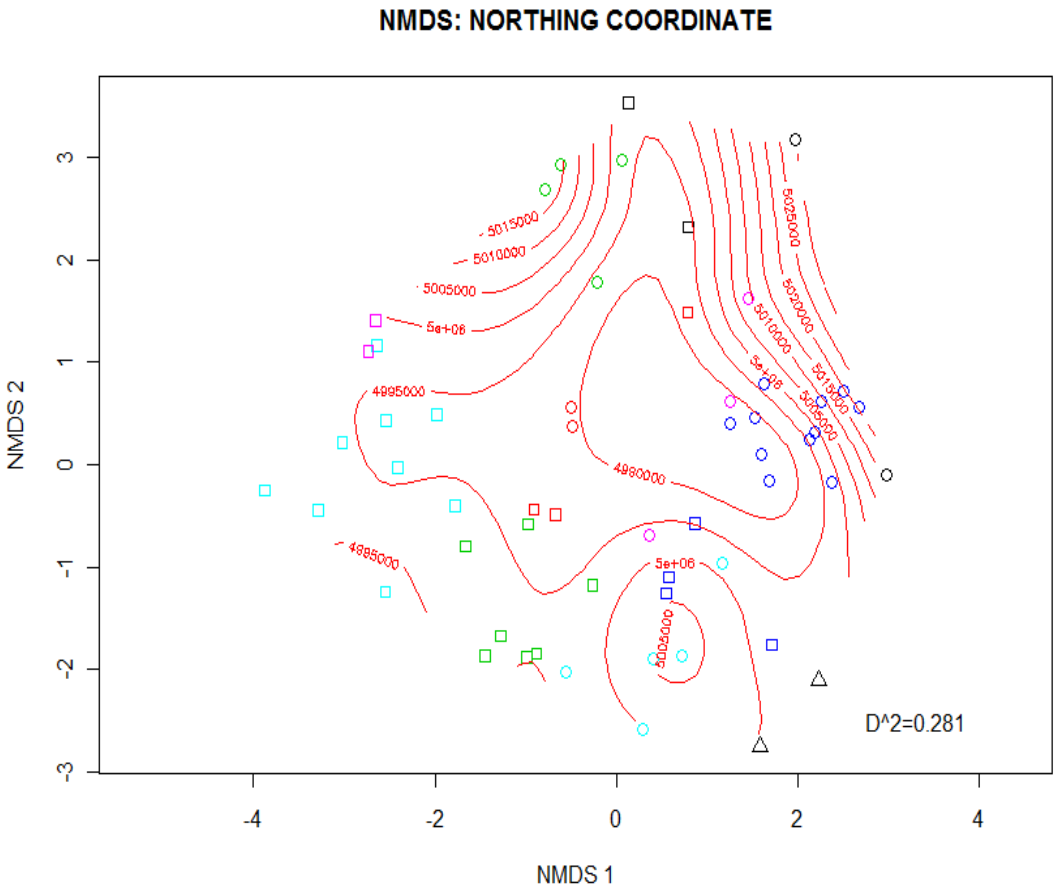


Figure 4.12. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.281$ for smooth of Northing coordinate on three dimensions. Associations identified in this analysis are denoted by the symbols listed below.

Cluster 1:	Black Circle:	*Dryas octopetala* var. *hookeriana/Carex rupestris*
Cluster 2:	Red Circle:	*Helianthela uniflora-Astragalus alpinus*
Cluster 3:	Green Circle:	*Salix planifolia/Carex scopulorum*
Cluster 4:	Blue Circle:	*Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens*
Cluster 5:	Cyan Circle:	*Carex phaeochephala/Sibbaldia procumbens*
Cluster 6:	Violet Circle:	*Salix glauca* var. *villosa*/*Geum rossii* var. *turbinatum*
Cluster 7:	Black Triangle:	*Salix reticulata* var. *nana*/*Polygonum viviparum*
Cluster 8:	Red Triangle:	*Deschampsia cespitosa-Carex microptera-Carex macloviana*
Cluster 9:	Green Triangle:	*Antennaria lanata-Hieracium triste* var. *gracile*
Cluster 10:	Blue Triangle:	*Picea engelmannii-Pinus albicaulis/Carex nardina*
Cluster 11:	Cyan Triangle:	*Carex nigricans/Veronica wormskjoldii*
Cluster 12:	Violet Triangle:	*Senecio triangularis-Mertensia ciliata*
Cluster 13:	Black Square:	*Senecio fremontii-Draba incerta*

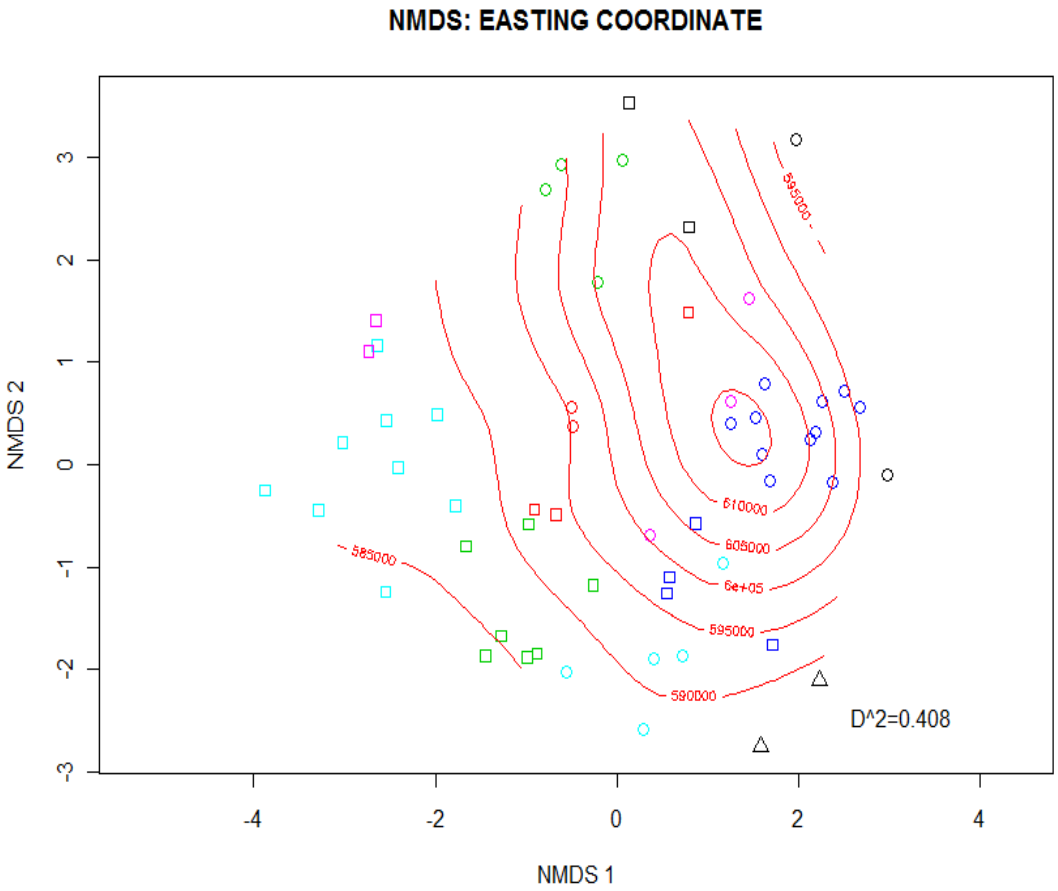


Figure 4.13. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.408 for smooth of Easting coordinate on three dimensions. Associations identified in this analysis are denoted by the symbols listed below.

Cluster 1:	Black Circle:	*Dryas octopetala* var. *hookeriana/Carex rupestris*
Cluster 2:	Red Circle:	*Helianthela uniflora-Astragalus alpinus*
Cluster 3:	Green Circle:	*Salix planifolia/Carex scopulorum*
Cluster 4:	Blue Circle:	*Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens*
Cluster 5:	Cyan Circle:	*Carex phaeochephala/Sibbaldia procumbens*
Cluster 6:	Violet Circle:	*Salix glauca* var. *villosa*/*Geum rossii* var. *turbinatum*
Cluster 7:	Black Triangle:	*Salix reticulata* var. *nana*/*Polygonum viviparum*
Cluster 8:	Red Triangle:	*Deschampsia cespitosa-Carex microptera-Carex macloviana*
Cluster 9:	Green Triangle:	*Antennaria lanata-Hieracium triste* var. *gracile*
Cluster 10:	Blue Triangle:	*Picea engelmannii-Pinus albicaulis/Carex nardina*
Cluster 11:	Cyan Triangle:	*Carex nigricans/Veronica wormskjoldii*
Cluster 12:	Violet Triangle:	*Senecio triangularis-Mertensia ciliata*
Cluster 13:	Black Square:	*Senecio fremontii-Draba incerta*

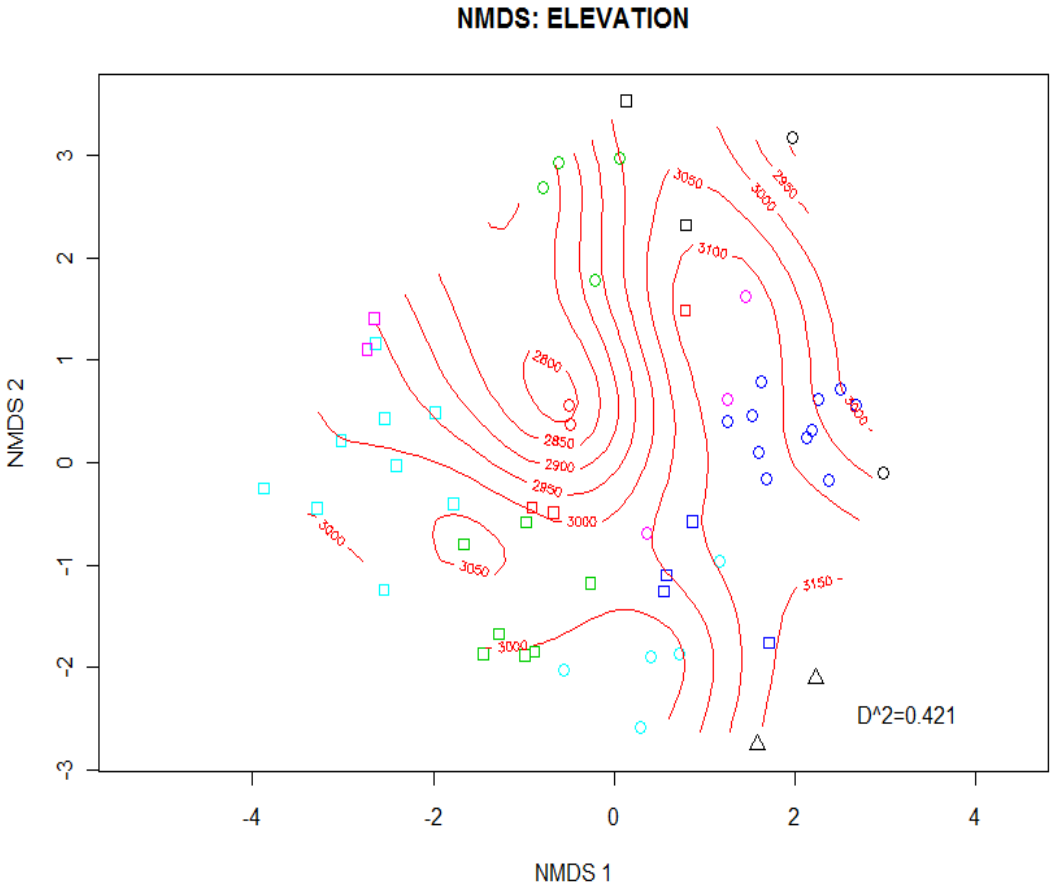


Figure 4.14. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.421for smooth of elevation (m) on three dimensions. Associations identified in this analysis are denoted by the symbols listed below.

Cluster 1:	Black Circle:	*Dryas octopetala* var. *hookeriana/Carex rupestris*
Cluster 2:	Red Circle:	*Helianthela uniflora-Astragalus alpinus*
Cluster 3:	Green Circle:	*Salix planifolia/Carex scopulorum*
Cluster 4:	Blue Circle:	*Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens*
Cluster 5:	Cyan Circle:	*Carex phaeochephala/Sibbaldia procumbens*
Cluster 6:	Violet Circle:	*Salix glauca* var. *villosa*/*Geum rossii* var. *turbinatum*
Cluster 7:	Black Triangle:	*Salix reticulata* var. *nana*/*Polygonum viviparum*
Cluster 8:	Red Triangle:	*Deschampsia cespitosa-Carex microptera-Carex macloviana*
Cluster 9:	Green Triangle:	*Antennaria lanata-Hieracium triste* var. *gracile*
Cluster 10:	Blue Triangle:	*Picea engelmannii-Pinus albicaulis/Carex nardina*
Cluster 11:	Cyan Triangle:	*Carex nigricans/Veronica wormskjoldii*
Cluster 12:	Violet Triangle:	*Senecio triangularis-Mertensia ciliata*
Cluster 13:	Black Square:	*Senecio fremontii-Draba incerta*

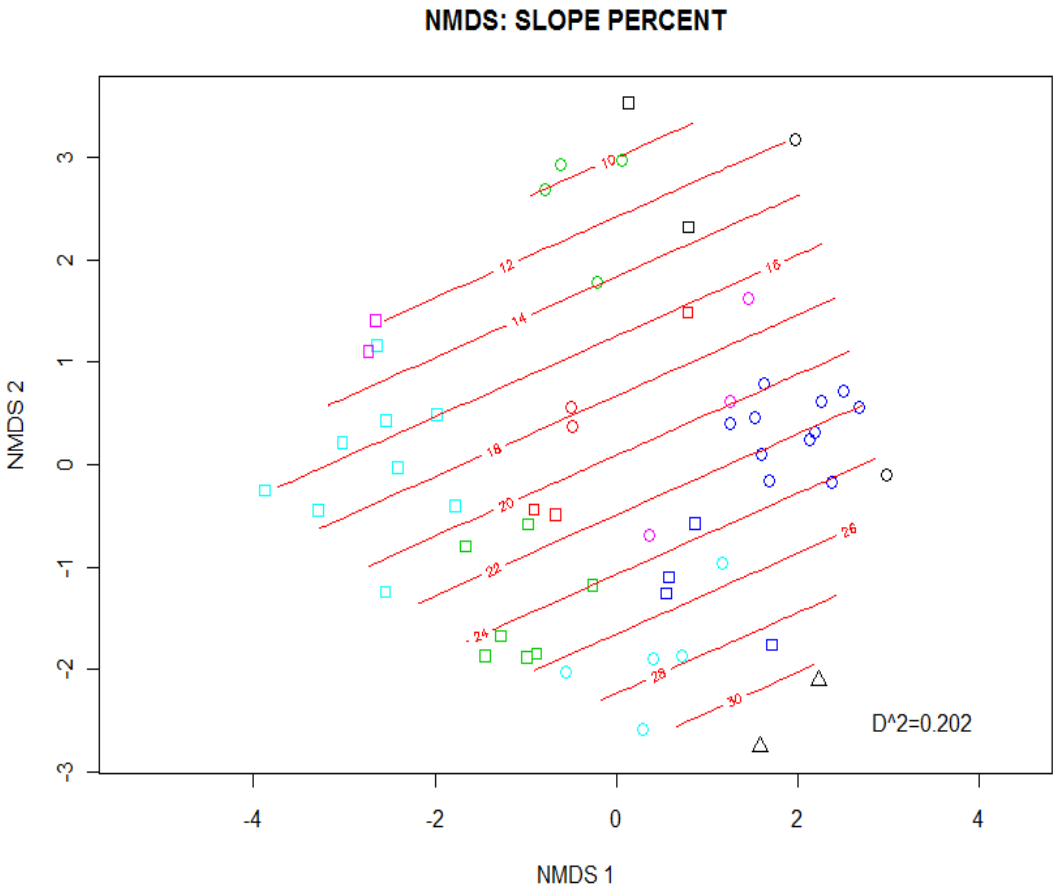


Figure 4.15. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.202 for smooth of slope percent (%) on three dimensions. Associations identified in this analysis are denoted by the symbols listed below.

Cluster 1:	Black Circle:	*Dryas octopetala* var. *hookeriana/Carex rupestris*
Cluster 2:	Red Circle:	*Helianthela uniflora-Astragalus alpinus*
Cluster 3:	Green Circle:	*Salix planifolia/Carex scopulorum*
Cluster 4:	Blue Circle:	*Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens*
Cluster 5:	Cyan Circle:	*Carex phaeochephala/Sibbaldia procumbens*
Cluster 6:	Violet Circle:	*Salix glauca* var. *villosa*/*Geum rossii* var. *turbinatum*
Cluster 7:	Black Triangle:	*Salix reticulata* var. *nana*/*Polygonum viviparum*
Cluster 8:	Red Triangle:	*Deschampsia cespitosa-Carex microptera-Carex macloviana*
Cluster 9:	Green Triangle:	*Antennaria lanata-Hieracium triste* var. *gracile*
Cluster 10:	Blue Triangle:	*Picea engelmannii-Pinus albicaulis/Carex nardina*
Cluster 11:	Cyan Triangle:	*Carex nigricans/Veronica wormskjoldii*
Cluster 12:	Violet Triangle:	*Senecio triangularis-Mertensia ciliata*
Cluster 13:	Black Square:	*Senecio fremontii-Draba incerta*

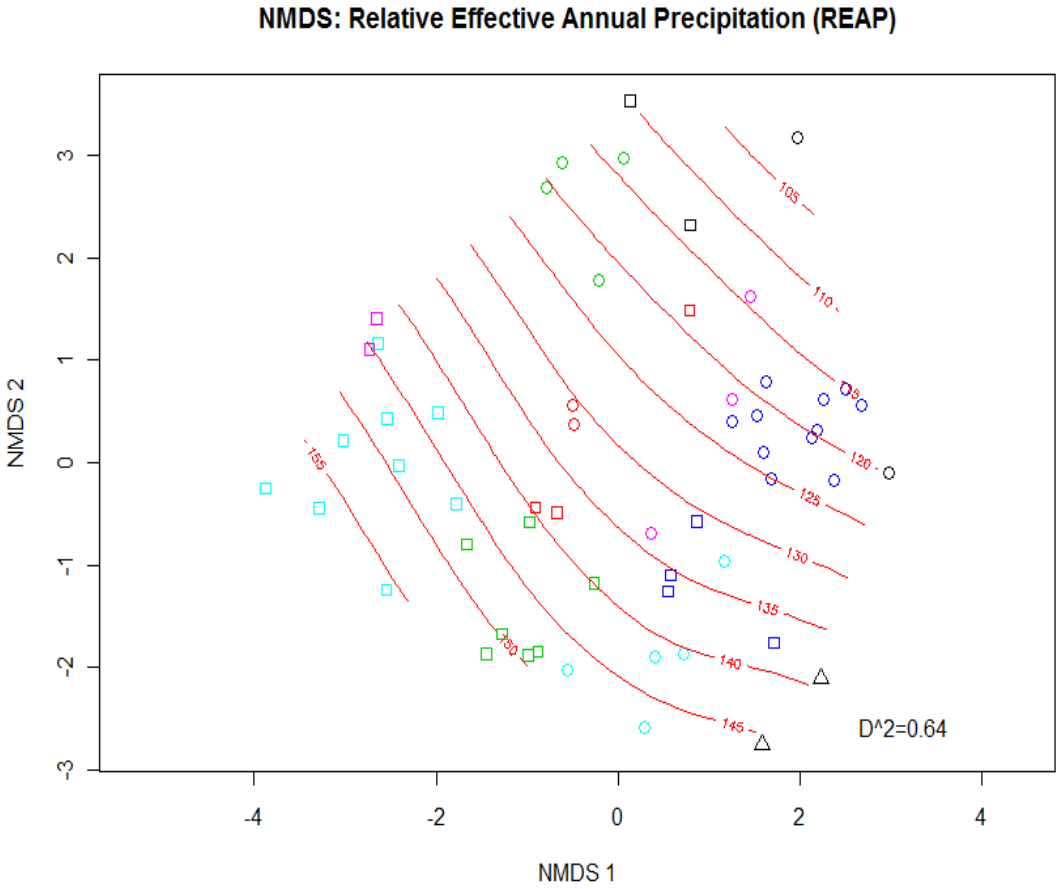


Figure 4.16. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.64 for smooth of relative effective annual precipitation (REAP) on three dimensions. Associations identified in this analysis are denoted by the symbols listed below.

Cluster 1:	Black Circle:	*Dryas octopetala* var. *hookeriana/Carex rupestris*
Cluster 2:	Red Circle:	*Helianthela uniflora-Astragalus alpinus*
Cluster 3:	Green Circle:	*Salix planifolia/Carex scopulorum*
Cluster 4:	Blue Circle:	*Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens*
Cluster 5:	Cyan Circle:	*Carex phaeochephala/Sibbaldia procumbens*
Cluster 6:	Violet Circle:	*Salix glauca* var. *villosa*/*Geum rossii* var. *turbinatum*
Cluster 7:	Black Triangle:	*Salix reticulata* var. *nana*/*Polygonum viviparum*
Cluster 8:	Red Triangle:	*Deschampsia cespitosa-Carex microptera-Carex macloviana*
Cluster 9:	Green Triangle:	*Antennaria lanata-Hieracium triste* var. *gracile*
Cluster 10:	Blue Triangle:	*Picea engelmannii-Pinus albicaulis/Carex nardina*
Cluster 11:	Cyan Triangle:	*Carex nigricans/Veronica wormskjoldii*
Cluster 12:	Violet Triangle:	*Senecio triangularis-Mertensia ciliata*
Cluster 13:	Black Square:	*Senecio fremontii-Draba incerta*

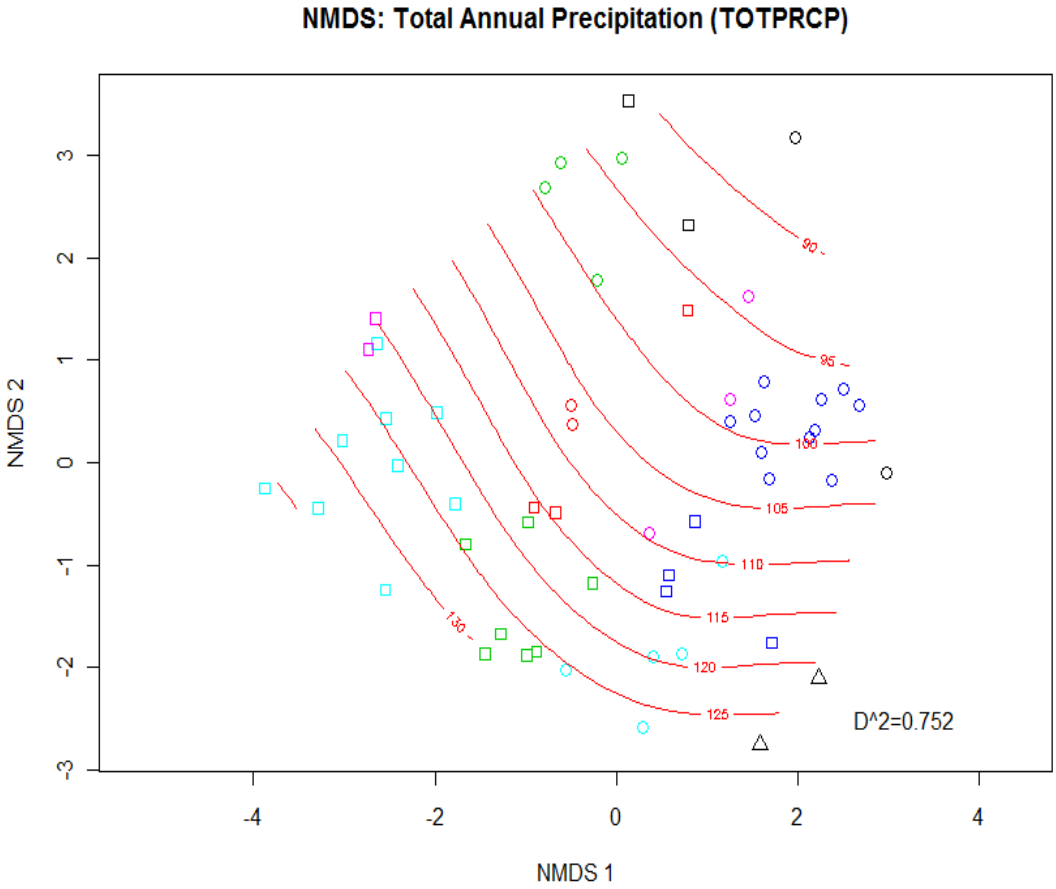


Figure 4.17. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.752 for smooth of total annual precipitation (TOTPRCP) on three dimensions. Associations identified in this analysis are denoted by the symbols listed below.

Cluster 1:	Black Circle:	*Dryas octopetala* var. *hookeriana/Carex rupestris*
Cluster 2:	Red Circle:	*Helianthela uniflora-Astragalus alpinus*
Cluster 3:	Green Circle:	*Salix planifolia/Carex scopulorum*
Cluster 4:	Blue Circle:	*Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens*
Cluster 5:	Cyan Circle:	*Carex phaeochephala/Sibbaldia procumbens*
Cluster 6:	Violet Circle:	*Salix glauca* var. *villosa*/*Geum rossii* var. *turbinatum*
Cluster 7:	Black Triangle:	*Salix reticulata* var. *nana*/*Polygonum viviparum*
Cluster 8:	Red Triangle:	*Deschampsia cespitosa-Carex microptera-Carex macloviana*
Cluster 9:	Green Triangle:	*Antennaria lanata-Hieracium triste* var. *gracile*
Cluster 10:	Blue Triangle:	*Picea engelmannii-Pinus albicaulis/Carex nardina*
Cluster 11:	Cyan Triangle:	*Carex nigricans/Veronica wormskjoldii*
Cluster 12:	Violet Triangle:	*Senecio triangularis-Mertensia ciliata*
Cluster 13:	Black Square:	*Senecio fremontii-Draba incerta*

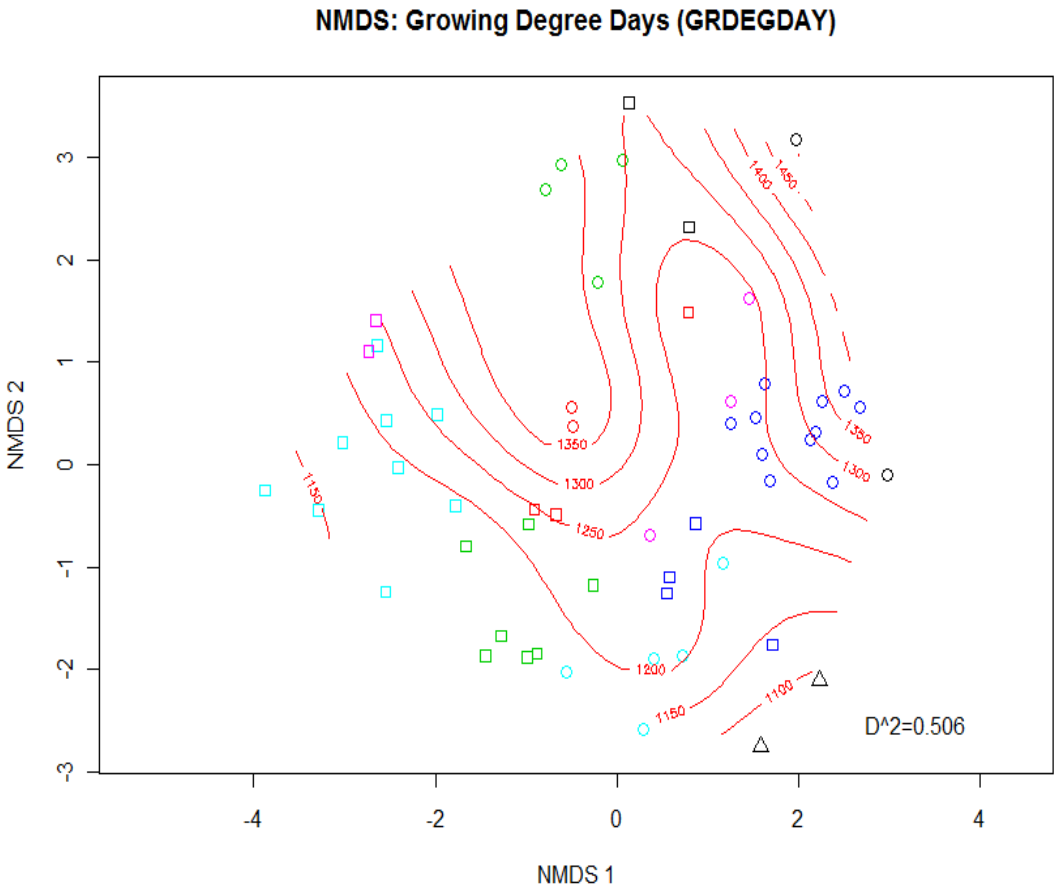


Figure 4.18. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.506 for smooth of growing degree days (GRDEGDAY) on three dimensions. Associations identified in this analysis are denoted by the symbols listed below.

Cluster 1:	Black Circle:	*Dryas octopetala* var. *hookeriana/Carex rupestris*
Cluster 2:	Red Circle:	*Helianthela uniflora-Astragalus alpinus*
Cluster 3:	Green Circle:	*Salix planifolia/Carex scopulorum*
Cluster 4:	Blue Circle:	*Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens*
Cluster 5:	Cyan Circle:	*Carex phaeochephala/Sibbaldia procumbens*
Cluster 6:	Violet Circle:	*Salix glauca* var. *villosa*/*Geum rossii* var. *turbinatum*
Cluster 7:	Black Triangle:	*Salix reticulata* var. *nana*/*Polygonum viviparum*
Cluster 8:	Red Triangle:	*Deschampsia cespitosa-Carex microptera-Carex macloviana*
Cluster 9:	Green Triangle:	*Antennaria lanata-Hieracium triste* var. *gracile*
Cluster 10:	Blue Triangle:	*Picea engelmannii-Pinus albicaulis/Carex nardina*
Cluster 11:	Cyan Triangle:	*Carex nigricans/Veronica wormskjoldii*
Cluster 12:	Violet Triangle:	*Senecio triangularis-Mertensia ciliata*
Cluster 13:	Black Square:	*Senecio fremontii-Draba incerta*

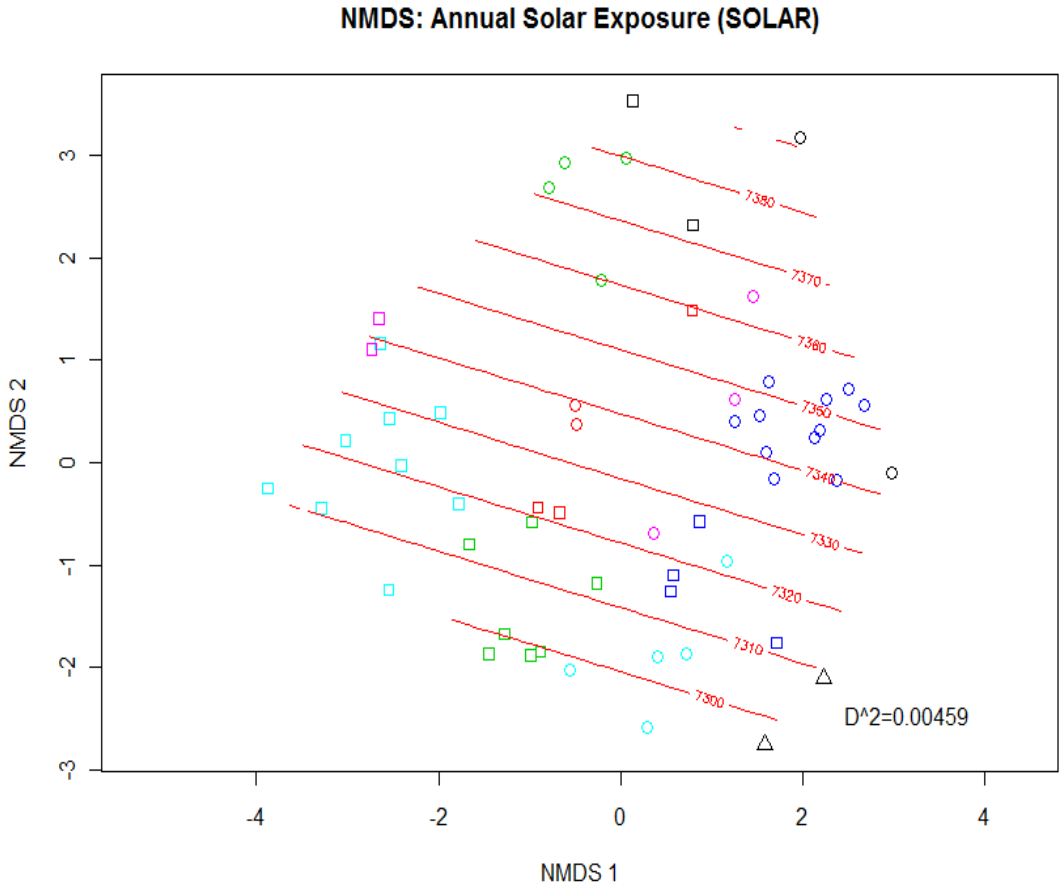


Figure 4.19. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and D^2 =0.00459 for smooth of annual solar exposure (SOLAR) on three dimensions. Associations identified in this analysis are denoted by the symbols listed below.

Cluster 1:	Black Circle:	*Dryas octopetala* var. *hookeriana/Carex rupestris*
Cluster 2:	Red Circle:	*Helianthela uniflora-Astragalus alpinus*
Cluster 3:	Green Circle:	*Salix planifolia/Carex scopulorum*
Cluster 4:	Blue Circle:	*Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens*
Cluster 5:	Cyan Circle:	*Carex phaeochephala/Sibbaldia procumbens*
Cluster 6:	Violet Circle:	*Salix glauca* var. *villosa*/*Geum rossii* var. *turbinatum*
Cluster 7:	Black Triangle:	*Salix reticulata* var. *nana*/*Polygonum viviparum*
Cluster 8:	Red Triangle:	*Deschampsia cespitosa-Carex microptera-Carex macloviana*
Cluster 9:	Green Triangle:	*Antennaria lanata-Hieracium triste* var. *gracile*
Cluster 10:	Blue Triangle:	*Picea engelmannii-Pinus albicaulis/Carex nardina*
Cluster 11:	Cyan Triangle:	*Carex nigricans/Veronica wormskjoldii*
Cluster 12:	Violet Triangle:	*Senecio triangularis-Mertensia ciliata*
Cluster 13:	Black Square:	*Senecio fremontii-Draba incerta*

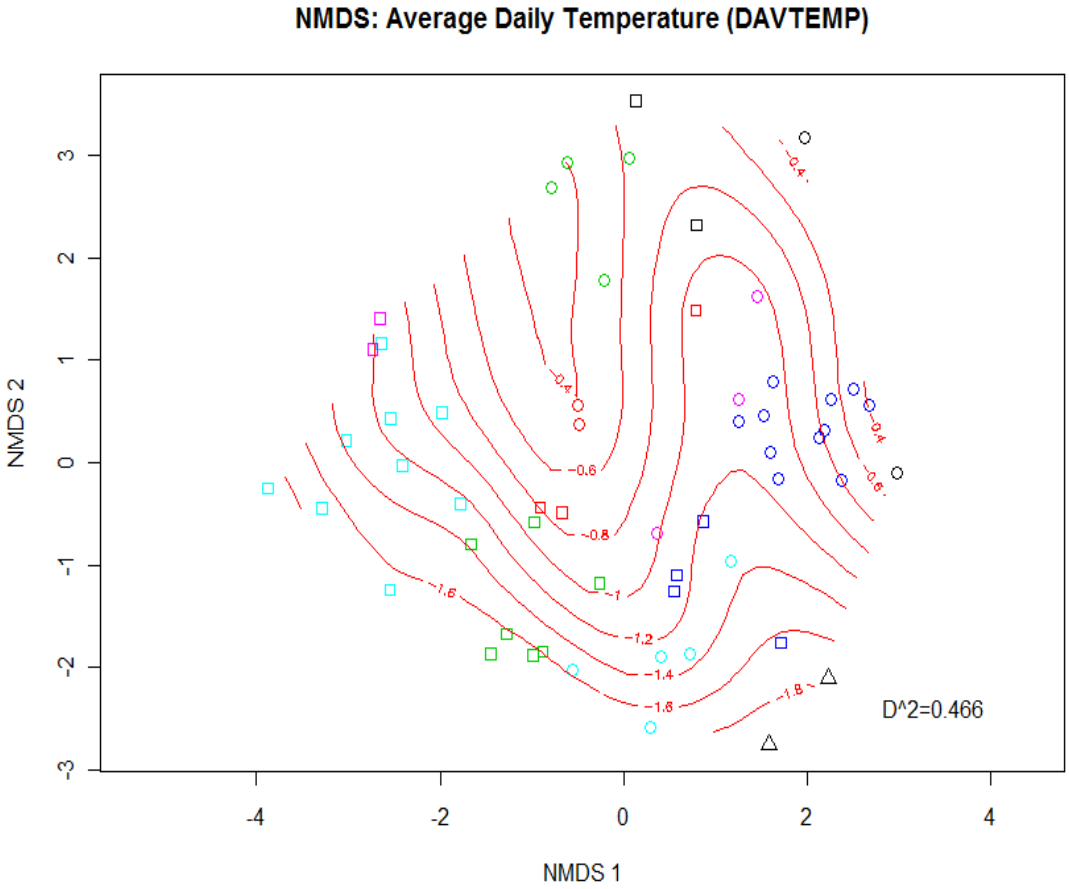


Figure 4.20. First two dimensions of 3-dimensional NMDS ordination plot, with Gaussian GAM surface fit to first two dimensions and $D^2 = 0.466$ for smooth of average daily temperature (DAVTEMP) on three dimensions. Associations identified in this analysis are denoted by the symbols listed below.

Cluster 1:	Black Circle:	*Dryas octopetala* var. *hookeriana/Carex rupestris*
Cluster 2:	Red Circle:	*Helianthela uniflora-Astragalus alpinus*
Cluster 3:	Green Circle:	*Salix planifolia/Carex scopulorum*
Cluster 4:	Blue Circle:	*Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens*
Cluster 5:	Cyan Circle:	*Carex phaeochephala/Sibbaldia procumbens*
Cluster 6:	Violet Circle:	*Salix glauca* var. *villosa*/*Geum rossii* var. *turbinatum*
Cluster 7:	Black Triangle:	*Salix reticulata* var. *nana*/*Polygonum viviparum*
Cluster 8:	Red Triangle:	*Deschampsia cespitosa-Carex microptera-Carex macloviana*
Cluster 9:	Green Triangle:	*Antennaria lanata-Hieracium triste* var. *gracile*
Cluster 10:	Blue Triangle:	*Picea engelmannii-Pinus albicaulis/Carex nardina*
Cluster 11:	Cyan Triangle:	*Carex nigricans/Veronica wormskjoldii*
Cluster 12:	Violet Triangle:	*Senecio triangularis-Mertensia ciliata*
Cluster 13:	Black Square:	*Senecio fremontii-Draba incerta*

Table 4.4. D^2 values of GAMs fit to continuous environmental variables, based on the three dimensional NMDS ordination. All models are Gaussian.

VARIABLE	GAM D^2 (%)
Northing Coordinate (UTM)	28.1%
Easting Coordinate (UTM)	40.8%
Elevation (m)	42.1%
Slope Percent (%)	20.2%
Relative effective annual precipitation (REAP)	64%
Total precipitation (TOTPRCP)	**75.2%**
Growing degree day (GRDEGDAY)	50.6%
Annual solar exposure (SOLAR)	0.459%
Average daily temperature (DAVTEMP)	46.6%

Table 4.5. P-values and chi-squared values from Kruskal-Wallis Rank Sum Test for each of the continuous environmental variables. P-values < .05 are bolded.
d.f.= 12

VARIABLE	p-value	Chi-squared value
Northing Coordinate (UTM)	0.2185	15.4357
Easting Coordinate (UTM)	**0.002958**	29.8335
Elevation (m)	**0.008018**	26.8883
Slope Percent (%)	**0.01129**	25.845
Relative effective annual precipitation (REAP)	**0.003830**	29.0824
Total precipitation (TOTPRCP)	**0.004678**	28.4957
Growing degree day (GRDEGDAY)	**0.01579**	24.8013
Annual solar exposure (SOLAR)	0.1602	16.7272
Average daily temperature (DAVTEMP)	**0.04632**	21.288

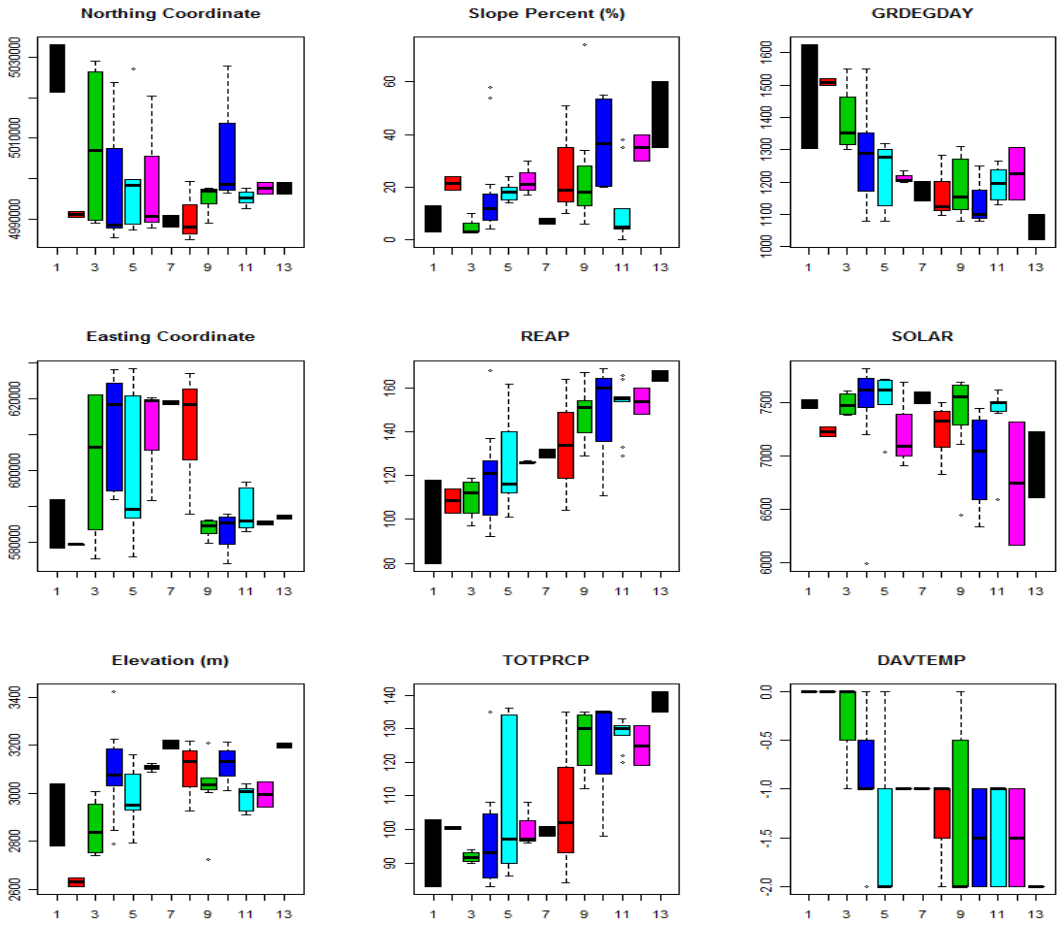


Figure 4.21. Boxplots of continuous environmental variables elevation, slope percent (%), relative effective annual precipitation (REAP), total annual precipitation (TOTPRCP), growing degree days (GRDEGDAY), annual solar exposure (SOLAR) and average daily temperature (DAVTEMP).

Cluster 1: *Dryas octopetala* var. *hookeriana/Carex rupestris*
Cluster 2: *Helianthela uniflora-Astragalus alpinus*
Cluster 3: *Salix planifolia/Carex scopulorum*
Cluster 4: *Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens*
Cluster 5: *Carex phaeochephala/Sibbaldia procumbens*
Cluster 6: *Salix glauca* var. *villosa*/*Geum rossii* var. *turbinatum*
Cluster 7: *Salix reticulata* var. *nana*/*Polygonum viviparum*
Cluster 8: D*eschampsia cespitosa-Carex microptera-Carex macloviana*
Cluster 9: *Antennaria lanata-Hieracium triste* var. *gracile*
Cluster 10: *Picea engelmannii-Pinus albicaulis/Carex nardina*
Cluster 11: *Carex nigricans/Veronica wormskjoldii*
Cluster 12: *Senecio triangularis-Mertensia ciliata*
Cluster 13: *Senecio fremontii-Draba incerta*

Table 4.6. Ordtest p-values for topographic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level.

	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIACS2	CAPH2 / SIPR	SAGLV / GERO2	SANI8 / POVI3	DECE - CAMI7 - CAMA9	ANLA3 - HIGRG	PIEN - PIAL / CANA2	CANI2 - VEWO2	SETR / MECI3	SEFR3 / DRIN2	p-val
Topographic Position														**0.007**
Backslope	0	0	1	4	2	3	1	3	4	2	2	2	2	0.538
Footslope	0	2	0	0	1	0	1	0	0	0	3	0	0	0.159
Shoulder	1	0	0	5	2	0	0	0	2	2	0	0	0	0.899
Summit	1	0	0	2	0	0	0	0	0	0	0	0	0	0.392
Toeslope	0	0	3	0	0	0	0	0	1	0	4	0	0	**0.001**
Primary Landform														**0.001**
Cirque	0	0	0	1	0	0	1	1	0	1	0	0	1	0.671
Cirque headwall	0	0	0	0	0	0	0	1	0	0	0	0	0	0.8
Dipslope	1	0	0	0	0	0	0	0	0	0	0	0	0	**0.022**
Drainageway	0	0	1	0	0	0	1	0	0	0	3	2	0	**0.015**
Erosion Remnant	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Flood plain	0	0	1	0	0	0	0	0	0	0	1	0	0	1
Glacial-valley Floor	0	0	0	0	0	0	0	0	0	0	1	0	0	0.25
Glacial-valley Wall	0	0	0	2	0	1	0	0	1	1	1	0	1	0.594
Ground Moraine	0	0	0	1	1	0	0	0	0	0	0	0	0	0.743
Knob	0	0	0	1	0	0	0	0	2	0	0	0	0	0.995
Mountain Slope	0	0	0	0	2	0	0	0	0	1	0	0	0	0.791
Plateau	1	0	1	6	1	2	0	0	0	0	1	0	0	0.327
Recessional moraine	0	0	0	0	1	0	0	0	0	0	0	0	0	0.435
U-shaped Valley	0	2	0	0	0	0	0	1	4	1	2	0	0	0.106
V-shaped Valley	0	0	1	0	0	0	0	0	0	0	0	0	0	0.23
Slope Complex														0.68
Complex Broken	0	0	0	0	0	0	0	0	1	2	0	0	0	1
Complex Patterned	0	0	2	0	0	0	1	1	0	0	2	0	0	**0.055**
Complex Undulating	0	0	0	1	1	1	0	1	0	0	1	0	0	0.992
Simple Concave	0	0	0	1	1	2	0	0	0	0	1	1	0	0.216
Simple Convex	0	2	0	3	2	0	0	1	5	0	0	1	0	0.545
Simple Linear	2	0	2	6	1	0	1	0	1	2	5	0	2	**.065**

Table 4.6. Ordtest p-values for topographic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level (continued).

	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIACS2	CAPH2 / SIPR	SAGLV / GERO2	SANI8 / POVI3	DECE - CAMI7 - CAMA9	ANLA3 - HIGRG	PIEN - PIAL / CANA2	CANI2 - VEWO2	SETR / MECI3	SEFR3 / DRIN2	p-val
Slope Complexity														0.866
Complex	0	0	2	1	1	1	1	2	1	2	3	0	0	0.876
Simple	2	2	2	10	4	2	1	1	6	2	6	2	2	0.877
Verticle Slope Shape														**0.024**
Broken	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Concave	1	0	1	3	1	2	1	1	1	0	2	2	0	0.104
Convex	0	0	0	4	1	0	0	1	4	4	1	0	2	0.641
Linear	1	2	1	4	2	0	0	0	1	0	4	0	0	0.34
Patterened	0	0	2	0	0	0	1	1	0	0	2	0	0	**0.035**
Undulating	0	0	0	0	1	1	0	0	1	0	0	0	0	0.821
Horizontal Slope Shape														0.681
Broken	0	0	0	0	0	0	0	0	1	2	0	0	0	0.999
Concave	0	0	0	1	1	2	0	0	0	0	1	1	0	0.228
Convex	0	2	0	3	2	0	0	1	5	0	0	1	0	0.512
Linear	2	0	2	6	1	0	1	0	1	2	5	0	2	**0.07**
Patterened	0	0	2	0	0	0	1	1	0	0	2	0	0	**0.054**
Undulating	0	0	0	1	1	1	0	1	0	0	1	0	0	0.989

Table 4.7. Ordtest p-values for climatic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variable at the $p < 0.1$ level.

	DROC / CARU3	**HEUN / ASAL7**	**SAPL2 / CASC12**	**GERO2 / SIACS2**	**CAPH2 / SIPR**	**SAGLV / GERO2**	**SANI8 / POVI3**	**DECE - CAMI7 - CAMA9**	**ANLA3 -HIGRG**	**PIEN - PIAL / CANA2**	**CANI2 - VEWO2**	**SETR / MECI3**	**SEFR3 / DRIN2**	**p-val**
Soil Temperature Regime (STR)														**0.052**
Cryic	1	2	4	11	5	2	1	2	7	4	7	2	2	**0.046**
Frigid	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Gelic	1	0	0	0	0	1	1	1	0	0	2	0	0	**0.04**
Soil Moisture Regime (SMR)														**0.007**
Aquic	0	0	2	0	0	1	0	0	0	0	5	0	0	**0.01**
Udic	2	2	2	11	5	2	2	3	7	4	4	2	2	**0.005**
Ustic	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Soil Moisture Sub Class (SMSC)														**0.044**
Aquic	1	0	1	0	0	0	1	1	0	0	0	0	0	**0.027**
Aridic	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Oxyaquic	0	1	0	0	1	0	1	2	0	0	1	0	0	0.265
Typic	1	1	3	11	4	3	0	0	7	4	8	2	2	**0.047**
Udic	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ustic	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4.8. Ortest p-values for the categorical variable, disturbance, based on the three dimensional NMDS ordination. Bolding indicates significance of variables at the $p < 0.1$ level.

	DROC / CARU3	**HEUN / ASAL7**	**SAPL2 / CASC12**	**GERO2 / SIACS2**	**CAPH2 / SIPR**	**SAGLV / GERO2**	**SANI8 / POVI3**	**DECE - CAMI7 - CAMA9**	**ANLA3 - HIGRG**	**PIEN - PIAL / CANA2**	**CANI2 - VEWO2**	**SETR / MECI3**	**SEFR3 / DRIN2**	**p-val**
Disturbance														0.58
Foliage														
Disease	0	0	0	0	0	0	0	0	0	0	1	0	0	0.36
None	2	1	4	11	5	3	2	1	5	4	7	2	2	0.55
Rodents	0	1	0	0	0	0	0	0	2	0	0	0	0	0.44
Snow Accumulation	0	0	0	0	0	0	0	2	0	0	0	0	0	1

Table 4.9. Ordtest p-values for geologic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variable at the $p < 0.1$ level.

	DROC / CARU3	**HEUN / ASAL7**	**SAPL2 / CASC12**	**GERO2 / SIACS2**	**CAPH2 / SIPR**	**SAGLV / GERO2**	**SANI8 / POVI3**	**DECE - CAMI7 - CAMA9**	**ANLA3 - HIGRG**	**PIEN PIAL / CANA2**	**CANI2 - VEWO2**	**SETR / MECI3**	**SEFR3 / DRIN2**	**p-val**
Soil Depth														0.485
Deep	1	2	1	7	5	3	2	2	1	2	7	1	1	0.51
Moderate	1	0	1	1	0	0	0	0	3	1	0	0	0	0.741
Shallow	0	0	0	1	0	0	0	0	0	1	1	0	0	0.772
Soil Particle Size														0.109
clayey skeletal	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4.9. Ordtest p-values for geologic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variable at the p < 0.1 level (continued).

	DROC / CARU3	**HEUN / ASAL7**	**SAPL2 / CASC12**	**GERO2 / SIACS2**	**CAPH2 / SIPR**	**SAGLV / GERO2**	**SANI8 / POVI3**	**DECE - CAMI7 - CAMA9**	**ANLA3 - HIGRG**	**PIEN PIAL / CANA2**	**CANI2 - VEWO2**	**SETR / MECI3**	**SEFR3 / DRIN2**	**p-val**
coarse loamy	0	0	0	0	0	0	0	0	0	0	0	0	0	1
fine loamy	0	2	0	0	0	0	0	0	0	0	0	0	0	1
fragmental	0	0	0	0	0	0	0	0	0	0	0	0	0	1
loamy	0	0	0	1	0	0	0	1	0	0	2	0	0	1
loamy skeletal	2	0	0	8	2	2	1	2	2	2	6	2	0	1
sandy	0	0	0	0	0	0	0	0	1	0	0	0	0	1
sandy skeletal	0	0	1	2	3	1	0	0	4	2	1	0	2	1
Soil SubGroup														**0.005**
Aquic Dystrogelepts	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Aquic Haploturbels	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Eutric Haplocryalfs	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Histic Cryaquepts	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Lithic Cryaquepts	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Lithic Cryohemists	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Lithic Cryorthents	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Lithic Haplocryepts	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Oxyaquic Argicryolls	0	1	0	0	1	0	0	0	0	0	0	0	0	1
Oxyaquic Dystrocryepts	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Oxyaquic Haplocryolls	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Oxyaquic Humicryepts	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Typic Argicryolls	0	1	0	1	0	0	0	0	0	0	0	0	0	1
Typic Cryaquents	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Typic Cryaquepts	0	0	0	0	0	0	0	0	0	0	2	0	0	1
Typic Cryorthents	0	0	0	1	1	0	0	0	1	1	0	0	2	1
Typic Dystrocryepts	0	0	0	2	1	0	0	0	3	0	1	0	0	1

Table 4.9. Ordtest p-values for geologic categorical variables based on the three dimensional NMDS ordination. Bolding indicates significance of variable at the $p < 0.1$ level (continued).

	DROC / CARU3	**HEUN / ASAL7**	**SAPL2 / CASC12**	**GERO2 / SIACS2**	**CAPH2 / SIPR**	**SAGLV / GERO2**	**SANI8 / POVI3**	**DECE - CAMI7 - CAMA9**	**ANLA3 - HIGRG**	**PIEN PIAL / CANA2**	**CANI2 - VEWO2**	**SETR / MECI3**	**SEFR3 / DRIN2**	**p-val**
Typic Gelaquents	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Typic Gelaquepts	0	0	0	0	0	0	0	0	0	0	2	0	0	1
Typic Haplocryepts	1	0	0	2	2	1	0	0	0	0	1	0	0	1
Typic Haplocryolls	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Typic Historthels	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Typic Humicryepts	0	0	0	4	0	1	0	0	2	1	0	2	0	1

Alpine Vegetation Association Descriptions

Cluster 1: *Dryas octopetala* var. *hookeriana* Association (n=2)

Vegetation. In this association, *Dryas octopetala* var. *hookeriana* dominates the shrub layer, and occurs in moderate abundance (10-20%). *Carex rupestris* is consistently present in the graminoid layer and occurs with trace to low abundance (.1-1%). Other commonly occurring graminoid species include *Festuca brachyphylla* and *Poa alpina*. Other commonly occurring forb species include: *Androsace chamaejasme, Antennaria umbrinella, Aquilegia jonesii, Castilleja pulchella, Pentaphylloides floribunda, Eriogonum flavum, Eritrichium howardii, Eritrichium nanum, Erigeron rydbergii, Geum rossii, Hedysarum sulphurescens, Llyodia serotina, Minuartia obtusiloba, Oxytropis sericea, Phlox diversifolia, Polygonum bistortoides, Potentilla diversifolia, Rhodiola integrifolia ssp. integrifolia*, *Saxifraga oppositifolia, Saxifraga rhomboidea, Senecio fremontii, Sedum lanceolatum, Silene acaulis* var. *subacaulescens* and *Zigadenus elegans*. *Salix glauca* var. *villosa* and *Salix reticulata* var. *nana* var. *nana* are occasionally occurring shrub species.

Environment. This association occurs at middle elevations in the alpine (2,750 m and 3,050 m) on north and northeast-facing slopes that receive very little precipitation and have the highest average daily temperature of clusters in the alpine sample analysis. Slope percent is generally low (3-13%). The local topography is simple linear. The soil temperature regime is cryic or gelic, the soil moisture regime is udic and the soil moisture

subclass is typic or aquic. Soils are moderately deep or deep and formed from either limestone or granite residuum. The soil particle size is loamy skeletal. Soils of this type were classified as Typic Haplocryepts and Aquic Haploturbels.

Other Classifications. Johnson and Billings (1962) described a *Dryas octopetala* mat community type occurring along the Beartooth Highway in the eastern portion of the Beartooth Mountains. Both Lesica (1993) and Bamberg (1961) identified a *Dryas octopetala/Carex rupestris* community type on Line Creek Plateau of the Beartooth Mountains that occurs on moist, north-facing gentle slopes, where *Silene acaulis* var. *subacaulescens, Geum rossii, Trifolium nanum, Calamagrostis purpurascens* and *Carex rupestris* are commonly associated species. Cooper et al. (1997) and Bamberg and Major (1968) each described a nearly identical community in their Montana study areas, as did Potkin and Munn (1987) and Wells (2008) for the Wind River Range of Wyoming.

Cluster 2: *Helianthela uniflora-*
Astragalus alpinus Association (n=2)

Vegetation. This is a subalpine meadow association dominated by *Helianthella uniflora*, which occurs with moderate to high abundance (30-50%). *Erigeron ursinus, Hydrophyllum capitatum, Lupinus argenteus, Pedicularis bracteosa* var. *paysoniana, Ranunculus eschscholtzii, Senecio crassulus, Collomia linearis, Delphinium glaucum, Agoseris glauca, Arabis drummondii, Chamerion angustifolium, Delphinium bicolor, Mertensia ciliata, Solidago multiradiata*, *Symphyotrichum foliaceum* var. *apricum,*

Valeriana occidentalis and *Astragalus alpinus* are commonly associated forbs. *Bromus emarginatus, Poa reflexa, Melica spectabilis* and *Trisetum spicatum* are commonly associated graminoid species. *Lupinus argenteus* occurs in low to moderately low abundance (4-15%). All other species occur with trace to low abundance (.1-5%).

Environment. This association occurs on the floor of U-shaped valleys at elevations between 2,600 m and 2,650 m on east and southwest-facing aspects with moderate (20-25%) slope. This association occurs at the lowest elevations and warmest sites in the alpine region and should probably be considered a mountainous, rather than alpine, association. Local topography is simple convex. The soil temperature regime is cryic, the soil moisture regime is udic and the soil moisture subclass is typic or oxyaquic. Soils are deep and formed from granitic colluvium. The soil particle size is fine loamy. Soils of this type were classified as Typic Argicryolls and Oxyaquic Argicryolls.

Other Classifications. Neither Johnson and Billings (1962) or Lesica (1993) described a similar community for the Beartooth Mountains. Cooper et al. (1997) did not describe a similar community type either, most likely because this is a subalpine rather than an alpine community type.

Cluster 3: *Salix planifolia/Carex scopulorum* Association (n=4)

Vegetation. *Salix planifolia* is well represented and dominates the shrub layer. *Carex scopulorum* is also well represented and generally dominates the graminoid layer. *Potentilla diversifolia* occurs consistently with trace to low abundance (.1-2%) in the forb

layer. Forb species extremely common to this habitat type, but not occurring on all sample plots, include: *Rhodiola integrifolia* ssp. *integrifolia, Caltha leptosepala, Pentaphylloides floribunda, Gentiana alpina, Geum rossii, Pedicularis groenlandica, Pedicularis oederi, Polygonum bistortoides, Polygonum viviparum, Saxifraga subapetala, Solidago multiradiata, Stellaria longipes, Trollius laxus* ssp. *albiflorus*. Graminoid species extremely common to this habitat type, but not occurring on all sample plots, include: *Calamagrostis canadensis, Deschampsia cespitosa, Festuca brachyphylla* and *Poa alpina. Betula gl*and*ulosa, Potentilla glandulosa* and *Salix reticulata* var. *nana* are commonly occurring shrub species.

Environment. This association occurs in large drainageways and on the floor of U and V-shaped valleys between 2,700 m and 3,000 m elevation on north and east-facing aspects with low relief (3-10% slope). This type occurs at the lowest elevations and on the warmest sites of the three willow-dominated types. Local topography can be complex patterned or simple linear. The soil temperature regime is cryic, the soil moisture regime is aquic or udic and the soil moisture subclass is generally typic and occasionally aquic. Soils are formed from granite alluvium and have a sandy skeletal or loamy skeletal soil particle size. Soils were classified as Typic Cryaquents, Lithic Cryohemists or Histic wetland soils.

Other Classifications. Cooper et al. (1997) identified a *Sailx planifolia/Carex scopulorum* community type that occurs on stream terraces and seep areas in the Beaverhead National Forest. Their type is dominated by *Salix planifolia* in the shrub

layer, *Carex scopulorum* and *Deschampsia cespitosa* in the graminoid layer and *Caltha leptosepala, Sedum rhodanthum* and *Senecio cymbalarioides* in the forb layer. Johnson and Billings (1962) described a *Salix planifolia* dominated bog community (*Salix* thicket) that is similar in general composition and topographic position in the Beartooth Mountains. Lesica (1993) described a *Salix planifolia/Carex paysonis* type on Line Creek Plateau of the Beartooth Mountains. The major difference between the type identified in this analysis and the *Salix planifolia* type identified in Lesica's analysis is the co-dominance of *Carex scopulorum* rather than *Carex paysonis*. Potkin and Munn (1987) also described a similar *Salix planifolia/Carex scopulorum* type in the Wind River Range of Wyoming.

Cluster 4: *Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens* Association (n=11)

Vegetation. This association is dominated by *Geum rossii* in the forb layer and *Carex rupestris* in the graminoid layer. *Geum rossii* occurs with low to moderate abundance (3-40%). *Carex rupestris* occurs with abundance of up to 15%. *Silene acaulis* var. *subacaulescens, Geum rossii, Minuartia obtusiloba, Polygonum bistortoides, Phlox pulvinata, Potentilla diversifolia, Sedum lanceolatum, Artemisia scopulorum, Bupleurum americanum, Eritrichium nanum, Mertensia alpina, Packera cana, Smelowskia calycina* and *Trifolium nanum* are commonly associated forb species. *Silene acaulis* var. *subacaulescens, Potentilla diversifolia* and *Trifolium nanum* occurred with abundance of up to 10%. *Lupinus argenteus* occurs with abundance of up to 15%. All other forb species occurred with trace to low abundance (.1-5%). Other commonly

associated graminoid species include: *Festuca brachyphylla, Luzula spicata* and *Trisetum spicatum*. *Trisetum spicatum* occurs with abundance of up to 8%. There was one occurrence of the shrub species *Arctostaphylos uva-ursi* with an abundance of 40%.

Environment. This cushion plant-dominated association can be viewed as an alpine desert association. It occurs on high elevation (2,750 m to 3,450 m) shoulder and summit sites on the plateau where precipitation is most commonly received as snow and then blown free, exposing the site to the highest annual amounts of direct solar insolation. The soil temperature regime is cryic, the soil moisture regime is udic and the soil moisture subclass is typic. Soils range from shallow to deep and are formed from granite colluvium, residuum and till. The soil particle size is generally loamy skeletal and occasionally sandy skeletal or loamy. Soils were classified as Typic Humicryepts, Typic Haplocryepts, Typic Cryorthents, Typic Dystrocryepts, Typic Argicryolls and Lithic Cryorthents.

Other Classifications. Lesica (1993) described a similar *Carex elynoides* community type reported to occur on gravelly, poorly developed soils of upper slopes, ridge crests and other wind-exposed sites. *Geum rossii, Carex rupestris, Kobresia bellardii* and *Poa rupicola* are common dominants of his *Carex elynoides* type. *Minuartia obtusiloba, Silene acaulis* var. *subacaulescens, Trifolium parryi, Luzula spicata, Festuca ovina* and *Lupinus argenteus* were other commonly associated species. Similar turf communities dominated by either *Carex rupestris* or *Carex elynoides* have been described for southwest Montana (Cooper et al., 1997). Johnson and Billings

(1962) referred to this vegetation as the cushion plant community in *Geum* turf vegetation. Bamberg (1961) identified a fellfield community and a dry *Carex* type that likely represent drier variations of the *Geum* turf type. A similar community was also described from the Wind River Range in Wyoming (Potkin and Munn, 1987; Wells, 2008).

Cluster 5: *Carex phaeochephala/Sibbaldia procumbens* Association (n=5)

Vegetation. This is a relatively common graminoid-dominated turf association. *Carex phaeochephala* is the dominant graminoid and only indicator species for this association. *Carex phaeochephala* generally occurs with > 10% abundance. This association is not depauperate. The most frequently associated forbs include: *Erigeron simplex, Hieracium triste* var. *gracile, Minuartia obtusiloba, Oreostemma alpigenum* var. *haydenii* and *Sibbaldia procumbens*, all of which occur in low abundance. *Juncus* spp. (*drummondii* and/or *parryi*) are frequently present in low to moderate abundance. Common, but less consistent forb species include: *Achillea millefolium, Agoseris glauca, Eremogone congesta, Polygonum bistortoides, Potentilla diversifolia, Sedum lanceolatum, Antennaria lanata* and *Lewisia pygmaea*. Common, but less consistent graminoid species include: *Deschampsia cespitosa, Festuca brachyphylla, Carex paysonis, Carex scopulorum, Juncus parryi, Luzula spicata* and *Trisetum spicatum*.

Environment. The *Carex phaeochephala/Sibbaldia procumbens* association occurs on moderately cold and moist sites that receive a high degree of direct annual

solar insolation at elevations between 2,790 m and 3,200 m. Ground and recessional moraines, knobs, mountain slopes and plateaus are landforms commonly associated with the type. The soil temperature regime is cryic, the soil moisture regime is udic and the soil moisture subclass is typic. Soils are deep and generally formed from granite till and colluvium. One abnormally rich and productive sample included in this type occurred on soils derived from serpentine alluvium. This sample had an oxyaquic soil moisture subclass and the soil was classified as an Oxyaquic Argicryoll. Either *Carex phaeochephala* was misidentified or some factor, such as the presence of serpentine soils, is causing increased species abundance and richness. All other soils were classified as Typic

Other Classifications. The *Carex scirpoidea/Potentilla diversifolia* community type identified by Cooper et al. (1997) is somewhat similar to this association. Similarities include the presence and occasional dominance of *Carex phaeochephala*. Forbs consistently present in both types include *Erigeron simplex, Polygonum bistortoides* and *Potentilla diversifolia*. However, the consistent presence of *Eremegone congesta* and absence of *Carex scirpoidea* suggests that this type is drier than the *Carex scirpoidea/Potentilla diversifolia* identified by Cooper et al. (1997). Cooper et al. (1997) associated the *Carex scirpoidea/Potentilla diversifolia* community type with sites that are not as wind-impacted as the *Carex elynoides* type. They hypothesized that these sites "are turf because they occur in windswept positions (little winter snow accumulation); but the sites are also moist because they are in runoff collecting positions or on slopes with low solar insolation (north-facing) (Cooper et al., 1997)." Neither Lesica (1990) nor

Johnson and Billings (1962) described a similar alpine community type for the Beartooth Mountains.

Cluster 6: *Salix glauca* var. *villosa/*
Geum rossii var. *turbinatum* Association (n=3)

Vegetation. This association is dominated by *Salix glauca* in the shrub layer. *Artemisia scopulorum, Geum rossii, Minuartia obtusiloba, Polygonum bistortoides, Potentilla diversifolia* and *Sedum lanceolatum* are all indicator species and are consistently present in the forb layer. *Festuca brachyphylla* is consistently present in the graminoid layer. *Dodecatheon pulchellum, Gentiana algida, Lloydia serotina, Pedicularis oederi, Penstemon procerus, Saxifraga rhomboidea,* and *Tephroseris lindstroemii* are common, but slightly less frequent, in the forb layer. *Carex scirpoidea, Deschampsia cespitosa, Luzula spicata, Phleum alpinum* and *Trisetum spicatum* are common, but slightly less frequent in the graminoid layer. *Salix reticulata* var. *nana* var. *nana* is common, but slightly less frequent, in the shrub layer.

Environment. This association occurs on cool, concave, moderately sloped (15 to 30%) sites on the plateau between 3,050 and 3,150 m elevation. The soil temperature regime is cryic or gelic, the soil moisture regime is udic or aquic and the soil moisture subclass is typic. Soils are deep and are formed from granite colluvium, alluvium and till. The soil particle size is loamy skeletal or sandy skeletal. Soils were classified as Typic Humicryepts, Typic Haplocryepts and Typic Gelaquents.

Other Classifications. Lesica (1993) identified a *Salix glauca/Deschampsia cespitosa* community type that occurs on broad, gently concave, cool upper slopes. His community is dominated by dense thickets of *Salix glauca* with lesser amounts of *Salix planifolia*. Common graminoid species of his type include *Deschampsia cespitosa, Carex paysonis, Carex scirpoidea* and *Luzula spicata* and common forbs species include *Lupinus argenteus, Geum rossii, Artemisia scopulorum* and *Solidago multiradiata.* Cooper et al. (1997) classified and described a *Salix glauca* community type that occurs adjacent to the *Carex elynoides* turf community and moist slope association on calcareous parent materials in southwest Montana. No other shrubs were present in their type. The graminoids, *Poa alpinum* and *Agropyron caninum,* are present but have low cover. *Oreostemma alpigenum* var. *haydenii, Hedysarum sulphurescens, Senecio crassulus* and *Synthyris pinnatifida* are commonly associated forb species. This type is also likely to be broadly lumped with the *Salix* thicket type described by Johnson and Billings (1962). Potkin and Munn (1987) described a similar *Salix glauca/Deschampsia* type for the Wind River Range of Wyoming.

Cluster 7: *Salix reticulata* var. *nana/*
Polygonum viviparum Association (n=2)

Vegetation. This is a minor alpine association where *Salix reticulata* var. *nana* is well represented and more abundant than *Salix planifolia* which is often present in low abundance. *Carex scopulorum* (10-20%) occurs with higher abundance than other graminoids. *Pedicularis oenothera, Polygonum viviparum, Potentilla nivea, Gentiana algida* and *Rhodanthum integrifolium* are consistently occurring forb species. *Polygonum*

viviparum occurs with the greatest abundance. *Carex microphylla*, *Festuca brachyphylla* and *Luzula spicata* are consistently occurring graminoid species. *Eriophorum callitrix* was present on one sample with 4% cover.

Environment. This association is similar to the *Salix planifolia/Carex scopulorum* association, but occurs at higher elevations (~3,200 m) and at the head of alpine plateau drainageways and glacial cirque basins. This type was only observed in the northeast portion of the study area near Hellroaring Plateau. The soil temperature regime is Gelic or Cryic, the soil moisture regime is udic and the soil moisture subclass is oxyaquic or aquic. Soils are deep and formed from granite till and alluvium. One soil was classified as a Histic wetland soil and the other was classified as a Typic Historthel.

Other Classifications. Cooper and Lesica (1997) identified a *Salix reticulata* var. *nana/Caltha leptosepala* community type that carpets active solifluction slopes possessing a soil mantle on northerly aspects that are sub-irrigated from late-persisting snowfields above. While the environments are similar, the *Salix reticulata* var. *nana* var. *nana /Polygonum viviparum* association identified in this analysis has different characteristic species. Cooper and Lesica's (1997) type is characterized by dense *Salix reticulata* var. *nana* cover under which a sparse graminoid canopy consisting primarily of *Carex haydenii*, *Carex nova, Carex scirpoidea, Deschampsia cespitosa, Luzula spicata*, and *Poa alpina* is present. *Caltha leptosepala* and *Silene acaulis* var. *subacaulescens* are forbs commonly associated with their type. The major difference between their type and the *Salix reticulata* var. *nana* var. *nana/Polygonum viviparum* association identified in

this analysis is the presence and common dominance of *Caltha leptosepala* in their type. *Polygonum viviparum, Pedicularis oenothera, Potentilla nivea* and *Gentiana algida,* rather, are the dominant and characteristic forb species of the *Salix reticulata* var. *nana* var. *nana/Polygonum viviparum* type identified in this analysis.

Cluster 8: *Deschampsia cespitosa-Carex microptera –Carex macloviana* Association (n=3)

Vegetation. This association is dominated by *Deschampsia cespitosa* with moderate to high abundance (30-60%) in the graminoid layer and by *Potentilla diversifolia* with trace to low abundance (1-7%) in the forb layer. Other commonly occurring graminoid species include: *Carex macloviana, Carex microphylla, Carex paysonis, Carex scopulorum, Festuca brachyphylla, Luzula spicata, Poa alpina* and *Trisetum spicatum*. Common forb species include: *Geum rossii, Polygonum bistortoides, Polygonum viviparum, Solidago multiradiata, Achillea millefolium, Agoseris glauca, Agoseris lackschewitzii.* Most commonly associated species occur in trace to low abundance (.1-2%). *Carex microphylla* had an abundance of 15% on one sample plot, *Carex paysonis* ranged in abundance from 3 to 10% and *Geum rossii* had 15% cover on one sample plot.

Environment. This association occurs on cirque headwalls or toeslopes of U-shaped valleys between 2,900 m and 3,200 m on north, northeast and southeast-facing sites with 10 to 50% slope. Sites supporting this association are cold and wet. The local topography is complex undulating, simple convex or complex patterned. The soil

temperature regime is cryic, the soil moisture regime is udic and the soil moisture subclass is oxyaquic or aquic. Soils are deep and formed from granite colluvium, alluvium and till. The soil particle size is loamy skeletal or loamy. Soils of this type were classified as Oxyaquic Haplocryolls, Oxyaquic Humicryepts and Aquic Dystrogelepts.

Other Classifications. Lesica (1993) described a *Deschampsia cespitosa* type for Line Creek Plateau in the Beartooth Mountains, which is very similar to the association identified in this analysis. He describes the community as occurring on subirrigated stream terraces near timberline. His type was also characterized by the dominance of *Deschampsia cespitosa* and presence of *Carex macloviana* in the graminoid layer and presence of *Caltha leptosepala, Potentilla diversifolia* and *Polygonum bistortoides* in the forb layer. Lesica (1993) suggested the occurrence of a drier *Deschampsia cespitosa/Geum rossii* association in the Beartooth Mountain Range. Cooper et al. (1997) described a *Deschampsia cespitosa/Potentilla diversifolia* community type that is similar to the *Deschampsia cespitosa-Carex microptera-Carex macloviana* association identified in this analysis. Their community type occurred from above treeline to over 3,300 m in the drier mountain ranges of the Beaverhead National Forest on cool slopes, valley bottoms and depressions where soils are deep and remain moist until at least mid-summer. Old erosion terraces and slopes showing evidence of solifluction are commonly associated site characteristics. Sites are protected by snow cover throughout the winter and fed by upslope snow release until mid or late summer. Mueggler and Stewart (1980) described a high elevation *Deschampsia cespitosa* type, similar to the *Deschampsia cespitosa-Carex microptera-Carex macloviana* association identified in this analysis, but

drier and warmer than the alpine *Deschampsia cespitosa* community type described by Cooper et al. (1992). Finally, Potkin and Munn (1987) identified a *Deschampsia cespitosa* for the Wind River Range of Wyoming that is also similar.

Cluster 9: *Antennaria lanata-Hieracium triste* var. *gracile* Association (n=7)

Vegetation. *Antennaria lanata* dominates the forb layer, *Hieracium triste* var. *gracile* is consistently present, though often in low abundance and *Sibbaldia procumbens, Oreostemma alpigenum, Polygonum bistortoides* and *Claytonia lanceolata* are also present to well represented. *Vaccinium scoparium* can become abundant on moist sites of this type. Other forb species that are common to the habitat type include: *Arnica latifolia, Potentilla diversifolia* and *Erigeron peregrinus. Carex paysonis* and *Juncus parryi* are common in the graminoid layer, along with *Carex phaeochephala, Deschampsia cespitosa, Juncus parryi, Luzula spicata, Poa cusickii, Trisetum spicatum* and *Luzula parviflora*.

Environment. This association occurs between 2,700 m and 3,070 m elevation on snowbed sites that are locally convex or linear and remain saturated for less of the growing season than the *Carex nigricans/Veronica wormskjoldii* association. U-shaped valleys are the most commonly associated landform, followed by knobs and glacial valley walls. The soil temperature regime is cryic, the soil moisture regime is udic and the soil moisture subclass is typic. Soils are either moderately deep or deep and formed from granitic colluvium and till and volcanic residuum. Soil particle size is either sandy

skeletal or loamy skeletal. Soils were classified as Typic Humicryepts, Typic Dystrocryepts, Typic Haplocryolls and Typic Cryorthents.

Other Classifications. Cooper et al. (1997) identified a *Juncus drummondii/Antennaria lanata* community type. It was characterized by much higher graminoid abundance and slightly higher forb abundance. The two communities share the following associated species: *Carex paysonis, Antennaria lanata, Erigeron peregrinus, Arnica latifolia* and *Vaccinium scoparium. Juncus drummondii* and *Poa fendleriana* were also associated in Cooper et al.'s (1997) type, while *Juncus parryi* and *Poa cusickii* are more common in the *Antennaria lanata/Hieracium triste* var. *gracile* association identified in this cluster analysis.

Lesica (1993) also identified a *Juncus drummondii/Antennaria lanata* community type that occurs on late snowmelt areas on lee slopes and in shallow accumulation areas. It is dominated by *Antennaria lanata, Carex paysonis* and *Juncus drummondii*. Other common species include: *Deschampsia cespitosa, Carex scirpoidea, Luzula spicata, Sibbaldia procumbens* and *Antennaria umbrinella*. Lesica (1990) noted that sites identified as the *Juncus drummondii/Antennaria lanata* community type were usually dominated by either *Antennaria lanata* or *Juncus drummondii* but generally not a mixture of the two. Johnson and Billings (1962) did not identify and describe a similar habitat. Types similar to the *Juncus drummondii/Antennaria lanata* association were also identified in the Madison Range of southwest Montana (Cooper and Lesica, 1992) and the Wind River Range of Wyoming (Potkin and Munn, 1987).

Cluster 10: *Picea engelmannii-Pinus albicaulis/ Carex nardina* Association (n=4)

Vegetation. In this association, *Abies lasiocarpa, Picea engelmannii* and *Pinus albicaulis* are extremely stunted and occur in very low abundance (< 1%). *Carex phaeochephala*, *Luzula spicata* and *Carex scopulorum* occur in low abundance and are the most common graminoid species. *Antennaria lanata, Artemisia scopulorum, Draba incerta, Erigeron simplex, Geum rossii, Llyodia serotina, Mertensia alpina, Minuartia obtusiloba, Oreostemma alpigenum, Polygonum bistortoides, Potentilla diversifolia, Ranunculus eschscholtzii, Sedum lanceolatum, Sibbaldia procumbens, Silene acaulis* var. *subacaulescens* and *Smelowskia calycina* are the most commonly associated forbs, generally occurring with trace to low abundance (.1-4%). *Carex nardina* is an indicator species for this cluster because it occurs only in this cluster. *Festuca brachyphylla, Juncus drummondii, Poa alpina, Poa secunda* and *Trisetum spicatum* are commonly associated graminoid species. All species in this association occur in abundances of less than 5%. Compositionally, this association contains wet site adapted species characteristic of the *Antennaria lanata/Hieracium triste* var. *gracile* association, as well as, species characteristic of sites with minimal soil development and extreme wind exposure, such as those represented in the *Senecio fremontii/Draba incerta* association and the *Carex phaeochephala/Sibbaldia procumbens* association identified here. This suggests that sites remain moist, at least in patches, throughout much of the growing seasons despite extreme wind exposure, erosion and minimal soil development.

Environment. This is an alpine fellfield association that generally occurs in cirques, U-shaped valleys and on mountain slopes near upper timberline. This association occurs on less exposed, though not always lee, aspects of wind-blasted slopes between 3,000 to 3,200 m elevation on northeast and west-facing slopes with 20-60% slope. Local topography can be complex broken or simple linear. Sorting was observed on several sites. The soil temperature regime is cryic, the soil moisture regime is udic and the soil moisture subclass is typic. Soil depth ranges from shallow to deep. Soils are formed from granite and monzonite colluvium and residuum. Soil particle size is either sandy skeletal or loamy skeletal. Soils were classified as Typic Humicryepts, Lithic Haplocryepts and Eutric Haplocryalfs.

Other Classifications. Cooper et al. (1997) described a dry slope community type characterized by low total vegetative cover (<20%) that is environmentally similar to the 'dry fellfield' of Colorado's Front Range, which is described as having discontinuous or no winter snow cover, a growing season exceeding 3 months, windswept exposure and often severe soil erosion. The less cushion-plant dominated the dry slope community, the less windswept they presumed the site to be. Based on this logic, this association should occur on sites with more wind exposure than the *Senecio fremontii/Draba incerta* association combined with more moisture retention and slightly less wind exposure than the *Geum rossii/Silene acaulis* var. *subacaulescens* cushion association. Moisture retention appears to be a factor of either aspect or the presence of stones and boulders on the soil surface that catch and hold snow. This association and the *Senecio fremontii/Draba incerta* association, may represent varying aspects of the drier, less

developed *Carex elynoides* type described by Lesica (1993) and *Geum* turf community described by Johnson and Billings (1962) for the Beartooth Mountains.

Cluster 11: *Carex nigricans/Veronica wormskjoldii* Association (n=9)

Vegetation. *Carex nigricans* is the dominant graminoid species and *Veronica wormskjoldii* is the most consistently associated forb species, though it often occurs in low abundance. *Carex nigricans* generally occurs in moderate to high abundance (7-90%). Other commonly occurring forb species, though each is not present in every sample, include: *Hieracium triste* var. *gracile, Antennaria lanata, Senecio triangularis, Erigeron peregrinus, Caltha leptosepala, Packera subnuda, Pedicularis groenlandica, Claytonia lanceolata, Polygonum bistortoides, Castilleja rhexiifolia, Kalmia microphylla* and *Ranunculus eschscholtzii*. *Caltha leptosepala* is well represented or has moderate abundance (5-30%), *Antennaria lanata* is occasionally well represented (.1-8%) and *Kalmia microphylla* occurred once with an abundance of 20% but only had trace to low abundance on other sample plots in this type. Other slightly less consistently associated graminoid species include: *Deschampsia cespitosa, Phleum alpinum, Carex paysonis, Juncus drummondii, Poa cusickii* and *Juncus mertensianus*. *Poa cusickii* and *Poa cusickii* var. *epilis* both occur in this type. *Poa cusickii* occurs in trace to low abundance and *Poa cusickii* var. *epilis* occurs in moderate abundance (10-25%). All other commonly occurring shrub, forb and graminoid species occur with trace to low abundance (.1-6%).

Environment. This is a common association, generally occurring where snow persists and/or soils are saturated the longest between 2,900 and 3,050 m elevation on a variety of aspects with slopes between 0 and 40%. Local topography is highly variable, but never convex. The soil temperature regime is usually cryic but can be gelic, the soil moisture regime can be either aquic or udic and the soil moisture subclass is usually typic but occasionally oxyaquic. Soils are deep and the soil particle size is generally loamy skeletal, but can also be sandy skeletal or loamy. Soils were classified as Typic Cryaquepts, Histic Cryaquepts, Typic Haplocryepts, Oxyaquic Dystrocryepts, Typic Gelaquepts, Typic Dystrocryepts and Lithic Cryaquepts.

Other Classifications. Cooper et al. (1997) identified a *Carex nigricans* community type that was found between 2,900 m and 3,050 m in the Anaconda, Madison, Pioneer and Tobacco Root Mountains, the wettest ranges in the Beaverhead National Forest study area. Their *Carex nigricans* community "occurred on nearly level sites at the base of slopes and in swales and valley bottoms where blowing snow is deposited and meltoff does not occur until well into the growing season… [on] sites with perennially moist or saturated soil and with the shortest snow-free season of any snowbed community type" (Cooper et al., 1997). The *Carex nigricans/Veronica wormskjoldii* association identified in this cluster analysis is very similar to Cooper et al.'s type. They occupy similar environments and share a large number of associated species, including: *Carex nigricans*, *Juncus drummundiana, Carex paysonis, Phleum alpinum, Caltha leptosepala, Antennaria lanata* and *Erigeron peregrinus*. Cooper et al. (1997) indicate that the *Carex nigricans* community type appears to be more common in wetter ranges,

such as in the North Cascades and Canadian Rockies. Neither Johnson and Billings (1962) nor Lesica (1993) identified a similar type for the Beartooth Mountains.

Cluster 12: *Senecio triangularis-*
Mertensia ciliata Association (n=2)

Vegetation. This is a minor association characterized by moderately high abundance (30-70%) of *Senecio triangularis* and the presence and occasional high abundance of *Mertensia ciliata* (1-70%). *Arnica latifolia, Epilobium hornemannii, Erigeron peregrinus, Ranunculus eschscholtzii* and *Veronica wormskjoldii* are also common in trace to low abundance in the forb layer and *Carex nigricans, Carex spectabilis, Juncus drummondii, Juncus mertensianus, Poa cusickii* and *Poa reflexa* are common in trace to low abundance in the graminoid layer. Forb species less consistently associated with the habitat type include: *Castilleja rhexiifolia, Chamerion angustifolium, Claytonia lanceolata, Dodecatheon pulchellum, Heracleum maximum, Hieracium gracile* var. *gracile, Mimulus lewisii, Polygonum bistortoides, Saxifraga occidentalis, Stellaria calycantha, Stellaria umbellata* and *Symphyotrichum foliaceum*. All associated forb species occur in trace to low abundance (.1-2%). Less consistently associated graminoid species include: *Agrostis variabilis, Carex microphylla, Deschampsia cespitosa, Elymus canadensis, Luzula spicata* and *Phleum alpinum*.

Environment. This association occurs along moderately steep (30-40% slope) and narrow seep drainageways between 2,940 m and 3,050 m elevation. The soil temperature regime is cryic, the soil moisture regime is udic and the soil moisture subclass is typic.

The soils are deep and formed from granitic colluvium. The soil particle size is loamy skeletal. Soils were classified as Typic humicryepts.

Other Classifications. Cooper et al. (1997) did not identify a similar community type from the Beaverhead National Forest and neither Lesica (1990) nor Johnson and Billings (1962) described a similar association in their Beartooth Mountain studies.

Cluster 13: *Senecio fremontii-Draba incerta* Association (n=2)

Vegetation. This is a depauperate association with < 5% total cover. *Senecio fremontii* and *Draba incerta* are the dominant forbs. *Carex phaeochephala, Trisetum spicatum* and *Festuca brachyphylla* are the dominant graminoids. Other commonly associated graminoid species include: *Agrostis humilis, Deschampsia cespitosa, Luzula spicata, Poa lettermanii* and *Poa vivipara*. Other commonly associated forb species include: *Eremegone congesta, Minuartia obtusiloba, Oxyria digyna* and *Saxifraga bronchialis*.

Environment. This association occurs at the highest elevations (> 3,150 m) on extremely cold, north and northwest-facing sites that also receive the highest total annual precipitation. However, the association occurs on steep (35-60%) talus slopes with > 80% cobble and stone-sized rock fragments and minimal soil development. The resultant environment is characterized by a depauperate mix of moisture-tolerant species and those more adapted to the harsh, wind-exposed climate of the plateau. Local topography is linear horizontally and convex vertically and simple linear in general. The soil

temperature regime is cryic, the soil moisture regime is udic and the soil moisture subclass is typic. The soil particle size is sandy skeletal and soils were classified as Typic Cryorthents.

Other Classifications. Cooper et al. (1997) describe a dry slope community type characterized by low total vegetative cover (<20%). In their study, *Agropyron scribneri* was the only species with higher constancy and average cover than other species. They note that this association appears to be associated with both gravelly, unstable slopes and stable, calcareous habitats. They hypothesized that these open, early seral stands occur in most mountain ranges but end up in the 'no-fit' category and go unreported in the literature. They also speculate that the dry slopes community type is environmentally similar to the 'dry fellfield' of Colorado's Front Range, described as having discontinuous or no winter snow cover, a growing season exceeding 3 months, windswept exposures, and often severe soil erosion. Diminished cushion plant dominance in the dry slope community may indicate that sites are slightly less windswept than sites with greater cushion plant dominance (Cooper et al., 1997). Neither Lesica (1990) nor Johnson and Billings (1962) described a similar community type, though it seems to be a depauperate turf or cushion plant association.

Discussion

Plant associations of the alpine region of the Custer National Forest portion of the Beartooth Mountains, referred to here as the Beartooth Mountains study area, appear to

be well classified using a 13-cluster BESTOPT model. Of the 13 associations identified in this analysis, 7 represented community types previously described by Lesica (1993) for Line Creek Plateau in the Beartooth Mountains. Each of the 5 broad associations previously described for the Beartooth Mountains by Johnson and Billings (1962) were also represented.

In addition to sharing compositional and environmental distribution attributes with vegetation associations previously described for the Beartooth Plateau (Lesica, 1993; Johnson and Billings, 1962), the associations identified in this analysis also share compositional similarities with community types identified and described for the alpine ranges of the Beaverhead National Forest in southwestern Montana (Cooper et al., 1997), the Big Snowy, Lewis and Flint Creek ranges of Montana (Bamberg and Major, 1968) and the Wind River Range of northwestern Wyoming (Potkin and Munn, 1987). The *Helianthela uniflora-Astragalus alpinus* association, the *Senecio triangularis-Mertensia ciliata* association and the *Senecio fremontii-Draba incerta* association are minor associations that were not previously or clearly described in other alpine studies.

Lesica (1993) described a *Festuca idahoensis/Geum rossii* type that was not described in this analysis. Some component of this type may be included in the *Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens* association. The *Carex scirpoidea/Geum rossii* type identified by Lesica (1993) appears to be most similar to the *Carex phaeochephala/Sibbaldia procumbens* association identified in this analysis. Lesica (1993) also described the following community types: *Dryas octopetala* var. *hookeriana/Carex rupestris, Juncus drummondii/Antennaria lanata, Salix glauca* var.

villosa/Deschampsia cespitosa, Salix planifolia/Carex paysonis and *Deschampsia cespitosa/Caltha leptosepala*, each of which was clearly represented by an association identified in this analysis.

Johnson and Billings (1962) identified the following alpine associations on the Beartooth Plateau: *Geum* turf, *Deschampsia* meadow, *Dryas octopetala* mats, *Carex scopulorum* bog vegetation and *Salix* thicket vegetation. Billings and Johnson (1962) proposed that *Geum* turf, *Deschampsia* meadow, *Carex scopulorum* bog vegetation and *Salix* thicket intergrade along environmental gradients and that each type is associated with characteristic topographic sites. *Geum* turf is associated with summits, ridges, and upper slopes. *Deschampsia* meadow is associated with lower slopes and depressions. *Carex* bogs are associated with basins and water-saturated sites. *Salix* thickets occur in drainage channels of the low alpine zone. *Dryas octopetala* mats are uncommon and occur on extremely dry, extremely wind-exposed sites.

The broad trends of vegetation distribution across environmental gradients described by Johnson and Billings (1962) for the eastern portion of the Beartooth Mountains were observed to persist across the central and western portions of the Custer National Forest portion of the Beartooth Mountain alpine region. However, it was difficult to explain the distribution of associations across environmental variables due to the amount of correlation between variables and the significance of so many variables at once. All of the continuous variables, except Northing coordinate and annual solar exposure (SOLAR) were found to be significantly related to cluster, or association, membership.

The *Dryas octopetala/Carex rupestris* association occurs at middle elevations in the alpine (2,750 m and 3,050 m) on north and northeast-facing gentle slopes that receive very little precipitation and have the highest average daily temperature of clusters in the alpine sample analysis. The *Dryas octopetala/Carex rupestris* association is a particularly warm and dry alpine association.

The *Helianthela uniflora-Astragalus alpinus* association is a subalpine meadow association which occurs on the floor of U-shaped valleys at elevations between 2,600 m and 2,650 m on east and southwest-facing aspects with moderate slope. This association occurs at the lowest elevations and warmest sites of samples included in the alpine association analysis and should probably be considered a mountainous, rather than alpine, association.

Three alpine *Salix*-dominated associations were described and, in descending elevational order, include: the *Salix reticulata* var. *nana/Polygonum viviparum* association, the *Salix glauca* var. *villosa/Geum rossii var. turbinatum* association and the *Salix planifolia/Carex scopulorum* association. The *Salix reticulata* var. *nana/Polygonum viviparum* association is a minor alpine association of the Beartooth Mountains. This association is similar to the *Salix planifolia/Carex scopulorum* association, but occurs at higher elevations (~3,200 m) at the head of alpine plateau drainageways and glacial cirque basins. *Salix reticulata* var. *nana* is well represented and more abundant than *Salix planifolia* which is often present in low abundance. The *Salix reticulata* var. *nana/Polygonum viviparum* association receives relatively low amounts of total annual precipitation but due to its topographic occurrence in drainageways, has

moderate relative effective annual precipitation. The *Salix glauca* var. *villosa/Geum rossii var. turbinatum* association occurs on cool, concave, moderately sloped sites on the plateau between 3,050 and 3,150 m elevation. The *Salix planifolia/Carex scopulorum* association occurs in large drainageways and on the floor of U and V-shaped valleys between 2,700 m and 3,000 m elevation on north and east-facing aspects with low relief (3-10% slope). This type occurs on the warmest sites of the three willow-dominated types.

The *Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens* association is one of the driest alpine associations in the Beartooth Mountains study area, despite its occurrence at relatively high elevations, due to its position on shoulders and summits of the plateau where precipitation is primarily received as snow and blown free, leaving sites exposed to increased solar radiation. Modeled values of total annual precipitation and relative effective annual precipitation are extremely low for sites included in this association considering the general positive correlation of both variables with elevation.

The *Carex phaeochephala/Sibbaldia procumbens* association is a relatively common graminoid-dominated turf association in the Beartooth Mountains study area that occurs on moderately cold and moist sites that receive a high amount of direct annual solar exposure, such as ground and recessional moraines, knobs, mountain slopes and the flat plateau. The *Carex scirpoidea/Potentilla diversifolia* community type identified by Cooper et al. (1997) is somewhat similar to this association. Similarities include the presence and occasional dominance of *Carex phaeochephala* and presence of *Erigeron simplex, Polygonum bistortoides* and *Potentilla diversifolia*. However, the consistent

presence of *Eremegone congesta* and absence of *Carex scirpoidea* suggests that the *Carex phaeochephala/Sibbaldia procumbens* association is drier than the *Carex scirpoidea/Potentilla diversifolia* identified by Cooper et al. (1997). These sites are likely turf because they occur in somewhat windswept position but are also moist because they occur in runoff collecting positions or, at least in one instance, on slopes with low solar exposure.

The *Picea engelmannii-Pinus albicaulis/Carex nardina association* occurs in cirques, U-shaped valleys and on mountain slopes near upper timberline. This association occurs on less exposed, though not always lee, northeast and west-facing exposures of wind-blasted slopes. Soil sorting was observed on several sites. In this association, *Abies lasiocarpa, Picea engelmannii* and *Pinus albicaulis* are extremely stunted and occur in very low abundance (< 1%). All species in this association occur in abundances of less than 5%. Compositionally, this association contains wet site adapted species characteristic of the *Antennaria lanata/Hieracium triste* var. *gracile* association, as well as, species characteristic of sites with minimal soil development and extreme wind exposure, such as those represented in the *Senecio fremontii/Draba incerta* association and the *Carex phaeochephala/Sibbaldia procumbens* association identified here. This suggests that sites remain moist, at least in patches, throughout much of the growing seasons despite extreme wind exposure, soil erosion and minimal soil development. Moisture retention appears to be a factor of either aspect or the presence of stones and boulders on the soil surface that catch and hold snow. This association and the *Senecio fremontii/Draba incerta* association, may represent varying aspects of the

drier, less developed *Carex elynoides* type described by Lesica (1993) and *Geum* turf community described by Johnson and Billings (1962) for the Beartooth Mountains.

The *Carex nigricans/Veronica wormskjoldii, Antennaria lanata-Hieracium triste* var. *gracile*, and *Deschampsia cespitosa-Carex microptera–Carex macloviana* associations all occur in snowmelt positions and are listed in order of decreasing saturation. The *Carex nigricans/Veronica wormskjoldii* association is a common association in the Beartooth Mountains, occurring where snow persists and/or soils are saturated the longest between 2,900 and 3,050 m elevation. Lake margins and toeslopes below late persisting snowpack are commonly associated topographic features. The *Antennaria lanata-Hieracium triste* var. *gracile* association occurs on snowbed sites that remain saturated for less of the growing season than the *Carex nigricans/Veronica wormskjoldii* association. U-shaped valleys are the most commonly associated landform, followed by knobs and glacial valley walls. The *Deschampsia cespitosa-Carex microptera–Carex macloviana* association occurs on cirque headwalls and toeslopes of U-shaped valleys between 2,900 m and 3,200 m on north, northeast and southeast-facing sites with 10 to 50% slope. Sites supporting this association are cold and wet.

The *Senecio triangularis-Mertensia ciliata* association is a minor, forb-dominated association that occurs along moderately steep and narrow seep drainageways between 2,940 m and 3,050 m elevation.

The *Senecio fremontii-Draba incerta* association is a depauperate association that occurs at the highest elevations (> 3,150 m) on extremely cold, steep and talus-dominated northerly exposures. This association occurs on sites receiving the highest total annual

precipitation and having the highest relative effective annual precipitation, but is characterized by drier-site alpine species. These sites are likely to be windswept and have discontinuous winter snow cover. Diminished cushion plant dominance may indicate that sites are slightly less windswept than sites with greater cushion plant dominance, such as the *Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens* and *Picea engelmannii-Pinus albicaulis/Carex nardina* associations. Increased erosion due to steep slopes and wind-deflation and minimal soil development are likely the causes of the unusually depauperate vegetation cover observed in this association.

Conclusion

The goal of this chapter was to classify and describe the alpine plant associations of the Beartooth Mountains study area, located in south central Montana, using cluster analysis and to compare newly derived alpine associations with existing community type classifications for similar regions in Montana and Wyoming. Samples were well classified, as was evidenced by the optimization of geometric criteria, the identification of indicator species with meaningful ecological value and by the observed synonymy of the plant and environmental characteristics of newly described associations with those of previously described alpine community types and associations.

Literature Cited

Bamberg, S.A. 1961. Ecology of the vegetation and soils associated with calcareous parent materials in three alpine regions of Montana. Ecological Monographs, 1968.

Bamberg, S.A. and Major, J. 1968. Ecology of the vegetation and soils associated with calcareous parent materials in three alpine regions of Montana. Ecological Monographs 38: 127-167.

Bliss, L.C. 1963. Alpine plant communities of the Presidential Range, New Hampshire. Ecology 44:678-697.

Bray, J.R. and Curtis J.T. 1957. An ordination of the upland forest communities of Southern Wisconsin. Ecological Monographs. 27:325-349.

Choate, C.M. and Habeck, J.R. 1967. Alpine plant communities at Logan Pass, Glacier National Park, Montana. Proceedings of the Montana Academy of Sciences. 27: 36-54.

Cleland, D.T., Avers, P.E., McNab, W.H., Jensen, M.E., Bailey, R.G., King, T. and Russell. W.F. 1997. Chapter Nine: National Hierarchical Framework of Ecological Units. *Ecosystem Management: Applications for Sustainable Forest and Wildlife Resources.* Library of Congress Cataloging-in-Publication Data. Yale University, USA.

Cooper , S.V., Lesica, P., Page-Dumroese, D. 1997. Plant community classification for alpine vegetation on the Beaverhead National Forest, Montana. Gen. Tech. Rep. INT-GTR-362. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Daubenmire, R. F. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecological Monographs 22: 301-330.

Daubenmire, R. 1966. Vegetation: identification of typal communities. Science 151(3708): 291-298.

Dorn, R.D. 1977. Manual of the vascular plants of Wyoming. Garland Publishing, NY.

Dorn, R. D. 1984. Vascular plants of Montana. Mountain West Publishing, Cheyenne, WY.

Dufrêne, M., and Legendre, P. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67: 345-366.

Gordon, A.D. 1999. Classification. 2nd Edition. Chapman & Hall/CRC, Boca Raton, FL.

Haskins, D.M., Correll, Cynthia, S., Foster, R.A., Chatoian, J.M., Fincher, J.M., Strenger, S., Keys, J.E., Maxwell, J.R. and King, T. 1998. A Geomorphic Classification System. USDA Forest Service Department of Agriculture. Version 1.4.

Hitchcock, C.L., and Cronquist, A. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle, WA.

Jennings, M.D., Faber-Langendoen, D., Loucks, O.L., Peet, R.K., Roberts, D. 2009. Standards for associations and alliances of the U.S. National Vegetation Classification. Ecological Monographs, 79(2): 173-199.

Johnson, P.L. and Billings, W.D. 1962. The alpine vegetation of the Beartooth Plateau in relation to Cryopedogenic processes and patterns. Ecological Monographs 32: 105-135.

Kaufman, L. and Rousseeuw, P.J. 1990. Finding groups in data: an introduction to cluster analysis. John Wiley & Sons, Inc, NY.

Kenkel, N.C., Juhasz-N.P., Podani, J. 1989. On sampling procedures in population and community ecology. Vegetatio. 83: 195-207.

Kruskal, J.B. 1964. Nonmetric multidimensional scaling: a numerical method. Psychometrika. 29: 115-129.

Kruskal, J.B. and Wish, M. 1978. Multidimensional Scaling. Sage University Paper series on Quantitative Applications in the Social Sciences, number 07-011. Sage Publications, Newbury Park, CA.

Lavin, M. and Seibert, C. 2011. Grasses of Montana. Montana State University Herbarium. Department of Olant Sciences and Plant Pathology. Bozeman, MT.

Lesica, P. 1993. Vegetation and flora of the Line Creek Plateau Area, Carbon County, Montana. Unpublished report to U.S. Forest Service. Montana Natural Heritage Program. Helena. 30 pp.

Maechler, M., Rousseeuw, P., Struyf, A. and Hubert, M. 2005. cluster: Cluster Analysis Basics and Extensions. R package version 2.11.1.

Mueggler, W.F. and W.L. Steward. 1980. Grassland and Shrubland Habitat Types of Western Montana. USDA Forest Service General Technical Report INT-66, Odgen, Utah.

Potkin, M and L. Munn. 1987. Subalpine and alpine plant communities in the Bridger Wilderness, Wind River Range, Wyoming. Unpublished report to the Bridger-Teton National Forest, University of Wyoming Department of Plant, Soil and Insect Sciences, Laramie.

Pfister, R.D., and Arno, S.F.. 1980. Classifying forest habitat types based on potential climax vegetation. Forest Science 26: 52-70

R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Roberts, D.W. 2007. labdsv: Ordination and Multivariate Analysis for Ecology. R package version 2.11.1.

Roberts, D.W. 2011. optpart: Optimal partitioning of similarity relations. R package version 2.11.1.

Shoeneberger , P.J., Wysocki, D.A., Benham, E.C., Broderson, W.D. (ed.). 2002. Field book for describing and sampling soils. Version 2.0. USDA-NRCS, National Soil Survey Center. Lincoln, NE.

Silhouette, cluster package for R, Maechler, M., Rousseeuw, P., Struyf, A., Hubert, M. (2005). Cluster Analysis Basics and Extensions; unpublished

Spribille,T., Stroh, H.G. & Triepke, F.J. 2001. Are habitat types compatible with floristically-derived associations? Journal of Vegetation Science. 12: 791-796.

Steele, R., Cooper, S.V., Ondov, D.M., Roberts, D.W. & Pfister, R.D. 1983. Forest Habitat Types of Eastern Idaho-Western Wyoming. USDA Forest Service Intermountain Research Station General Technical Report INT-144, Ogden, UT.

Vaseth, R. and C. Montagne. 1980. Geologic parent materials of Montana Soils. Montana Agricultural Experiment Station Bulletim 721, Bozeman, MT.

Venables, W. N. & Ripley, B. D. 2002. Modern Applied Statistics with S. Fourth Edition. Springer, New York.

Wells, A. 1998. Custer National Forest National Cooperative Soil Survey and Terrestrial Ecological Unit Inventory: Pre-Mapping, Preliminary Data Analysis, and Study Design Development. Unpublished document.

Wilson, J.B. 1991. Does vegetation science exist? J. Veg. Sci. 2: 289-290.

Winthers, E., Fallon, D., Haglund, J., DeMeo, T., Nowacki, G., Tart, D., Ferwerda, M., Robertson, G., Gallegos, A., Rorick, A., Cleland, D.T., Robbie, W. 2005. Terrestrial Ecological Unit Inventory technical guide. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington, DC: U.S. Department of Agriculture. Forest Service. Washington Office, Ecosystem Management Coordination Staff. 245p.

Wood, 2004. mgcv: GAMs with GCV/AIC/REML smoothness estimation and GAMMs by PQL. R package version 2.7-10.

CHAPTER 5

CONCLUSION

The purpose of this thesis was to identify and describe the shrubland/grassland, woodland/forested and alpine plant associations of the Custer National Forest portion of the Beartooth Mountains, or the Beartooth Mountain study area. Samples were initially divided into the three broad ecological divisions outlined above. Using the vegetation composition data from 200 sample plots, 5 grassland/shrubland associations, 12 woodland/forested associations and 13 alpine associations were identified and described for the Beartooth Moutain study area. As would be expected, the grassland/shrubland associations occupy low elevations, the woodland/forested associations' mid-elevations and the alpine associations occupy high elevations of the study area.

The *Festuca idahoensis/Geranium viscosissimum* and *Alyssum alyssoides/Balsamorhiza sagittata* associations occupy the lowest elevation sites of the grassland/shrubland associations. The *Festuca idahoensis/Geranium viscosissimum* association spans higher relative effective annual precipitation ranges and occurs on less steep slopes than the *Alyssum alyssoides /Balsamorhiza sagittata* association, which occupies similar ranges of all other measured and modeled continuous environmental variables. The *Alyssum alyssoides /Balsamorhiza sagittata* association experiences the highest average daily temperatures and low relative effective annual precipitation, second only to the *Elymus spicatus/Artemisia frigida* association. The *Elymus spicatus/Artemisia frigida* association spans the same elevation range as the *Festuca*

idahoensis/Elymus spicatus association, but occurs on generally steeper slopes. The *Festuca idahoensis/Elymus spicatus* association occurs on sites receiving the highest annual solar exposure and also having the lowest average daily temperatures and shortest growing season of all five grassland/shrubland associations. The *Festuca idahoensis/Elymus spicatus* and *Artemisia tridentata* var. *vaseyana/Festuca idahoensis* associations are the wettest of the grassland/shrubland associations.

The *Pseudotsuga menziesii* var. *glauca*/mixed mesic shrub and the *Pinus flexilis/Symphoricarpos albus* associations extend to the lowest elevations of the woodland/forested associations. The *Pseudotsuga menziesii* var. *glauca*/mixed mesic shrub and *Pinus flexilis/Symphoricarpos albus* associations also represent the highest ranges of relative effective annual precipitation of the low elevation woodland/forested associations. The main difference between the two is the *Pinus flexilis/Symphoricarpos albus* association occupies sites with slightly higher average daily temperatures, greater annual solar exposure and is consistently associated with soils formed from limestone parent materials. The *Pinus flexilis/Agoseris glauca* association occurs on sites with low total annual precipitation, low relative effective annual precipitation and high annual solar exposure. *Pseudotsuga menziesii* var. *glauca* is characteristically absent from the overstory and understory of this association. The *Pinus flexilis/Artemisia frigida* association is similar to the *Pinus flexilis/Agoseris glauca* association, but *Pseudotsuga menziesii* var. *glauca* is present in the overstory. These differences in vegetation composition between the *Pinus flexilis/Artemisia frigida* association and the *Pinus flexilis/Agoseris glauca* association could be attributable to the slight increase in annual

solar exposure represented by the *Pinus flexilis/Agoseris glauca* association, which may make conditions too dry for *Pseudotsuga menziesii* var. *glauca*. The *Pseudotsuga menziesii* var. *glauca/*mixed xeric shrub association also occurs at fairly low elevationson steep slopes with shallow soils. These sites tend to be wetter and colder than the *Pinus flexilis/Agoseris glauca* association and are drier, colder and have longer shorter growing seasons than the *Pseudotsuga menziesii* var. *glauca/*mixed mesic shrub association.

The next highest forested elevation band is occupied by the *Abies lasiocarpa/Arnica cordifolia* association on wetter, cooler sites and by the *Pseudotsuga menziesii* var. *glauca/Juniperus communis* var. *depressa* association on drier, warmer sites.

Above the *Abies lasiocarpa/Arnica cordifolia* association and the *Pseudotsuga menziesii* var. *glauca/Juniperus communis* var. *depressa* association, the *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* association dominates. At higher elevations, conditions are often too harsh for *Abies lasiocarpa* to persist and understory vegetation is similar to alpine vegetation.

The *Pinus albicaulis/Arctostaphylos uva~ursi* association identified and described here is unlike any community type currently described for eastern Idaho and western Wyoming (Steele et al., 1983), western Montana (Pfister et al., 1977) or the Beartooth Mountains (Lesica, 1993) in south central Montana. However, it appears to be well resolved as the two samples included in this association share a number of compositional and environmental attributes.

The *Picea engelmannii/Minuartia obtusiloba* association, which also occurs at some of the highest elevations observed in the study area occupies sites with the lowest annual solar exposure budget while spanning similar average daily temperature and growing degree days ranges as the *Pinus albicaulis/Arctostaphylos uva~ursi* association. The *Picea/engelmannii/Minuartia obtusiloba* association occurs on characteristically steeper slopes and spans lower average ranges of relative effective annual precipitation and total precipitation than the *Pinus albicaulis/Arctostaphylos uva~ursi* association, indicating it may be characteristic of colder and drier high timberline sites.

The *Helianthela uniflora-Astragalus alpinus* association is a subalpine meadow association which occurs on the floor of U-shaped valleys on east and southwest-facing aspects of moderate slope (~20%). This association occurs at the lowest elevations and warmest sites in the alpine region and should probably be considered a mountainous, rather than alpine, association.

The *Dryas octopetala/Carex rupestris*, *Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens* association, *Senecio fremontii-Draba incerta* and *Picea engelmannii-Pinus albicaulis/Carex nardina* associations are all fairly dry alpine associations. These associations often occur in windswept positions where precipitation is primarily received as snow and then blown free, thus exposing sites to the higher annual solar exposure.

The *Dryas octopetala/Carex rupestris* association is a particularly warm and dry alpine association that occurs at middle elevations in the alpine (2,750 m. and 3,050 m) on north and northeast-facing slopes that receive very little precipitation and have the highest average daily temperature. The *Geum rossii* var. *turbinatum-Silene acaulis* var.

subacaulescens association is one of the driest alpine associations in the Beartooth Mountain study area, second only to the *Dryas octopetala/Carex rupestris* association though generally colder. The *Senecio fremontii-Draba incerta* association is a depauperate association that occurs at the highest elevations (> 3,150 m.) on extremely cold, steep and talus-dominated northerly exposures. The diminished cushion plant dominance found on these sites may indicate slightly less windswept positions than those on which the *Geum rossii* var. *turbinatum-Silene acaulis* var. *subacaulescens* and *Picea engelmannii-Pinus albicaulis/Carex nardina* associations occur. The paucity of species richness and abundance on these sites is most likely a result of minimal soil development, which only occurs in the cracks of talus stones and boulders. The *Picea engelmannii-Pinus albicaulis/Carex nardina* association occurs on less exposed, though not always lee, northeast and west-facing exposures of wind-blasted slopes. Soil sorting was observed on several sites.

The *Carex phaeochephala/Sibbaldia procumbens var. subacualescens* association is a relatively common graminoid-dominated turf association in the Beartooth Mountain study area that occurs on moderately cold and moist sites that receive a high amount of direct annual solar exposure, such as ground and recessional moraines, knobs, mountain slopes and the flat plateau. These sites are likely turf because they occur in somewhat windswept position but are also moist because they occur in runoff collecting positions or, at least in one instance, on slopes with low solar exposure.

The three alpine *Salix*-dominated associations, in order of descending elevation, include: the *Salix reticulata* var. *nana/Polygonum viviparum* association, the *Salix glauca*

var. *villosa* association and the *Salix planifolia/Carex scopulorum* association. The *Salix reticulata* var. *nana/Polygonum viviparum* association occurs at the heads of alpine plateau drainageways and glacial cirque basins, generally above 3,150 m. The *Salix glauca* var. *villosa* association occurs on cool, concave, moderately sloped, snowmelt and runoff collecting positions on the plateau between 3,050 and 3,150 m. elevation. The warmest *Salix*-dominated association, the *Salix planifolia/Carex scopulorum* association, occurs in the gently sloping floors of north and east trending drainageways and U-shaped valleys below 3,000 m. elevation.

The *Carex nigricans/Veronica wormskjoldii, Antennaria lanata-Hieracium triste* var. *gracile*, and *Deschampsia cespitosa-Carex microptera–Carex macloviana* associations all occur in positions receiving increased snow accumulation and/or water from snowmelt, generally referred to as snowbed associations. The *Carex nigricans/Veronica wormskjoldii* association is a very common association in the Beartooth Mountains, occurring where snow persists and/or soils are saturated the longest between 2,900 and 3,050 m. elevation. Lake margins and toeslopes below late persisting snowpack are commonly associated landforms. The *Antennaria lanata-Hieracium triste* var. *gracile* association occurs on snowbed sites that remain saturated for less of the growing season than the *Carex nigricans/Veronica wormskjoldii* association. U-shaped valleys are the most commonly associated landform, followed by knobs and glacial valley walls. The *Deschampsia cespitosa-Carex microptera–Carex macloviana* association occurs on cirque headwalls and toeslopes of U-shaped valleys between 2,900

m. and 3,200 m. on north, northeast and southeast-facing sites with 10 to 50% slope. Sites supporting this association are cold and wet.

The *Senecio triangularis-Mertensia ciliata* association is a minor, forb-dominated association that occurs along moderately steep and narrow seep drainageways between 2,940 m. and 3,050 m. elevation.

The grassland/shrubland, woodland/forested and alpine associations classified and described in this analysis for the Beartooth Mountains study area, 30 in all, tend to reflect the position of the range along the western margin of the Great Basin in their representation of drier and colder habitat types than are typically observed further to the west in wetter mountain ranges. Most of the associations here classified and described have been previously described as either a habitat type or community type/association in other ecologically relavent studies. Where associations were not previously described, such as the *Pinus albicaulis*/*Arctostaphylos uva~ursi* association, the clusters were well resolved and the environment occupied consistent enough to be easily described.

While associations are well classified, some associations seemed either too broad or too narrow in their ecological amplitude, and would likely be better resolved with the addition of more representative sample plots. For example, the addition of grassland/shrubland and woodland samples might help to better resolve the role of fire in shaping grassland/shrubland and woodland associations. The small number of grassland/shrubland samples included in this analysis did not allow for me to confidently determine to what degree vegetation composition was reflecting environmental factors, such as climate and geology, and/or to what degree vegetation composition was reflecting

stage in succession or time since and frequency of disturbance. Of all the associations classified and described in this analysis, I felt that the grassland/shrubland and woodland associations, primarily those dominated by *Pinus flexilis* and a mix of *Pinus flexilis* and *Pseudotsuga menziesii* var. *glauca,* would benefit the most from further sampling.

LITURATURE CITED

Aho, K., Roberts, D.W., and Weaver, T. 2008. Using Geometric and Non- Geometric Internal Evaluators to Compare Eight Vegetation Classification Methods. Journal of Vegetation Scients 19(4): 549-562.

Alt, D.D. and Hyndman, D.W. 1986. Roadside Geology of Montana. Mountain Press Pub. Co. Missoula, MT. 427 p.

Arno, S.F. and Gruell, G.E. fire history at the forest-grassland ecotone in southwestern Montana. Accepted for publication by J. of Range Management.

Bamberg, S.A. 1961. Ecology of the vegetation and soils associated with calcareous parent materials in three alpine regions of Montana. Ecological Monographs, 1968.

Bamberg, S.A. and Major, J. 1968. Ecology of the vegetation and soils associated with calcareous parent materials in three alpine regions of Montana. Ecological Monographs 38: 127-167.

Bevan, A. 1923. Summary of the Geology of the Beartooth Mountains, Montana. The Journal of Ecology. 31 (6): pp. 441-465.

Billings, W. 1978. Alpine phytogeography across the Great Basin. Great Basin Naturalist Memoirs, North America.

Billings, W.D. 1988. Alpine vegetation. In Barbour, M.C. and Billings, W.D., eds. *North American terrestrial vegetation*. Second edition. Cambridge, UK: Cambridge University Press: 391-420.

Bliss, L.C. 1963. Alpine plant communities of the Presidential Range, New Hampshire. Ecology 44:678-697.

Bray, J.R. and Curtis J.T. 1957. An ordination of the upland forest communities of Southern Wisconsin. Ecological Monographs. 27:325-349.

Choate, C.M. and Habeck, J.R. 1967. Alpine plant communities at Logan Pass, Glacier National Park, Montana. Proceedings of the Montana Academy of Sciences. 27: 36-54.

Cleland, D.T., Avers, P.E., McNab, W.H., Jensen, M.E., Bailey, R.G., King, T. and Russell. W. F. 1997. Chapter Nine: National Hierarchical Framework of Ecological Units. *Ecosystem Management: Applications for Sustainable Forest and Wildlife Resources.* Library of Congress Cataloging-in-Publication Data. Yale University, USA.

Cooper , S.V., Lesica, P., Page-Dumroese, D. 1997. Plant community classification for alpine vegetation on the Beaverhead National Forest, Montana. Gen. Tech. Rep. INT-GTR-362. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Dale, M.B. 1975. On objectives of methods of ordination. Vegetatio 30:15-32.

Daubenmire, R. 1966. Vegetation: identification of typal communities. Science 151(3708): 291-298.

Daubenmire, R. F. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecological Monographs 22: 301-330.

Dorn, R.D. 1977. *Manual of the vascular plants of Wyoming*. Garland Publishing, NY.

Dorn, R. D. 1984. *Vascular plants of Montana*. Mountain West Publishing, Cheyenne, WY.

Daubenmire, R. 1966. Vegetation: identification of typal communities. Science 151(3708): 291-298.

Daubenmire, R. F. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecological Monographs 22: 301-330.

Dufrêne, M., and Legendre, P.1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67: 345-366.

Everitt, B.S. 1979. Unresolved problems in cluster analysis. Biometrics. 35:169-181

Everitt, B.S. 1993. Cluster Analysis. Oxford University Press, London.

Faith, D.P., Minchin, P.R. and Belbin, L. Compositional dissimilarity as a robust measure .of ecological distance. Plant Ecology 69 (1-3): 57-68.

Fischer, W.C. and Clayton, B.D. 1983. Fire ecology of Montana forest habitat types east of the Continental Divide. USDA Intermountain Forest and Range Experiment Station General Technical Report INT-141, Ogden, UT.

Gauch, H.G. 1973. A quantitative evaluation of the Bray-Curtis ordination. Ecology 54: 829-836.

Gauch, H. G. 1982. *Multivariate analysis in community ecology*. Cambridge University Press, London, UK.

Gordon, A.D. 1999. Classification. 2nd Edition. Chapman & Hall/CRC, Boca Raton, FL.

Greig-Smith, P. 1983. *Quantitative Plant Ecology*. 3rd Edition. Oxford, Blackwell Scientific.

Hanson, P.L., Pfister, R.D., Boggs, K., Cook, B.J., Joy, J. and Hinckley, D.K. 1995. Classification and Management of Montana's Riparian and Wetland Sites. Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana, Missoula, MT. Miscellaneous Publication No. 54.

Haskins, D.M., Correll, Cynthia, S., Foster, R.A., Chatoian, J.M., Fincher, J.M., Strenger, S., Keys, J.E., Maxwell, J.R. and King, T. 1998. A Geomorphic Classification System. USDA Forest Service Department of Agriculture. Version 1.4.

Hitchcock, C.L., and Cronquist, A. 1973. *Flora of the Pacific Northwest*. University of Washington Press, Seattle, WA.

Holmgren, N.H. 1972. Plant geography of the Intermountain Region. pp. 77-161. *In*: A. Cronquist, A.H. Holmgren, N.H. Holmgren, and J.L. Reveal (eds.), Intermountain flora. Vol. 1. Hafner Publ. Co., New York.

Jennings, M.D., Faber-Langendoen, D., Loucks, O.L., Peet, R.K., Roberts, D. 2009. Standards for associations and alliances of the U.S. National Vegetation Classification. Ecological Monographs, 79(2): 173-199.

Johnson, P.L. and Billings, W.D. 1962. The alpine vegetation of the Beartooth Plateau in relation to Cryopedogenic processes and patterns. Ecological Monographs 32: 105-135.

Jongmann, R.H.G., ter Braak, C.J.G. and van Tongeren, O.F.R.. 1995. Data analysis in community and landscape ecology. Cambridge University Press, Cambridge, UK.

Kaufman, L. and Rousseeuw, P.J. 1990. Finding groups in data: an introduction to cluster analysis. John Wiley & Sons, Inc, NY.

Kenkel, N.C. and Orloci, L. 1986. Applying metric and nonmetric multidimensional scaling to ecological studies: some new results. Ecology 67:919-928.

Kenkel, N.C., Juhasz-N.P., Podani, J. 1989. On sampling procedures in population and community ecology. Vegetatio. 83: 195-207.

Kent, M., and Coker, P. 1992. Vegetation description and analysis: a practical approach. Belhaven Press, London, UK.

Kruskal, J.B. 1964. Nonmetric multidimensional scaling: a numerical method. Psychometrika. 29: 115-129.

Kruskal, J.B. and Wish, M. 1978. Multidimensional Scaling. Sage University Paper series on Quantitative Applications in the Social Sciences, number 07-011. Sage Publications, Newbury Park, CA.

Kruskal, W.H. and Wallis, W.A. 1952. Use of Ranks in One-Criterion Variance Analysis. Journal of the American Statistical Association. 47 (260): 583-621.

Lavin, M. and Seibert, C. 2011. Grasses of Montana. Montana State University Herbarium. Department of Olant Sciences and Plant Pathology. Bozeman, MT

Legendre, P. and Legendre, L. 1998. Numerical ecology. 2nd English edition. Elsevier Science BV, Amsterdam.xv+853 p.

Lesica, P. 1993. Vegetation and flora of the Line Creek Plateau Area, Carbon County, Montana. Unpublished report to U.S. Forest Service. Montana Natural Heritage Program. Helena. 30 pp.

Maechler, M., Rousseeuw, P., Struyf, A. and Hubert, M. 2005. cluster: Cluster Analysis Basics and Extensions. R package version 2.11.1.

McClain, J.O. and Rao, V.R. 1975. CLUSTISZ: A program to test for the quality of clutering of a set of objects. Journal of Marketing Research. 12:456-460.

Minchin, P.R. 1987. An evaluation of the relative robustness of techniques for ecological ordination. Plant Ecology. 69 (1-3):89-107.

Mueller-Dombois, D. and Ellenburg, H. 1974. Aims and methods of vegetation ecology. John Wiley, New York, New York, USA.

Mueggler, W.F. and W.L. Steward. 1980. Grassland and Shrubland Habitat Types of Western Montana. USDA Forest Service General Technical Report INT-66, Odgen, Utah.

Noy-Meir, I. and van der Maarel, E. 1987. Relations between community theory and community analysis in vegetation science: some historical perspectives. Vegetatio. 69: 5-15.

Pfister, R.D., and Arno, S.F. 1980. Classifying forest habitat types based on potential climax vegetation. Forest Science 26: 52-70

Pfister, R.D., Kovalchik, B.L., Arno, S.F. and Presby, R.C.. 1977. Forest Habitat Types of Montana. USDA Forest Service General Technical Report INT-34, Ogden, Utah.

Podani, J. 1989. Comparison of Ordinations and Classifications of Vegetation Data. Vegetatio 83:111-128.

Potkin, M and L. Munn. 1987. Subalpine and alpine plant communities in the Bridger Wilderness, Wind River Range, Wyoming. Unpublished report to the Bridger-Teton National Forest, University of Wyoming Department of Plant, Soil and Insect Sciences, Laramie.

R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Roberts, D.W. 2007. labdsv: Ordination and Multivariate Analysis for Ecology. R package version 2.11.1.

Roberts, D.W. 2011. optpart: Optimal partitioning of similarity relations. R package version 2.11.1.

Rousseeauw, P.J. 1987. Silhoueetes: A graphical aid to the interpretation and validation of cluster analysis. Journal of Computational and Applied Mathematics. 20:53-65.

Shepard, R.N. 1974. Representation of structure in similarity data: problems and prospects. Psychometricka 39: 373-421.

Shoeneberger, P.J., Wysocki, D.A., Benham, E.C., Broderson, W.D. (ed.). 2002. Field book for describing and sampling soils. Version 2.0. USDA-NRCS, National Soil Survey Center. Lincoln, NE.

Silhouette, cluster package for R, Maechler, M., Rousseeuw, P., Struyf, A., Hubert, M. (2005). Cluster Analysis Basics and Extensions; unpublished

Spribille,T., Stroh, H.G. & Triepke, F.J. 2001. Are habitat types compatible with floristically-derived associations? Journal of Vegetation Science. 12: 791-796.

Steele, R., Cooper, S.V., Ondov, D.M., Roberts, D.W. & Pfister, R.D. 1983. Forest Habitat Types of Eastern Idaho-and Western Wyoming. USDA Forest Service Intermountain Research Station General Technical Report INT-144, Ogden, UT.

Steele, R., Pfister, R.D., Ryker, R.A. & Kittams, J.A. 1981. Forest Habitat Types of Central Idaho. USDA Forest Service Intermountain Forest and Range Experimental Station General Technical Report. INT-114, Ogden, UT.

Stride, labdsv package for R; Roberts, 2010.

Vaseth, R. and C. Montagne. 1980. *Geologic parent materials of Montana Soils*. Montana Agricultural Experiment Station Bulletim 721, Bozeman, MT.

Venables, W. N. & Ripley, B. D. (2002) Modern Applied Statistics with S. Fourth Edition. Springer, New York. ISBN 0-387-95457-0

Wells, A. 1998. Custer National Forest National Cooperative Soil Survey and Terrestrial Ecological Unit Inventory: Pre-Mapping, Preliminary Data Analysis, and Study Design Development. Unpublished document.

Wilson, J.B. 1991. Does vegetation science exist? J. Veg. Sci. 2: 289-290.

Winters, E., Fallon, D., Haglund, J., DeMeo, T., Nowacki, G., Tart, D., Ferwerda, M., Robertson, G., Gallegos, A., Rorick, A., Cleland, D.T., Robbie, W. 2005. Terrestrial Ecological Unit Inventory technical guide. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington, DC: U.S. Department of Agriculture. Forest Service. Washington Office, Ecosystem Management Coordination Staff. 245p.

Wood, 2004. mgcv: GAMs with GCV/AIC/REML smoothness estimation and GAMMs by PQL. R package version 2.7-10.

APPENDICES

APPENDIX A

KEY TO GRASSLAND AND SHRUBLAND SERIES AND HABITAT TYPES

READ THESE INSTRUCTIONS FIRST!

1. Use this key for stands that are not severely disturbed by grazing, logging, forest fire, etc. (If the stand is severely disturbed or in an early successional stage, the habitat type can best be determined by extrapolating from the nearest mature stand occupying a similar site.)
2. Accurately identify and record canopy coverage for all indicator species.
3. Check plot data in the field to verify that the plot is representative of the stand as a whole. If not, select another plot.
4. Identify the correct potential climax shrub or graminoid species in the SERIES key. (Generally, a tree species is considered reproducing successfully if 10 or more individuals per acre occupy or will occupy the site.)
5. Within the appropriate series, key to HABITAT TYPE and PHASE by following the key literally Verify your identification by comparing the stand conditions with the written descriptions. (The first phase in the key that fits the stand is the correct one.)
6. Use the definitions diagramed below for canopy coverage terms in the key. If you have difficulty deciding between types, refer to constancy and coverage data and the habitat type descriptions.
7. In stands where undergrowth is obviously depauperate (unusually sparse) because of dense shading or duff accumulations, adjust the definitions diagramed below to the next lower coverage class (for example, well represented >1%, common >0%.
8. Remember, the key is NOT the classification! Validate the determination made using the key by checking the written description.

INTERPRETATION OF CANOPY COVER TERMINOLOGY EMPLOYED IN KEY

Absent …… **0% canopy cover**
Present …… **.01 to 100% canopy cover**
Trace …… **< 1% canopy cover**
Common …… **1 to 100% canopy cover**
Poorly Represented …… **< 5% canopy cover**
Well Represented …… **5 to 100% canopy cover**
Not Abundant …… **<25% canopy cover**
Abundant …… **25 to 100% canopy cover**

1a. *Festuca idahoensis* well represented to abundant (>5% cover) …….....…… 2
1b. *Festuca idahoensis* poorly represent or absent (<5% cover) …...……...…… 3

2a. Community representing a grassland aspect. Shrubs, if present, are widely scattered or are sub-shrubs like *Artemisia frigida.* *Elymus spicatus* common (usually > 5% cover) ……...…… ……..…….. ***Festuca idahoensis-Elymus spicatus*** **h.t.**
2b. Community representing a shrubland aspect. *Artemisia tridentata* var. *vaseyana* (occasionally *Artemisia tridentata* var. *wyomingensis* dominates on Lindley conglomerate substrate in SE portion of study area) well represented to abundant (>5%) ..... ……..…… ***Artemisia tridentata*** var. ***vaseyana/Festuca idahoensis*** **h.t.**
(*Artemisia tridentata* var. ***wyomingensis/Festuca idahoensis*** **h.t.)**

a. *Geranium viscosissimum, Potentilla gracilis,* or *Potentilla gl*and*ulosa* and *Agropyron caninum* or *Bromus carinatus* var. *linearis* present ....***Geranium viscosissimum*** **phase**

3a. Community representing a shrubland aspect. *Artemisia tridentata* var. *vaseyana* (occasionally *Artemisia tridentata* var. *wyomingensis* dominates on Lindley conglomerate substrate in SE portion of study area) and *Elymus spicatus* well represented to abundant (both generally >5%) …… ***Artemisia tridentata*** var. ***vaseyana/Elymus spicatus*** **h.t.**
3b. Not as above ……..…… **unsampled grassland/shrubland h.t.**

APPENDIX B

KEY TO GRASSLAND AND SHRUBLAND ASSOCIATIONS

READ THESE INSTRUCTIONS FIRST!

1. This key is best used in stands that are not severely disturbed by grazing, logging, forest fire, etc., but can be used in stands with disturbance as well.
2. Accurately identify and record canopy coverage of all species.
3. Check plot data in the field to verify that the plot is representative of the stand as a whole. If not, select another plot.
4. Use the definitions diagramed below for canopy coverage terms in the key. If you have difficulty deciding between types, refer to constancy and coverage data (Appendix C) and the habitat type descriptions.
5. In stands where undergrowth is obviously depauperate (unusually sparse) because of dense shading or duff accumulations, adjust the definitions below to the next lower coverage class (for example, well represented >1%, common >0%.
6. Remember, the key is NOT the classification! Validate the determination made using the key by checking the written description.

INTERPRETATION OF CANOPY COVER TERMINOLOGY EMPLOYED IN KEY

Absent …… **0% canopy cover**
Present …… **.01 to 100% canopy cover**
Trace …… **<1% canopy cover**
Common …… **1 to 100% canopy cover**
Poorly Represented …… **< 5% canopy cover**
Well Represented …… **5 to 100% canopy cover**
Not Abundant …… **<25% canopy cover**
Abundant …… **25 to 100% canopy cover**

1a. *Artemisia tridentata* var*. vaseyana* the dominant shrub, >30% cover .... ***Artemisia tridentata*** var. ***vaseyana/Festuca idahoensis*** **association**
1b. Not as above ……...……. 2

2a. *Festuca idahoensis* dominant and well represented (>5% cover) or, if *Festuca idahoensis* cover less then *Geranium viscosissimum* present ……..…….…… 3
2b. *Festuca idahoensis* poorly represented (<5%) and *Geranium viscosissimum* absent...4

3a. *Festuca idahoensis* clearly the dominant graminoid, consistently more abundant than *Elymus spicatus*. *Antennaria microphylla* and *Artemisia frigida* commonly associated species ….....……..… ***Festuca idahoensis-Elymus spicatus*** **association**
3b. *Festuca idahoensis* present in trace to moderate abundance but is not the clear dominant, often sharing dominance with *Poa pratensis* and/or *Elymus spicatus*. *Geranium viscosissimum*, *Galium boreale, Lupinus sericeus, Taraxacum officionale, Carex petasata, Achnatherum occidentale, Bromus carinatus* var. *linearis, Campanula rotundifolia, Silene latifolia, Potentilla gracilis* var. *flabelliformis* are commonly associated species ..... ***Festuca idahoensis/Geranium viscosissimum*** **association**

4a. Early seral or disturbed community. *Balsamorhiza sagittata* and *Alyssum alyssoides* abundant (>15%), *Lupinus argenteus* and *Bromus tectorum* well represented (>5%) and *Artemisia frigida* absent ……. ***Alyssum alyssoides/Balsamorhiza sagittata*** **association**
4b. Not as above. *Elymus spicatus* well represented to abundant (>15%) and *Artemisia frigida* present in low abundance (<5%)... ***Elymus spicatus/Artemisia frigida*** **association**

APPENDIX C

COVER AND CONSTANCY TABLE FOR GRASSLAND/SHRUBLAND ASSOCIATIONS OF THE BEARTOOTH MOUNTAINS STUDY AREA

Table C.1. Cover and Constancy for Grassland/Shrubland Associations of the Beartooth Mountains Study Area.

STRATA_*Species name*	ASAL/BASA3	FEID/GEVI	ARTRV/FEID	FEID/PSSPS	PSSPS/ARFR
CM_Selaginella sp. (densa or watsonii)	50(0.0)	25(0.0)	66(25.0)	63(10.5)	50(6.3)
FB_Achillea millefolium var. lanulosa	100(0.1)	75(0.6)	100(1.4)	45(0.3)	50(0.0)
FB_Agoseris glauca	50(0.0)	100(0.3)	66(0.4)	45(0.6)	75(0.8)
FB_Allium cernuum	0(0.0)	0(0.0)	0(0.0)	45(0.2)	25(0.5)
FB_Allium textile	100(0.1)	25(0.0)	33(0.0)	36(0.0)	50(0.0)
FB_Alyssum alyssoides	100(47.5)	75(1.3)	0(0.0)	27(0.9)	50(1.2)
FB_Alyssum desertorum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Anaphalis margaritacea	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Androsace septentrionalis var. subulifera	0(0.0)	0(0.0)	33(0.3)	0(0.0)	0(0.0)
FB_Anemone multifida	0(0.0)	50(0.5)	0(0.0)	9(0.0)	0(0.0)
FB_Anemone patens var. multifida	50(0.0)	75(0.1)	0(0.0)	45(2.8)	50(0.0)
FB_Antennaria microphylla	50(0.0)	25(0.0)	100(3.0)	90(4.9)	75(1.0)
FB_Antennaria rosea	0(0.0)	0(0.0)	33(0.0)	27(1.5)	25(0.0)
FB_Apocynum androsaemifolium	0(0.0)	0(0.0)	33(0.0)	9(0.4)	0(0.0)
FB_Arabis hirsuta	0(0.0)	50(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Arnica fulgens	0(0.0)	25(0.0)	0(0.0)	18(0.0)	0(0.0)
FB_Arnica mollis	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Arnica sororia	0(0.0)	75(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Artemisia campestris	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Artemisia ludoviciana	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Astragalus drummondii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Astragalus laxmannii var. robustior	0(0.0)	50(0.0)	33(0.0)	18(0.3)	75(0.1)
FB_Astragalus miser	0(0.0)	25(0.0)	33(1.0)	18(0.0)	50(0.3)
FB_Balsamorhiza incana	0(0.0)	0(0.0)	33(0.3)	9(0.1)	0(0.0)
FB_Balsamorhiza sagittata	100(25.0)	0(0.0)	66(1.0)	27(4.3)	50(1.8)
FB_Besseya wyomingensis	0(0.0)	50(0.0)	33(0.7)	9(0.0)	0(0.0)
FB_Boechera angustifolia	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Boechera exilis	0(0.0)	0(0.0)	0(0.0)	18(0.0)	25(0.0)
FB_Boechera holboellii	50(0.0)	25(0.0)	0(0.0)	18(0.0)	0(0.0)
FB_Boechera nuttallii	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Bupleurum americanum	0(0.0)	0(0.0)	33(0.0)	18(0.1)	0(0.0)
FB_Calochortus gunnisonii	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Camelina microcarpa	0(0.0)	100(0.1)	0(0.0)	18(0.0)	50(0.3)
FB_Campanula rotundifolia	0(0.0)	100(0.8)	66(0.1)	9(0.0)	50(0.0)
FB_Castilleja angustifolia var. dubia	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Castilleja crista-galli	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Castilleja miniata	0(0.0)	0(0.0)	33(0.0)	9(0.0)	0(0.0)
FB_Castilleja pallescens	0(0.0)	0(0.0)	0(0.0)	27(0.2)	0(0.0)
FB_Castilleja pilosa var. longispica	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Castilleja pulchella	50(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Cerastium arvense	100(2.5)	75(0.3)	100(3.0)	90(2.6)	100(0.6)
FB_Chamerion angustifolium	0(0.0)	0(0.0)	0(0.0)	9(0.0)	25(0.0)
FB_Chenopodium album	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Claytonia lanceolata	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Clematis hirsutissima	50(0.0)	25(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Collinsia parviflora	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Collomia linearis	100(0.1)	75(0.1)	66(0.1)	0(0.0)	25(0.0)
FB_Comandra umbellata var. pallida	50(0.0)	25(0.0)	33(0.3)	63(0.4)	75(1.0)

Table C.1. Cover and Constancy for Grassland/Shrubland Associations of the Beartooth Mountains Study Area (continued).

STRATA_*Species name*	ASAL3/BASA3	FEID/GEVI2	ARTRV/FEID	FEID/PSSPS	PSSPS/ARFR4
FB_Crepis atribarba	0(0.0)	25(0.0)	33(0.0)	0(0.0)	25(0.0)
FB_Crepis intermedia	100(0.1)	25(0.0)	100(0.1)	18(0.0)	0(0.0)
FB_Crepis modocensis	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Cryptantha celosioides	0(0.0)	0(0.0)	0(0.0)	9(0.0)	25(0.0)
FB_Cynoglossum officinale	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Delphinium bicolor	50(0.0)	100(0.1)	66(0.1)	36(0.5)	25(0.0)
FB_Descurainia incana	50(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Dodecatheon conjugens	0(0.0)	50(0.0)	0(0.0)	27(0.0)	0(0.0)
FB_Dodecatheon pulchellum	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Draba nemorosa	0(0.0)	0(0.0)	0(0.0)	27(0.0)	0(0.0)
FB_Eremogone congesta	0(0.0)	75(0.3)	100(1.7)	54(0.1)	25(0.5)
FB_Eremogone hookeri var. hookeri	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Erigeron caespitosus	0(0.0)	0(0.0)	66(0.7)	27(0.0)	25(0.0)
FB_Erigeron corymbosus	0(0.0)	0(0.0)	0(0.0)	9(0.1)	0(0.0)
FB_Erigeron eatonii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Erigeron gracilis	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Erigeron ochroleucus	0(0.0)	25(0.0)	0(0.0)	45(0.0)	0(0.0)
FB_Erigeron speciosus	0(0.0)	75(0.1)	0(0.0)	0(0.0)	50(0.0)
FB_Eriogonum flavum	0(0.0)	25(0.0)	0(0.0)	27(0.0)	25(0.0)
FB_Eriogonum umbellatum	0(0.0)	0(0.0)	66(0.4)	9(0.1)	25(0.2)
FB_Eriophyllum lanatum var. integrifolium	0(0.0)	0(0.0)	0(0.0)	18(0.0)	0(0.0)
FB_Erysimum asperum	0(0.0)	0(0.0)	33(0.0)	27(0.0)	25(0.0)
FB_Euphorbia brachycera var. robusta	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Frasera speciosa	0(0.0)	25(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Fritillaria pudica	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Gaillardia aristata	0(0.0)	75(0.3)	66(0.1)	45(0.2)	50(0.0)
FB_Galium aparine	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Galium boreale	50(1.0)	100(6.5)	33(0.3)	27(0.6)	25(0.2)
FB_Geranium viscosissimum	0(0.0)	100(4.0)	0(0.0)	9(0.0)	0(0.0)
FB_Geum triflorum	50(0.0)	100(0.1)	66(2.0)	54(0.2)	25(0.0)
FB_Helianthella uniflora	50(0.5)	50(0.0)	33(0.0)	9(0.0)	0(0.0)
FB_Heterotheca villosa	0(0.0)	0(0.0)	33(0.0)	18(0.4)	50(0.0)
FB_Heuchera cylindrica var. suksdorfii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Heuchera parvifolia	0(0.0)	25(0.0)	0(0.0)	27(0.1)	0(0.0)
FB_Hieracium cynoglossoides	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Hymenopappus filifolius var. luteus	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Lesquerella alpina	0(0.0)	0(0.0)	0(0.0)	18(0.0)	0(0.0)
FB_Lewisia rediviva	0(0.0)	0(0.0)	33(0.0)	27(0.1)	50(0.0)
FB_Linum lewisii	0(0.0)	0(0.0)	0(0.0)	18(0.0)	25(0.0)
FB_Lithophragma parviflorum	50(0.0)	50(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Lithospermum ruderale	50(1.0)	25(0.2)	66(0.1)	9(0.0)	50(0.3)
FB_Lomatium attenuatum	0(0.0)	0(0.0)	0(0.0)	18(0.6)	0(0.0)
FB_Lomatium cous	50(0.0)	50(0.0)	0(0.0)	27(0.3)	50(0.8)
FB_Lomatium foeniculaceum	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Lomatium triternatum	100(0.1)	0(0.0)	33(0.0)	0(0.0)	0(0.0)

Table C.1. Cover and Constancy for Grassland/Shrubland Associations of the Beartooth Mountains Study Area (continued).

STRATA_*Species name*	ASAL3/BASA3	FEID/GEVI2	ARTRV/FEID	FEID/PSSPS	PSSPS/ARFR4
FB_Lupinus argenteus	100(12.5)	25(0.2)	66(1.3)	36(1.3)	25(1.2)
FB_Lupinus polyphyllus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Lupinus sericeus	0(0.0)	75(8.2)	33(2.0)	27(0.7)	25(0.2)
FB_Machaeranthera grindelioides	0(0.0)	0(0.0)	0(0.0)	18(0.0)	0(0.0)
FB_Maianthemum stellatum	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Mertensia ciliata	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Mertensia oblongifolia	0(0.0)	0(0.0)	66(0.7)	18(0.0)	50(0.0)
FB_Microseris nutans	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Minuartia nuttallii	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Minuartia rubella	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Monarda fistulosa var. menthifolia	0(0.0)	50(1.5)	33(0.0)	0(0.0)	0(0.0)
FB_Myosotis alpestris	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Myosotis arvensis	0(0.0)	75(0.1)	33(0.0)	9(0.0)	0(0.0)
FB_Myosotis micrantha	0(0.0)	0(0.0)	0(0.0)	9(0.5)	0(0.0)
FB_Nothocalais cuspidata	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Opuntia fragilis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Opuntia polyacantha	50(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
FB_Oxytropis borealis var. viscida	50(0.0)	0(0.0)	33(0.0)	27(0.0)	0(0.0)
FB_Oxytropis deflexa	0(0.0)	0(0.0)	33(0.7)	0(0.0)	0(0.0)
FB_Oxytropis lagopus	0(0.0)	0(0.0)	0(0.0)	27(0.1)	0(0.0)
FB_Oxytropis sericea	0(0.0)	25(0.0)	0(0.0)	27(0.5)	25(0.0)
FB_Packera cana	0(0.0)	0(0.0)	33(0.0)	45(0.1)	75(0.1)
FB_Packera werneriifolia	0(0.0)	0(0.0)	0(0.0)	9(0.3)	0(0.0)
FB_Penstemon eriantherus	0(0.0)	0(0.0)	0(0.0)	27(0.0)	50(0.0)
FB_Penstemon nitidus	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Penstemon procerus	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Perideridia montana	0(0.0)	50(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Phacelia hastata	0(0.0)	0(0.0)	33(0.3)	9(0.0)	0(0.0)
FB_Phacelia linearis	100(0.1)	25(0.0)	66(0.1)	9(0.0)	75(0.1)
FB_Phlox hoodii	50(0.0)	50(0.0)	66(0.4)	63(0.8)	75(0.1)
FB_Piperia unalascensis	0(0.0)	0(0.0)	0(0.0)	9(0.0)	25(0.0)
FB_Polygonum bistortoides	0(0.0)	75(0.3)	33(0.0)	18(0.2)	0(0.0)
FB_Polygonum douglasii	0(0.0)	25(0.0)	33(0.0)	9(0.0)	0(0.0)
FB_Potentilla bipinnatifida	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Potentilla concinna var. concinna	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Potentilla glandulosa	0(0.0)	25(0.0)	33(0.0)	0(0.0)	25(0.0)
FB_Potentilla gracilis var. flabelliformis	0(0.0)	75(0.6)	0(0.0)	0(0.0)	25(0.0)
FB_Potentilla ovina var. ovina	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Potentilla pensylvanica	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Rumex crispus	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Saxifraga rhomboidea	0(0.0)	25(0.0)	0(0.0)	18(0.1)	0(0.0)
FB_Sedum lanceolatum	0(0.0)	0(0.0)	33(0.0)	27(0.0)	0(0.0)
FB_Senecio integerrimus	0(0.0)	75(0.1)	0(0.0)	18(0.1)	0(0.0)
FB_Senecio sphaerocephalus	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)

Table C.1. Cover and Constancy for Grassland/Shrubland Associations of the Beartooth Mountains Study Area (continued).

STRATA_*Species name*	ASAL3/BASA3	FEID/GEVI2	ARTRV/FEID	FEID/PSSPS	PSSPS/ARFR4
FB_Silene drummondii	0(0.0)	0(0.0)	0(0.0)	27(0.0)	50(0.0)
FB_Silene latifolia	0(0.0)	75(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Silene oregana	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Sisymbrium altissimum	0(0.0)	0(0.0)	0(0.0)	18(0.0)	0(0.0)
FB_Solidago missouriensis	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Solidago multiradiata var. scopulorum	0(0.0)	0(0.0)	33(0.0)	9(0.0)	0(0.0)
FB_Solidago simplex	0(0.0)	50(0.3)	0(0.0)	0(0.0)	0(0.0)
FB_Symphyotrichum spathulatum	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Taraxacum laevigatum	50(0.0)	25(0.2)	33(0.0)	27(0.0)	0(0.0)
FB_Taraxacum officinale	50(0.0)	100(0.1)	0(0.0)	0(0.0)	25(0.0)
FB_Tetraneuris acaulis	0(0.0)	0(0.0)	0(0.0)	9(0.0)	25(0.0)
FB_Thlaspi arvense	50(1.0)	100(0.1)	33(0.0)	9(0.0)	0(0.0)
FB_Townsendia hookeri	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Tragopogon dubius	100(0.1)	50(0.0)	33(0.0)	36(0.0)	75(0.3)
FB_Trifolium longipes var. reflexum	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Veronica arvensis	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Vicia americana	100(0.1)	25(0.0)	0(0.0)	9(0.0)	25(0.0)
FB_Viola adunca	0(0.0)	0(0.0)	33(0.0)	9(0.0)	0(0.0)
FB_Zigadenus venenosus var. gramineus	50(0.0)	100(0.1)	66(0.1)	100(0.3)	100(0.6)
FE_Woodsia oregana	50(0.0)	0(0.0)	33(0.0)	9(0.0)	25(0.0)
GR_Achnatherum nelsonii	50(0.5)	25(0.0)	33(0.7)	9(0.0)	25(0.0)
GR_Achnatherum occidentale	0(0.0)	75(1.5)	0(0.0)	0(0.0)	0(0.0)
GR_Bromus carinatus var. linearis	50(0.0)	75(1.3)	0(0.0)	0(0.0)	0(0.0)
GR_Bromus inermis	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Bromus tectorum	100(11.0)	50(0.0)	33(0.0)	9(0.0)	50(1.0)
GR_Carex filifolia	0(0.0)	0(0.0)	0(0.0)	18(0.1)	0(0.0)
GR_Carex geyeri Boott	0(0.0)	0(0.0)	0(0.0)	18(0.7)	0(0.0)
GR_Carex hoodii	0(0.0)	50(0.5)	0(0.0)	0(0.0)	0(0.0)
GR_Carex obtusata	0(0.0)	25(0.0)	0(0.0)	18(0.1)	0(0.0)
GR_Carex pensylvanica	0(0.0)	25(0.0)	33(0.0)	0(0.0)	0(0.0)
GR_Carex petasata	50(0.0)	100(1.5)	100(0.1)	9(0.0)	0(0.0)
GR_Carex praticola	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Carex rossii	50(0.0)	0(0.0)	33(0.3)	27(0.1)	25(0.2)
GR_Carex sprengelii	0(0.0)	50(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex vallicola	50(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
GR_Danthonia intermedia	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
GR_Danthonia spicata	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Danthonia unispicata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.8)
GR_Elymus lanceolatus	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Elymus smithii	0(0.0)	50(0.0)	0(0.0)	0(0.0)	25(0.0)
GR_Elymus spicatus	100(8.0)	100(7.0)	100(7.3)	90(5.3)	100(22.5)
GR_Elymus trachycaulus	0(0.0)	50(0.0)	33(0.0)	0(0.0)	0(0.0)
GR_Festuca idahoensis	50(2.5)	100(11.3)	100(12.3)	100(28.2)	100(7.5)

Table C.1. Cover and Constancy for Grassland/Shrubland Associations of the Beartooth Mountains Study Area (continued).

STRATA_*Species name*	ASAL3/BASA3	FEID/GEVI2	ARTRV/FEID	FEID/PSSPS	PSSPS/ARFR4
GR_Hesperostipa comata	0(0.0)	0(0.0)	0(0.0)	18(0.0)	75(1.3)
GR_Koeleria macrantha	50(0.0)	75(0.5)	100(1.7)	81(1.6)	100(1.6)
GR_Leucopoa kingii	0(0.0)	50(1.3)	100(0.7)	54(1.0)	0(0.0)
GR_Melica bulbosa	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Melica subulata	0(0.0)	25(1.0)	0(0.0)	0(0.0)	0(0.0)
GR_Nassella viridula	0(0.0)	0(0.0)	0(0.0)	9(0.1)	0(0.0)
GR_Phleum pratense	0(0.0)	50(5.5)	33(0.0)	9(0.0)	0(0.0)
GR_Poa cusickii	0(0.0)	75(0.3)	66(0.1)	27(0.4)	50(0.3)
GR_Poa fendleriana	50(1.0)	0(0.0)	0(0.0)	9(1.8)	0(0.0)
GR_Poa glauca var. rupicola	0(0.0)	50(0.3)	0(0.0)	0(0.0)	0(0.0)
GR_Poa juncifolia	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Poa pratensis	50(1.0)	100(20.0)	33(5.0)	18(0.0)	25(0.0)
SH_Amelanchier alnifolia	0(0.0)	25(0.2)	0(0.0)	9(0.0)	25(0.5)
SH_Arctostaphylos uva-ursi	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
SH_Artemisia frigida	0(0.0)	0(0.0)	33(0.0)	72(1.1)	100(4.3)
SH_Artemisia tridentata var. vaseyana	0(0.0)	25(0.0)	100(53.3)	54(1.9)	75(3.8)
SH_Artemisia tridentata var. wyomingensis	50(12.5)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Chrysothamnus viscidiflorus	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
SH_Gutierrezia sarothrae	0(0.0)	0(0.0)	0(0.0)	18(0.1)	25(0.0)
SH_Juniperus communis var. depressa	0(0.0)	0(0.0)	33(0.0)	9(0.1)	0(0.0)
SH_Juniperus scopulorum	50(0.5)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Mahonia repens	0(0.0)	0(0.0)	0(0.0)	18(0.2)	25(0.0)
SH_Pentaphylloides floribunda	0(0.0)	25(0.8)	0(0.0)	0(0.0)	0(0.0)
SH_Prunus virginiana var. melanocarpa	0(0.0)	0(0.0)	0(0.0)	9(0.0)	25(0.8)
SH_Ribes cereum var. pedicellare	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
SH_Rosa nutkana var. hispida	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
SH_Rosa sayi	0(0.0)	25(0.0)	33(0.0)	9(0.4)	25(1.2)
SH_Rosa woodsii	0(0.0)	25(0.8)	0(0.0)	0(0.0)	0(0.0)
SH_Spiraea betulifolia	0(0.0)	0(0.0)	0(0.0)	9(0.0)	25(0.5)
SH_Symphoricarpos albus	0(0.0)	25(5.0)	0(0.0)	0(0.0)	0(0.0)
SH_Symphoricarpos occidentalis	0(0.0)	50(0.0)	0(0.0)	9(0.2)	25(0.5)
TR_Pinus contorta var. latifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
TR_Pinus flexilis	0(0.0)	0(0.0)	66(0.1)	0(0.0)	0(0.0)
TR_Pseudotsuga menziesii var. glauca	0(0.0)	25(0.0)	33(0.0)	0(0.0)	0(0.0)

APPENDIX D

KEY TO WOODLAND AND FORESTED SERIES AND HABITAT TYPE

READ THESE INSTRUCTIONS FIRST!

9. Use this key for stands with a mature tree canopy that are not severely disturbed by grazing, logging,forest fire, etc. (If the stand is severely disturbed or in an early successional stage, the habitat type can best be determined by extrapolating from the nearest mature stand occupying a similar site.)
10. Accurately identify and record canopy coverages for all indicator species.
11. Check plot data in the field to verify that the plot is representative of the stand as a whole. If not, select another plot.
12. Identify the correct potential climax tree species in the SERIES key. (Generally, a tree species is considered reproducing successfully if 10 or more individuals per acre occupy or will occupy the site.)
13. Within the appropriate series, key to HABITAT TYPE and PHASE by following the key literally Verify your identification by comparing the stand conditions with the written descriptions. (The first phase in the key that fits the stand is the correct one.)
14. Use the definitions diagramed below for canopy coverage terms in the key. If you have difficulty deciding between types, refer to constancy and coverage data and the habitat type descriptions.
15. In stands where undergrowth is obviously depauperate (unusually sparse) because of dense shading or duff accumulations, adjust the definitions diagramed below to the next lower coverage class (for example, well represented >1%, common >0%.
16. Remember, the key is NOT the classification! Validate the determination made using the key by checking the written description.

Key to Forest Climax Series

1a. Habitats on steep slopes (30º) composed primarily of unstable fine rock; undergrowth sparse, poorly developed and quite variable ……..…….....……...… **SCREE**

1b. Habitats on sites with some soil development and stability; undergrowth rather well developed and somewhat uniform …….....…….……..…… **2**

2a. *Abies lasiocarpa* present and reproducing successfully (or *Pinus albicaulis* the dominant tree) ….....… ……....……...…….. ***Abies lasiocarpa*** **Series**

2b. Not as above …….....……..…….…… **3**

3a. *Picea engelmannii* present and reproducing successfully .....…… ***Picea engelmannii*** **Series**

3b. Not as above ……...……..…….…… **4**

4a. *Pinus flexilis* a successfully reproducing dominant; often sharing dominance with *Pseudotsuga menziesii* …….…… ***Pinus flexilis*** **Series**

4b. *Pinus flexilis* absent or clearly seral ……...…..…….…… **5**

5a. *Pseudotsuga menziesii* var. *glauca* present and reproducing successfully ……...……...… ……..…..…… ***Pseudotsuga menziesii*** **var. glauca Series**

5b. Not as above, *Pinus contorta* var. latifolia dominant with little indication as to potential climax ……...……...…… ***Pinus contorta*** **var**. ***latifolia*** **Series**

Key to *Pinus contorta* var. *latifolia* Habitat Types

1a. *Vaccinium membranaceum* well represented ….……..... ……...……...…….. ***Pinus contorta*** **var**. ***latifolia/Vaccinium membranaceum*** **h.t.**

1b. *Vaccinium membranaceum* poorly represented ……...……...…….. 2

2a. *Spiraea betulifolia* well represented..…. ***Pinus contorta*** **var**. ***latifolia/Spiraea betulafolia*** **h.t.**

2b. *Spiraea betulifolia* poorly represented …….....…… 3

3a. *Carex geyeri* well represented ..…….…… ***Pinus contorta*** var. ***latifolia/Carex geyeri*** **h.t.**

3b. *Carex geyeri* poorly represented ……...…… 4

4a. *Shepherdia canadensis* well represented ..…..... .....***Pinus contorta* var**. ***latifolia/Shepherdia canadensis* h.t.**

Key to *Pseudotsuga menziesii* var. *glauca* Habitat Types

1a. *Physocarpus malvaceus* well represented …..... .....***Pseudotsuga menziesii*** var.***glauca/Physocarpus malvaceous* h.t.**

a. *Calamagrostis rubescens* dominates the undergrowth …..…..... .....***Calamagrostis rubescens* phase**
b. *Physocarpus malvaceous* dominates the undergrowth ……..... .....***Physocarpus malvaceous* phase**

1b. *Physocarpus malvaceous* poorly represented ……..…… **2**

2a. *Vaccinium membranaceum* well represented ...…….....……. ……...…….. ***Pseudotsuga menziesii* var**. ***glauca/Vaccinium membranaceum* h.t.**

2b. *Vaccinium membranaceum* poorly represented.……..……...…… **4**

4a. *Symphoricarpos albus* well represented.…….……...…… .....***Pseudotsuga menziesii* var**. ***glauca/Symphoricarpos albus* h.t.**

4b. *Symphoricarpos albus* poorly represented.…… **5**

5a. *Juniperus communis* var. *depressa* (or *J. horizontalis*) well represented or dominating the undergrowth …..…….…… ***Pseudotsuga menziesii/Juniperus communis* var. *depressa* h.t.**

5b. *Juniperus communis* var. *depressa* not well represented or dominating the undergrowth..... 6

6a. *Spiraea betulifolia* well represented…..... .....***Pseudotsuga menziesii* var**. ***glauca/Spiraea betulifolia* h.t.**

6b. *Spiraea betulifolia* poorly represented ……...…….…….…… 7

7a. *Arnica cordifolia* or *Antennaria racemosa* the dominant undergrowth …….....…… .....……..……...…… ***Pseudotsuga menziesii* var. *glauca/Arnica cordifolia* h.t.**

7b. *Arnica cordifolia* and *Antennaria racemosa* not the dominant undergrowth ……...…… 8

Key to *Pinus flexilis* Habitat Types

1a. *Festuca idahoensis* well represented ……..…… ***Pinus flexilis/Festuca idahoensis* h.t.**

1b. Not as above ……...……...…… **2**

2a. *Elymus spicatus* well represented …….....…… ***Pinus flexilis/ Elymus spicatus* h.t.**

2b. *Elymus spicatus* poorly represented, *Juniperus communis* (*J. horizontalis*) well represented .... ……...… ***Pinus flexilis/Juniperus communis* var. *depressa* h.t.**

Key to *Picea engelmannii* Habitat Types

1a. *Juniperus communis* well represented …..... .....***Picea engelmannii/Juniperus communis* var. *depressa* h.t.**

1b. Not as above ……...…....……..… undefined high elevation ***Picea engelmannii* h.t.**

Key to *Abies lasiocarpa* Habitat Types

A. Sites at or above the cold limits of *Pseudotsuga menziesii* var. *glauca* and also meeting one of the following criteria:

a. *Pinus albicaulis* well represented;
b. *Abies lasiocarpa* and *Picea engelmannii* have low abundance;
c. Stands at upper timberline

UPPER SUBALPINE AND TIMBERLINE……..……. 12

B. Not as above……...……..… 1

1a. *Vaccinium cespitosum* well represented ….…… ***Abies lasiocarpa/Vaccinium cespitosum* h.t.**

1b. *Vaccinium cespitosum* poorly represented ……..…...… 2

2a. *Alnus sinuata* well represented ……...……..…… ***Abies lasiocarpa/Alnus sinuata* h.t.**

2b. *Alnus sinuata* poorly represented ……...……...… 3

3a. *Vaccinium membranaceum* well represented.....…..
.....***Abies lasiocarpa/Vaccinium membranaceum* h.t.**

3b. *Vaccinium membranaceum* poorly represented ……...…… 4

4a. *Vaccinium scoparium* well represented …...…..... ***Abies lasiocarpa/Vaccinium scoparium* h.t.**
- a. *Pinus albicaulis* well represented ……..... ***Pinus albicaulis* phase**
- b. *Vaccinium scoparium* well represented ……..... ***Vaccinium scoparium* phase**

4b. *Vaccinium scoparium* poorly represented ...……...…...… 5

5a. *Arnica latifolia* well represented ...……....…. ***Abies lasiocarpa/Arnica latifolia* h.t.**

5b. *Arnica latifolia* poorly represented ...……...……....… 6

6a. *Symphoricarpos albus* well represented ...…….***Abies lasiocarpa/Symphoricarpos albus* h.t.**

6b. *Symphoricarpos albus* poorly represented ……..….……...… 7

7a. *Spiraea betulifolia* well represented ...……...….... ***Abies lasiocarpa/Spiraea betulifolia* h.t.**

7b. *Spiraea betulifolia* poorly represented ……..…….……..…….……...… 8

8a. *Juniperus communis* var. *depressa* well represented ……..……
.....***Abies lasiocarpa/Juniperus communis var. depressa* h.t.**

8b. *Juniperus communis* var. *depressa* poorly represented ……...……..... 9

9a. *Arnica cordifolia* well represented …….…….…..... ***Abies lasiocarpa/Arnica cordifolia* h.t.**
- a. *Shepherdia canadens*is well represented ……...….. ***Shepherdia canadensis* phase**

9b. *Arnica cordifolia* poorly represented …….……..……..... 11

11a. *Carex rossii* well represented or the dominant undergrowth species ….....…… .....……..…….…. ***Abies lasiocarpa/Carex rossii*** **h.t.**

11b. Not as above …….…...…….. **unsampled or other h.t.**

12a. *Abies lasiocarpa* and *Picea engelmannii* scarce. *Vaccinium scoparium* well represented...… ……..... ***Pinus albicaulis/Vaccinium scoparium*** **h.t.**

12b. *Vaccinium scoparium* poorly represented …… 13

13a. *Juniperus communis* var. *depressa* well represented…….....…… ...……..***Pinus albicaulis/Juniperus communis*** **var. *depressa* h.t.**

13b. *Juniperus communis* var. *depressa* poorly represented..…….……....……. 14

14a. *Carex rossii* well represented or the dominant undergrowth species …….…….……... …….....……..…… ***Pinus albicaulis/Carex rossii*** **h.t.**

14b. Not as above……...…...…..……. **Undefined *Pinus albicaulis* timberline habitat type**

APPENDIX E

KEY TO WOODLAND AND FORESTED ASSOCIATIONS

Appendix E: Key to Woodland and Forested Associations

1a. Community dominated by *Pinus contorta* var. *latifolia, Pinus flexilis* and/or *Pseudotsuga menziesii* var. *glauca* …….....2

1b. Community dominated by *Abies lasiocarpa, Picea engelmannii* and/or *Pinus albicaulis* …..……... 8

2a. *Pinus contorta* var. *latifolia* the dominant overstory species ..…….……... 3

2b. Not as above ……..…….…..…… 4

3a. Early seral community dominated by regenerating *Pinus contorta* var. *latifolia. Ceanothus velutinus, Spiraea betulifolia, Vaccinium membranaceum, Shepherdia canadensis* and *Mahonia repens* are consistently associated and range in cover from well represented to abundant. The forb *Epilobium angustifolium* is also present ….…….... ***Pinus contorta* var**. ***latifolia/Ceanothus velutinus* association**

3b. *Pinus contorta* var. *latifolia* the dominant overstory species. *Pinus albicaulis, Abies lasiocarpa, Picea engelmannii, Pinus flexilis* and *Pseudotsuga menziesii* var. *glauca* may be present, but occur with less cover than *Pinus contorta*. The shrub species, *Ceanothus velutinus* and *Mahonia repens*, and forb species, *Epilobium angustifolium,* are generally absent …….……..……..
..... ***Pinus contorta* var**. ***latifolia/Spiraea betulifolia* association**

4a. *Pseudotsuga menziesii* var. *glauca* the dominant overstory species …….……...… 5

4b. *Pinus flexilis* the dominant overstory species ……...…… 7

5a. *Pseudotsuga menziesii* var. *glauca* dominates the overstory and is abundant (> 30%). *Juniperus communis* var. *depressa* is absent or poorly represented (<2%). *Symphoricarpos albus* and *Physocarpus malvaceus* are frequently the dominant shrub species. *Arnica cordifolia* and *Galium boreale* are the most frequently associated forb species and *Poa wheeleri* is the most frequently associated graminoid species ..……...…….……..…. ***Pseudotsuga menziesii* var**. ***glauca/Arnica cordifolia* association**

5b. Not as above, *Pseudotsuga* var. *glauca* with less total cover ……..…… 6

6a. *Pseudotsuga menziesii* var. *glauca* occurring with relatively low abundance (< 30% cover). *Pinus flexilis* is often present and well-represented in the overstory. The shrub species *Spiraea betulifolia, Ribes cernuum* var. *pedicillare Juniperus scopulorum* and *Juniperus communis* var. *depressa* consistently occur in very low abundance (<5%). *Elymus spicatus* is the most consistently associated graminoid and also occurs in low abundance ……..... ***Pseudotsuga menziesii* var**. ***glauca/mixed xeric shrub* association**

6b. *Pseudotsuga menziesii* var. *glauca* occurring with relatively low abundance (<30% cover). *Juniperus communis* var. *depressa* is the dominant understory shrub and occurs with > 20% cover ….....
…...……..… ***Pseudotsuga menziesii* var**. ***glauca/Juniperus communis* var. *depressa* association**

7a. *Pinus flexilis* is the dominant overstory tree species. *Pseudotsuga menziesii* is often present and well represented in the overstory and understory. *Tragapogon dubius* is present in low abundance (<1%). *Elymus spicatus* and *Leucopoa kingii* are consistently present and often well represented graminoids. *Ribes cernuum* and *Symphoricarpos albus* are commonly associated shrubs. *Macranthera grindelioides, Eremegone congesta* and *Castilleja miniata* are commonly associated forbs ……..……
.....***Pinus flexilis/Artimisia frigida*** **association**

7b. *Pinus flexilis* is the dominant overstory tree species. *Pseudotsuga menziesii* is absent from the overstory and infrequently and poorly represented in the understory. *Tragopogon dubius* is absent. *Chaenactis douglasii, Phacelia linearis, Agoseris glauca* and *Astragalus miser* are commonly associated forb species ……..…… ……...***Pinus flexilis/Agoseris glauca*** **association**

8a. High elevation community dominated by extremely stunted *Pinus albicaulis*. Stunted *Abies lasiocarpa* and *Picea engelmannii* also occur, but in lesser abundance. *Arcotostaphylus uva-ursi* is present and can become well represented. *Juniperus communis*, *Luzula spicata*, *Carex paysonis*, *Sibbaldia procumbens, Minuartia obtusiloba* are consistently associated species ……..…..……..…
.....***Pinus albicaulis/Arctostaphylos uva-ursi*** **association**

8b. Not as above ..…..……...……..… 9

9a. High elevation *Picea engelmannii*-dominated community. *Pinus albicaulis* may be present on granitic substrates and *Pinus flexilis* on calcareous substrates. Vegetation composition highly variable. *Minuartia obtusiloba* and *Sedum lanceolatum* are commonly associated forbs. *Carex rossii* is the most common graminoid. Other cushion plant species and forb and graminoid species common to the alpine zone may be represented. No *Vaccinium scoparium* observed..…. ***Picea engelmannii/Minuartia obtusiloba*** **association**

9b. Not as above ……..…….…….……..…….. 10

10a. *Abies lasiocarpa* dominant tree in overstory and *Vaccinium scoparium* present or, if *Vaccinium scoparium* absent, *Pinus albicaulis* dominant tree in overstory or *Ribes lacustre, Alnus viridis, Vaccinium membranaceum, Arnica cordifolia, Arnica latifolia* and/or *Thalictrum occidentale* are present to well-represented ……..…..……..…… 11

10b. *Vaccinium scoparium* absent and *Symphoricarpos albus* abundant (>20%), *Balsamorhiza sagittata, Cerastium arvense, Fragaria virginiana, Galium boreale, Geranium viscosissimum, Lupinus argenteus, Taraxacum officionale, Amelanchier alnifolia, Mahonia repens, Prunus virginiana* var. *melanocarpa, Shepherdia canadensis* and *Spiraea betulifolia* are consistently associated species. *Pinus flexilis* present and reproducing successfully ……..... ***Abies lasiocarpa/Symphoricarpos albus*** **association**

11a. *Abies lasiocarpa* is the dominant tree in the overstory and is generally abundant (>40%). *Pinus albicaulis* is absent from or poorly represented in the overstory (<5%). *Ribes lacustre* and *Arnica cordifolia* are consistently present to well represented and occur in combination with at least one of the following species: *Alnus sinuata, Vaccinium membranaceum, Thalictrum occidentale* ….....……
.....…….... ***Abies lasiocarpa/Arnica cordifolia*** **association**

11b. *Abies lasiocarpa* dominant tree in overstory and *Vaccinium scoparium* well represented to abundant OR *Pinus albicaulis* dominant tree in overstory and *Vaccinium scoparium* representation variable. *Arnica latifolia* is the most commonly associated forb species, generally occurring with cover < 10% .....
...……..……...…… ***Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium*** **association**

APPENDIX F

COVER AND CONSTANCY TABLE FOR FORESTED ASSOCIATIONS OF THE BEARTOOTH MOUNTAINS STUDY AREA

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area.

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
CM_Selaginella sp. (densa or watsonii)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	16(0.2)	0(0.0)
FB_Achillea millefolium var. lanulosa	100(1.6)	22(0.0)	66(0.4)	66(0.1)	33(0.0)	42(0.0)
FB_Actaea rubra	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Agoseris glauca	50(1.5)	0(0.0)	33(0.0)	100(0.1)	0(0.0)	14(0.0)
FB_Allium cernuum	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Allium textile	0(0.0)	11(0.0)	33(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Anaphalis margaritacea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)	0(0.0)
FB_Androsace chamaejasme var. carinata	0(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Androsace septentrionalis var. subulifera	0(0.0)	22(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Anemone lithophila	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Anemone multifida	50(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Anemone patens var. multifida	50(1.0)	0(0.0)	33(0.3)	0(0.0)	0(0.0)	0(0.0)
FB_Angelica arguta	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Antennaria corymbosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Antennaria lanata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Antennaria media	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Antennaria microphylla	0(0.0)	11(0.0)	33(0.3)	0(0.0)	50(0.0)	28(0.0)
FB_Antennaria racemosa	0(0.0)	44(0.3)	33(0.0)	0(0.0)	16(0.0)	14(0.7)
FB_Antennaria rosea	0(0.0)	0(0.0)	33(0.0)	33(0.0)	0(0.0)	28(0.0)
FB_Antennaria umbrinella	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Apocynum androsaemifolium	50(2.5)	0(0.0)	0(0.0)	0(0.0)	16(0.0)	0(0.0)
FB_Aquilegia flavescens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Aquilegia formosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Aquilegia jonesii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Arabis hirsuta	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Arenaria capillaris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Arenaria serpyllifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Arnica cordifolia	100(2.0)	77(3.2)	0(0.0)	0(0.0)	83(0.2)	28(0.0)
FB_Arnica fulgens	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Arnica latifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.1)
FB_Arnica mollis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Arnica rydbergii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Arnica sororia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.3)
FB_Artemisia campestris	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Artemisia dracunculus	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Artemisia ludoviciana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	28(0.0)
FB_Artemisia michauxiana	0(0.0)	0(0.0)	33(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Artemisia scopulorum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Astragalus alpinus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Astragalus australis var. glabriusculus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Astragalus drummondii	0(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Astragalus gilviflorus	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Astragalus miser	50(0.5)	11(0.4)	0(0.0)	66(1.7)	0(0.0)	14(0.0)
FB_Balsamorhiza incana	50(1.5)	0(0.0)	33(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Balsamorhiza sagittata	100(1.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Besseya wyomingensis	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Boechera angustifolia	50(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)	28(0.0)
FB_Boechera exilis	0(0.0)	0(0.0)	33(0.0)	33(0.0)	16(0.0)	28(0.0)
FB_Boechera holboellii	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Boechera lyallii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Boechera microphylla	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Boechera nuttallii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	42(0.0)
FB_Bupleurum americanum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	28(0.0)
FB_Caltha leptosepala	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Calypso bulbosa	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Campanula rotundifolia	100(0.6)	33(0.0)	33(0.0)	66(0.1)	66(0.1)	71(0.1)
FB_Castilleja miniata	50(0.0)	0(0.0)	66(0.1)	0(0.0)	16(0.2)	28(0.0)
FB_Castilleja pulchella	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Castilleja rhexiifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Cerastium arvense	100(1.0)	0(0.0)	66(0.1)	66(0.1)	0(0.0)	14(0.0)
FB_Cerastium fontanum	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Chaenactis alpina	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Chaenactis douglasii var. montana	0(0.0)	0(0.0)	0(0.0)	66(0.1)	0(0.0)	0(0.0)
FB_Chamerion angustifolium	100(0.6)	33(0.0)	0(0.0)	0(0.0)	100(2.7)	28(0.0)
FB_Cirsium eatonii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Cirsium undulatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Claytonia lanceolata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Clematis columbiana	50(0.5)	22(0.6)	33(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Clematis hirsutissima	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Clematis occidentalis	0(0.0)	44(0.1)	0(0.0)	33(0.3)	0(0.0)	14(0.0)
FB_Collinsia parviflora	0(0.0)	22(0.0)	33(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Collomia linearis	0(0.0)	0(0.0)	33(0.0)	33(0.0)	0(0.0)	14(0.0)
FB_Comandra umbellata var. pallida	0(0.0)	0(0.0)	33(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Corallorhiza wisteriana	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Corydalis aurea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Crepis intermedia	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Cryptantha celosioides	0(0.0)	0(0.0)	66(0.1)	33(0.0)	0(0.0)	0(0.0)
FB_Cryptantha torreyana	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Cryptantha watsonii	0(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Cynoglossum officinale	0(0.0)	22(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Cystopteris fragilis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Delphinium bicolor	50(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)	14(0.0)
FB_Descurainia incana	0(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Dodecatheon conjugens	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Draba globosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Draba incerta	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Draba lonchocarpa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Epilobium anagallidifolium	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Epilobium ciliatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Equisetum arvense	0(0.0)	0(0.0)	0(0.0)	0(0.0)	16(0.2)	0(0.0)
FB_Eremogone congesta	50(3.0)	0(0.0)	66(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Eremogone hookeri var. hookeri	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron caespitosus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	28(0.0)
FB_Erigeron compositus var. discoideus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron peregrinus var. scaposus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron rydbergii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron simplex	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron speciosus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron ursinus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Eriogonum flavum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Eriogonum umbellatum	50(0.5)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Eriophyllum lanatum var. integrifolium	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erysimum asperum	50(0.0)	0(0.0)	66(0.1)	66(0.1)	0(0.0)	28(0.0)
FB_Eurybia conspicua	0(0.0)	11(0.0)	33(0.0)	0(0.0)	83(1.2)	14(0.0)
FB_Eurybia integrifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Fragaria vesca	0(0.0)	44(0.1)	0(0.0)	0(0.0)	16(0.0)	42(0.0)
FB_Fragaria virginiana	100(1.6)	22(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Frasera speciosa	50(0.0)	11(0.0)	33(0.0)	33(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Fritillaria atropurpurea	50(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Gaillardia aristata	0(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)	14(0.0)
FB_Galium bifolium	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Galium boreale	100(6.5)	77(0.3)	33(0.0)	33(0.0)	33(0.0)	28(0.1)
FB_Galium triflorum	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Geranium richardsonii	50(0.0)	0(0.0)	0(0.0)	0(0.0)	16(0.0)	0(0.0)
FB_Geranium viscosissimum	100(2.5)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.1)
FB_Geum rossii var. turbinatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Geum triflorum	0(0.0)	11(0.0)	33(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Goodyera oblongifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Hedysarum boreale	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Hedysarum sulphurescens	50(1.5)	0(0.0)	0(0.0)	33(1.0)	0(0.0)	14(0.0)
FB_Helianthella uniflora	50(2.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Heracleum sphondylium var. lanatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Heterotheca villosa	0(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Heuchera cylindrica var. suksdorfii	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)	28(0.3)
FB_Heuchera parvifolia	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Hieracium albiflorum	50(0.0)	0(0.0)	0(0.0)	0(0.0)	33(0.0)	14(0.0)
FB_Hieracium cynoglossoides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	16(0.0)	0(0.0)
FB_Hieracium triste var. gracile	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Kelseya uniflora	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Lithospermum ruderale	50(0.5)	0(0.0)	33(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Lloydia serotina	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Lomatium attenuatum	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	28(0.4)
FB_Lomatium cous	50(0.0)	0(0.0)	33(0.3)	66(0.1)	0(0.0)	0(0.0)
FB_Lomatium dissectum	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Lomatium triternatum	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Lupinus argenteus	100(5.0)	0(0.0)	0(0.0)	33(0.0)	16(0.0)	0(0.0)
FB_Lupinus sericeus	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Machaeranthera grindelioides	0(0.0)	0(0.0)	66(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Maianthemum racemosum var. amplexicaule	50(1.5)	22(0.4)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Maianthemum stellatum	50(0.0)	22(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Mertensia alpina	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Mertensia ciliata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Mertensia oblongifolia	50(0.5)	0(0.0)	33(0.0)	66(0.7)	0(0.0)	0(0.0)
FB_Microsteris gracilis	0(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Minuartia nuttallii	0(0.0)	0(0.0)	33(0.3)	0(0.0)	0(0.0)	14(0.0)
FB_Minuartia obtusiloba	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Mitella pentandra	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Moehringia lateriflora	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Monarda fistulosa var. menthifolia	50(0.5)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Myosotis alpestris	0(0.0)	11(0.0)	0(0.0)	33(0.0)	0(0.0)	14(0.0)
FB_Nepeta cataria	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Noccaea montana	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Oreostemma alpigenum var. haydenii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Orthilia secunda	0(0.0)	22(0.0)	0(0.0)	0(0.0)	16(0.2)	0(0.0)
FB_Osmorhiza berteroi	0(0.0)	11(0.2)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Osmorhiza depauperata	50(2.5)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Oxytropis borealis var. viscida	0(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Oxytropis lagopus	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Oxytropis sericea	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Packera cana	0(0.0)	0(0.0)	100(0.1)	100(0.1)	0(0.0)	28(0.0)
FB_Packera dimorphophylla var. paysonii	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Parnassia fimbriata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Paxistima myrsinites	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Pedicularis bracteosa var. paysoniana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Pedicularis oederi	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Penstemon fruticosus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	16(0.7)	14(0.6)
FB_Penstemon procerus	50(0.0)	0(0.0)	0(0.0)	33(0.7)	0(0.0)	14(0.0)
FB_Penstemon rydbergii	0(0.0)	0(0.0)	33(0.3)	0(0.0)	0(0.0)	0(0.0)
FB_Perideridia montana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Phacelia hastata	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	28(0.0)
FB_Phacelia linearis	0(0.0)	0(0.0)	0(0.0)	66(0.1)	0(0.0)	0(0.0)
FB_Phlox albomarginata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Phlox diffusa var. scleranthifolia	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Phlox hoodii	0(0.0)	0(0.0)	33(0.0)	66(0.1)	0(0.0)	0(0.0)
FB_Platanthera dilatata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Polygonum bistortoides	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Polygonum douglasii	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Potentilla diversifolia	0(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Potentilla glandulosa	0(0.0)	11(0.0)	33(0.3)	0(0.0)	0(0.0)	28(0.0)
FB_Potentilla gracilis var. flabelliformis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Potentilla ovina var. ovina	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Potentilla pensylvanica	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Prosartes trachycarpa	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Pterospora andromedea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Pyrola chlorantha	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.1)
FB_Pyrola picta var. dentata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Ranunculus eschscholtzii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Ranunculus pensylvanicus	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Ranunculus uncinatus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Saxifraga bronchialis var. austromantana	0(0.0)	33(0.4)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Saxifraga occidentalis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Saxifraga odontoloma	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Saxifraga rhomboidea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Sedum integrifolium	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Sedum lanceolatum	0(0.0)	22(0.0)	66(0.1)	33(0.0)	16(0.0)	14(0.0)
FB_Sedum rhodanthum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Senecio crassulus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Senecio integerrimus	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Senecio lugens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Senecio serra	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Senecio triangularis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Sibbaldia procumbens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Silene acaulis var. subacaulescens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Solidago canadensis	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Solidago multiradiata var. scopulorum	0(0.0)	11(0.0)	66(0.1)	33(0.0)	16(0.0)	14(0.1)
FB_Solidago velutina	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Stellaria monantha	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Stephanomeria runcinata	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Streptopus amplexifolius	0(0.0)	33(1.0)	33(0.0)	0(0.0)	16(0.0)	0(0.0)
FB_Symphyotrichum foliaceum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Symphyotrichum lanceolatum ssp. hesperium	0(0.0)	0(0.0)	0(0.0)	0(0.0)	16(0.3)	0(0.0)
FB_Taraxacum laevigatum	0(0.0)	11(0.0)	33(0.0)	0(0.0)	16(0.0)	0(0.0)
FB_Taraxacum officinale	100(0.1)	44(0.0)	33(0.0)	33(0.0)	33(0.0)	14(0.0)
FB_Telesonix heucheriformis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Thalictrum occidentale	0(0.0)	22(0.4)	0(0.0)	0(0.0)	16(0.7)	0(0.0)
FB_Townsendia parryi	0(0.0)	0(0.0)	66(0.1)	33(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Tragopogon dubius	0(0.0)	11(0.0)	100(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Trifolium fragiferum	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Trifolium haydenii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Trifolium repens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Trollius albiflorus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Valeriana dioica var. sylvatica	0(0.0)	33(0.6)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Valeriana edulis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Valeriana occidentalis	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Veronica wormskjoldii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Viola adunca	50(0.0)	11(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Viola nuttallii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FB_Viola praemorsa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Zigadenus elegans	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Zigadenus venenosus var. gramineus	50(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
FE_Cystopteris fragilis	50(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
FE_Polystichum lonchitis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FE_Woodsia oregana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
GR_Bromus tectorum	0(0.0)	0(0.0)	33(0.0)	33(0.0)	0(0.0)	14(0.0)
GR_Calamagrostis inexpansa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	16(2.5)	0(0.0)
GR_Calamagrostis purpurascens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Calamagrostis rubescens	0(0.0)	22(0.0)	0(0.0)	0(0.0)	33(1.4)	0(0.0)
GR_Carex backii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
GR_Carex capitata	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex elynoides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex filifolia	0(0.0)	11(0.0)	33(0.0)	66(0.1)	0(0.0)	0(0.0)
GR_Carex geyeri Boott	0(0.0)	0(0.0)	0(0.0)	0(0.0)	66(1.8)	28(0.0)
GR_Carex hoodii	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
GR_Carex microptera	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex obtusata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex paysonis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex petasata	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
GR_Carex phaeocephala	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex rossii	100(2.0)	55(0.0)	66(0.1)	0(0.0)	33(0.0)	71(0.3)
GR_Carex rupestris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex sprengelii	50(0.0)	11(0.6)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Danthonia intermedia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Deschampsia cespitosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Elymus elymoides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
GR_Elymus glaucus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	16(0.0)	0(0.0)
GR_Elymus spicatus	50(7.5)	0(0.0)	100(3.0)	66(0.4)	0(0.0)	56(0.4)
GR_Festuca brachyphylla	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
GR_Festuca campestris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Festuca idahoensis	0(0.0)	11(0.0)	33(1.7)	33(0.0)	0(0.0)	14(0.1)
GR_Festuca pratensis	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Juncus parryi	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Koeleria macrantha	50(0.0)	0(0.0)	66(0.1)	33(0.0)	0(0.0)	14(0.0)
GR_Leucopoa kingii	50(2.5)	11(0.0)	100(1.7)	66(0.1)	0(0.0)	28(0.0)
GR_Luzula parviflora	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Luzula spicata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Oryzopsis asperifolia	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Phleum alpinum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Phleum pratense	50(1.5)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.1)
GR_Piptatherum exiguum	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	28(0.0)
GR_Poa alpina	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
GR_Poa arctica var. arctica	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa cusickii	0(0.0)	0(0.0)	33(0.0)	33(0.0)	0(0.0)	28(0.3)
GR_Poa fendleriana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa glauca var. rupicola	0(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
GR_Poa interior	50(0.5)	0(0.0)	0(0.0)	33(0.0)	0(0.0)	14(0.0)
GR_Poa juncifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa palustris	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa pattersonii	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa pratensis	50(1.5)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	14(0.1)
GR_Poa reflexa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa secunda	50(0.5)	0(0.0)	66(0.1)	33(0.0)	0(0.0)	14(0.0)
GR_Poa wheeleri	50(1.5)	66(0.4)	0(0.0)	0(0.0)	16(0.0)	0(0.0)
GR_Trisetum spicatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
SH_Acer glabrum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	16(0.0)	28(0.4)
SH_Alnus viridis ssp. sinuata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	33(0.7)	0(0.0)
SH_Amelanchier alnifolia	100(1.0)	0(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)
SH_Arctostaphylos uva-ursi	50(0.0)	11(0.1)	0(0.0)	0(0.0)	16(0.2)	28(0.0)
SH_Artemisia arbuscula	0(0.0)	0(0.0)	33(1.3)	0(0.0)	0(0.0)	0(0.0)
SH_Artemisia frigida	0(0.0)	0(0.0)	100(0.4)	66(0.1)	0(0.0)	28(0.0)
SH_Artemisia tridentata var. vaseyana	50(1.5)	11(2.2)	100(2.4)	66(2.7)	0(0.0)	28(0.1)
SH_Ceanothus velutinus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	83(7.2)	28(0.0)
SH_Chimaphila umbellata var. occidentalis	0(0.0)	11(0.1)	0(0.0)	0(0.0)	0(0.0)	14(0.4)
SH_Chrysothamnus nauseosus	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Chrysothamnus viscidiflorus	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Dryas octopetala var. hookeriana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Gaultheria humifusa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Juniperus communis var. depressa	50(0.0)	55(0.2)	66(0.7)	66(4.0)	0(0.0)	100(1.9)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
SH_Juniperus horizontalis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Juniperus scopulorum	0(0.0)	0(0.0)	66(4.0)	66(2.3)	0(0.0)	42(1.7)
SH_Kalmia microphylla	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Ledum glandulosum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Linnaea borealis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Lonicera utahensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	16(0.2)	0(0.0)
SH_Mahonia repens	100(0.1)	0(0.0)	33(0.0)	0(0.0)	100(0.9)	14(0.1)
SH_Penstemon fruticosus	0(0.0)	11(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
SH_Pentaphylloides floribunda	0(0.0)	22(0.2)	33(0.0)	0(0.0)	0(0.0)	14(0.0)
SH_Phyllodoce empetriformis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Phyllodoce glanduliflora	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Physocarpus malvaceus	0(0.0)	44(1.1)	33(0.3)	0(0.0)	0(0.0)	28(0.0)
SH_Prunus emarginata	0(0.0)	11(0.2)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Prunus pensylvanica	0(0.0)	0(0.0)	0(0.0)	0(0.0)	16(0.0)	0(0.0)
SH_Prunus virginiana var. melanocarpa	100(2.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	14(0.4)
SH_Rhus aromatica var. trilobata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)
SH_Ribes cereum var. pedicellare	0(0.0)	11(0.0)	66(0.1)	0(0.0)	0(0.0)	42(0.3)
SH_Ribes inerme	0(0.0)	11(0.1)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Ribes lacustre	0(0.0)	11(0.0)	0(0.0)	0(0.0)	33(0.0)	14(0.0)
SH_Ribes montigenum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Ribes oxyacanthoides var. oxyacanthoides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Ribes oxyacanthoides var. setosum	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	14(0.0)
SH_Ribes viscosissimum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	83(1.0)	28(0.0)
SH_Rosa nutkana var. hispida	0(0.0)	11(0.3)	0(0.0)	0(0.0)	50(0.9)	14(0.0)
SH_Rosa sayi	50(1.5)	22(0.4)	33(1.0)	0(0.0)	33(0.3)	28(0.0)
SH_Rosa woodsii	50(1.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	14(0.0)
SH_Rubus idaeus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	33(0.0)	14(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
SH_Rubus parviflorus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	66(3.0)	0(0.0)
SH_Salix arctica var. petraea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Salix bebbiana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Salix glauca var. villosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Salix scouleriana	50(0.0)	0(0.0)	0(0.0)	0(0.0)	16(0.0)	0(0.0)
SH_Sambucus racemosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	33(0.0)	0(0.0)
SH_Shepherdia canadensis	100(0.1)	0(0.0)	0(0.0)	0(0.0)	100(4.0)	28(0.7)
SH_Spiraea betulifolia	100(1.0)	44(0.6)	33(0.0)	0(0.0)	100(8.3)	71(0.6)
SH_Symphoricarpos albus	100(25.0)	55(3.7)	66(0.4)	0(0.0)	50(1.2)	0(0.0)
SH_Symphoricarpos occidentalis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	16(0.3)	14(0.3)
SH_Symphoricarpos oreophilus var. utahensis	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)	28(1.1)
SH_Vaccinium cespitosum	0(0.0)	0(0.0)	0(0.0)	33(1.0)	16(0.0)	0(0.0)
SH_Vaccinium membranaceum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	66(6.8)	0(0.0)
SH_Vaccinium scoparium	0(0.0)	0(0.0)	0(0.0)	0(0.0)	33(2.8)	14(0.3)
TO_Abies lasiocarpa	50(15.0)	22(0.4)	0(0.0)	0(0.0)	0(0.0)	14(0.3)
TO_Picea engelmannii	0(0.0)	22(2.2)	0(0.0)	33(0.3)	0(0.0)	28(0.4)
TO_Pinus albicaulis	0(0.0)	11(0.1)	0(0.0)	0(0.0)	0(0.0)	14(0.7)
TO_Pinus contorta var. latifolia	50(10.0)	33(7.8)	0(0.0)	0(0.0)	16(0.2)	42(2.3)
TO_Pinus flexilis	50(5.0)	22(2.5)	100(3.7)	100(31.7)	0(0.0)	28(0.3)
TO_Pinus ponderosa	50(5.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
TO_Pseudotsuga menziesii var. glauca	0(0.0)	100(53.9)	66(1.0)	0(0.0)	0(0.0)	100(12.7)
TR_Abies lasiocarpa	50(0.0)	22(1.9)	0(0.0)	0(0.0)	16(0.0)	28(1.3)
TR_Picea engelmannii	0(0.0)	33(0.2)	33(0.0)	33(0.0)	0(0.0)	28(0.1)
TR_Pinus albicaulis	0(0.0)	11(0.2)	0(0.0)	0(0.0)	0(0.0)	28(0.0)
TR_Pinus contorta var. latifolia	0(0.0)	22(0.1)	0(0.0)	0(0.0)	100(51.7)	28(0.1)
TR_Pinus flexilis	100(1.0)	44(0.0)	100(3.7)	100(3.7)	0(0.0)	56(0.6)
TR_Populus tremuloides	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
TR_Pseudotsuga menziesii var. glauca	50(0.0)	100(1.6)	100(2.7)	33(0.0)	0(0.0)	85(3.0)
CM_Selaginella sp. (densa or watsonii)	4(0.0)	0(0.0)	8(0.4)	0(0.0)	18(0.3)	0(0.0)
FB_Achillea millefolium var. lanulosa	4(0.0)	50(0.0)	33(0.0)	0(0.0)	31(0.0)	50(0.0)
FB_Actaea rubra	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Agoseris glauca	0(0.0)	0(0.0)	8(0.0)	0(0.0)	40(0.1)	0(0.0)
FB_Allium cernuum	0(0.0)	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Allium textile	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Anaphalis margaritacea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	12(0.0)	0(0.0)
FB_Androsace chamaejasme var. carinata	0(0.0)	0(0.0)	0(0.0)	50(0.0)	0(0.0)	0(0.0)
FB_Androsace septentrionalis var. subulifera	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Anemone lithophila	0(0.0)	0(0.0)	8(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Anemone multifida	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Anemone patens var. multifida	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Angelica arguta	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Antennaria corymbosa	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	50(0.0)
FB_Antennaria lanata	0(0.0)	0(0.0)	0(0.0)	50(0.0)	34(0.3)	0(0.0)
FB_Antennaria media	0(0.0)	0(0.0)	8(0.0)	0(0.0)	15(0.0)	0(0.0)
FB_Antennaria microphylla	0(0.0)	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Antennaria racemosa	16(0.1)	50(0.5)	50(0.3)	0(0.0)	12(0.0)	0(0.0)
FB_Antennaria rosea	8(0.0)	0(0.0)	16(0.0)	0(0.0)	12(0.0)	0(0.0)
FB_Antennaria umbrinella	4(0.0)	50(0.0)	0(0.0)	50(0.0)	6(0.0)	50(1.0)
FB_Apocynum androsaemifolium	4(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Aquilegia flavescens	0(0.0)	0(0.0)	33(0.3)	0(0.0)	9(0.0)	0(0.0)
FB_Aquilegia formosa	0(0.0)	0(0.0)	8(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Aquilegia jonesii	0(0.0)	0(0.0)	0(0.0)	50(0.0)	0(0.0)	0(0.0)
FB_Arabis hirsuta	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Arenaria capillaris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Arenaria serpyllifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Arnica cordifolia	20(0.1)	50(0.0)	75(2.0)	0(0.0)	28(0.4)	0(0.0)
FB_Arnica fulgens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Arnica latifolia	0(0.0)	0(0.0)	16(0.9)	0(0.0)	75(2.1)	0(0.0)
FB_Arnica mollis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	6(0.0)	0(0.0)
FB_Arnica rydbergii	0(0.0)	50(1.0)	25(0.9)	50(0.5)	15(0.0)	0(0.0)
FB_Arnica sororia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Artemisia campestris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Artemisia dracunculus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Artemisia ludoviciana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Artemisia michauxiana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Artemisia scopulorum	0(0.0)	0(0.0)	0(0.0)	50(1.0)	0(0.0)	0(0.0)
FB_Astragalus alpinus	0(0.0)	0(0.0)	16(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Astragalus australis var. glabriusculus	4(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Astragalus drummondii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Astragalus gilviflorus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Astragalus miser	16(0.0)	0(0.0)	8(0.2)	0(0.0)	3(0.0)	0(0.0)
FB_Balsamorhiza incana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Balsamorhiza sagittata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Besseya wyomingensis	0(0.0)	0(0.0)	8(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Boechera angustifolia	0(0.0)	0(0.0)	8(0.0)	0(0.0)	6(0.0)	0(0.0)
FB_Boechera exilis	4(0.0)	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Boechera holboellii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Boechera lyallii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.5)
FB_Boechera microphylla	0(0.0)	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Boechera nuttallii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Bupleurum americanum	4(0.0)	50(0.0)	8(0.0)	50(0.0)	3(0.0)	0(0.0)
FB_Caltha leptosepala	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Calypso bulbosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Campanula rotundifolia	52(0.0)	100(0.1)	16(0.0)	50(0.0)	12(0.0)	50(0.0)
FB_Castilleja miniata	0(0.0)	0(0.0)	16(0.0)	0(0.0)	6(0.0)	0(0.0)
FB_Castilleja pulchella	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
FB_Castilleja rhexiifolia	0(0.0)	0(0.0)	16(0.1)	0(0.0)	21(0.0)	0(0.0)
FB_Cerastium arvense	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Cerastium fontanum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Chaenactis alpina	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
FB_Chaenactis douglasii var. montana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
FB_Chamerion angustifolium	4(0.0)	50(0.0)	57(0.6)	0(0.0)	53(0.1)	0(0.0)
FB_Cirsium eatonii	0(0.0)	0(0.0)	8(0.0)	0(0.0)	6(0.0)	0(0.0)
FB_Cirsium undulatum	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Claytonia lanceolata	0(0.0)	0(0.0)	25(0.3)	0(0.0)	31(0.1)	0(0.0)
FB_Clematis columbiana	4(0.0)	50(0.0)	8(0.2)	0(0.0)	0(0.0)	0(0.0)
FB_Clematis hirsutissima	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Clematis occidentalis	0(0.0)	0(0.0)	8(0.0)	50(0.0)	0(0.0)	0(0.0)
FB_Collinsia parviflora	0(0.0)	0(0.0)	8(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Collomia linearis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Comandra umbellata var. pallida	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Corallorhiza wisteriana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Corydalis aurea	4(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Crepis intermedia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Cryptantha celosioides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Cryptantha torreyana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Cryptantha watsonii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Cynoglossum officinale	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Cystopteris fragilis	0(0.0)	0(0.0)	16(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Delphinium bicolor	4(0.0)	0(0.0)	16(0.2)	0(0.0)	0(0.0)	0(0.0)
FB_Descurainia incana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Dodecatheon conjugens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Draba globosa	0(0.0)	0(0.0)	0(0.0)	50(0.0)	0(0.0)	0(0.0)
FB_Draba incerta	0(0.0)	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Draba lonchocarpa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
FB_Epilobium anagallidifolium	0(0.0)	0(0.0)	8(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Epilobium ciliatum	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Equisetum arvense	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Eremogone congesta	4(0.0)	0(0.0)	8(0.0)	0(0.0)	21(0.0)	50(0.0)
FB_Eremogone hookeri var. hookeri	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron caespitosus	0(0.0)	50(0.0)	0(0.0)	50(0.0)	0(0.0)	0(0.0)
FB_Erigeron compositus var. discoideus	0(0.0)	50(0.0)	0(0.0)	0(0.0)	6(0.0)	0(0.0)
FB_Erigeron peregrinus var. scaposus	0(0.0)	0(0.0)	25(0.5)	0(0.0)	25(0.3)	0(0.0)
FB_Erigeron rydbergii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
FB_Erigeron simplex	0(0.0)	0(0.0)	0(0.0)	50(0.0)	9(0.0)	50(0.0)
FB_Erigeron speciosus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Erigeron ursinus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Eriogonum flavum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Eriogonum umbellatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Eriophyllum lanatum var. integrifolium	0(0.0)	0(0.0)	0(0.0)	50(0.0)	0(0.0)	0(0.0)
FB_Erysimum asperum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Eurybia conspicua	4(0.0)	50(0.5)	16(0.1)	0(0.0)	3(0.0)	0(0.0)
FB_Eurybia integrifolia	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Fragaria vesca	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Fragaria virginiana	0(0.0)	0(0.0)	16(0.2)	0(0.0)	0(0.0)	0(0.0)
FB_Frasera speciosa	0(0.0)	0(0.0)	8(0.0)	50(0.0)	6(0.0)	0(0.0)
FB_Fritillaria atropurpurea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Gaillardia aristata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Galium bifolium	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Galium boreale	4(0.0)	0(0.0)	25(0.2)	0(0.0)	0(0.0)	0(0.0)
FB_Galium triflorum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Geranium richardsonii	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Geranium viscosissimum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Geum rossii var. turbinatum	0(0.0)	0(0.0)	0(0.0)	50(0.0)	9(0.0)	50(0.0)
FB_Geum triflorum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Goodyera oblongifolia	4(0.0)	0(0.0)	8(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Hedysarum boreale	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Hedysarum sulphurescens	24(0.2)	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Helianthella uniflora	4(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Heracleum sphondylium var. lanatum	0(0.0)	0(0.0)	8(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Heterotheca villosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Heuchera cylindrica var. suksdorfii	4(0.0)	100(0.1)	0(0.0)	0(0.0)	6(0.0)	0(0.0)
FB_Heuchera parvifolia	4(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Hieracium albiflorum	8(0.0)	50(0.0)	8(0.0)	0(0.0)	12(0.1)	0(0.0)
FB_Hieracium cynoglossoides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Hieracium triste var. gracile	0(0.0)	0(0.0)	0(0.0)	0(0.0)	43(0.3)	0(0.0)
FB_Kelseya uniflora	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Lactuca serriola	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Lesquerella alpina	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Lewisia pygmaea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	15(0.0)	0(0.0)
FB_Linum lewisii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Listera cordata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Lithophragma parviflorum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Lithospermum ruderale	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Lloydia serotina	0(0.0)	0(0.0)	0(0.0)	50(0.0)	3(0.0)	0(0.0)
FB_Lomatium attenuatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Lomatium cous	0(0.0)	0(0.0)	8(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Lomatium dissectum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Lomatium triternatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Lupinus argenteus	16(0.2)	0(0.0)	0(0.0)	50(2.0)	31(0.1)	0(0.0)
FB_Lupinus sericeus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Machaeranthera grindelioides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Maianthemum racemosum var. amplexicaule	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Maianthemum stellatum	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Mertensia alpina	0(0.0)	0(0.0)	0(0.0)	50(0.0)	3(0.0)	0(0.0)
FB_Mertensia ciliata	0(0.0)	0(0.0)	16(0.4)	0(0.0)	3(0.0)	0(0.0)
FB_Mertensia oblongifolia	0(0.0)	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Microsteris gracilis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Minuartia nuttallii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Minuartia obtusiloba	0(0.0)	0(0.0)	0(0.0)	100(0.1)	6(0.0)	100(0.6)
FB_Mitella pentandra	0(0.0)	0(0.0)	25(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Moehringia lateriflora	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Monarda fistulosa var. menthifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Myosotis alpestris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Nepeta cataria	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Noccaea montana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Oreostemma alpigenum var. haydenii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	15(0.0)	50(0.0)
FB_Orthilia secunda	4(0.0)	0(0.0)	33(0.3)	0(0.0)	9(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Osmorhiza berteroi	0(0.0)	0(0.0)	25(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Osmorhiza depauperata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Oxytropis borealis var. viscida	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Oxytropis lagopus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Oxytropis sericea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Packera cana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	50(0.0)
FB_Packera dimorphophylla var. paysonii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Parnassia fimbriata	0(0.0)	0(0.0)	16(0.0)	0(0.0)	6(0.0)	0(0.0)
FB_Paxistima myrsinites	0(0.0)	0(0.0)	0(0.0)	50(0.0)	0(0.0)	0(0.0)
FB_Pedicularis bracteosa var. paysoniana	0(0.0)	0(0.0)	8(0.2)	0(0.0)	6(0.0)	0(0.0)
FB_Pedicularis oederi	0(0.0)	0(0.0)	0(0.0)	50(0.0)	0(0.0)	0(0.0)
FB_Penstemon fruticosus	4(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.2)	0(0.0)
FB_Penstemon procerus	0(0.0)	0(0.0)	16(0.0)	0(0.0)	9(0.0)	50(1.0)
FB_Penstemon rydbergii	4(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Perideridia montana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Phacelia hastata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Phacelia linearis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Phlox albomarginata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
FB_Phlox diffusa var. scleranthifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Phlox hoodii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Platanthera dilatata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Polygonum bistortoides	0(0.0)	0(0.0)	0(0.0)	50(0.0)	31(0.0)	50(0.0)
FB_Polygonum douglasii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Potentilla diversifolia	0(0.0)	0(0.0)	25(0.0)	50(0.5)	50(0.1)	100(0.6)
FB_Potentilla glandulosa	0(0.0)	50(0.0)	0(0.0)	0(0.0)	6(0.0)	0(0.0)
FB_Potentilla gracilis var. flabelliformis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Potentilla ovina var. ovina	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Potentilla pensylvanica	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Prosartes trachycarpa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Pterospora andromedea	8(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Pyrola chlorantha	8(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Pyrola picta var. dentata	12(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Ranunculus eschscholtzii	0(0.0)	0(0.0)	16(0.1)	0(0.0)	15(0.0)	0(0.0)
FB_Ranunculus pensylvanicus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Ranunculus uncinatus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Saxifraga bronchialis var. austromantana	8(0.2)	100(2.0)	33(0.0)	50(1.5)	15(0.1)	50(0.5)
FB_Saxifraga occidentalis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Saxifraga odontoloma	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Saxifraga rhomboidea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Sedum integrifolium	0(0.0)	0(0.0)	0(0.0)	50(0.0)	0(0.0)	0(0.0)
FB_Sedum lanceolatum	12(0.0)	100(0.6)	33(0.0)	100(0.1)	46(0.0)	100(0.1)
FB_Sedum rhodanthum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
FB_Senecio crassulus	0(0.0)	0(0.0)	16(0.1)	0(0.0)	3(0.0)	0(0.0)
FB_Senecio integerrimus	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Senecio lugens	0(0.0)	0(0.0)	0(0.0)	50(1.0)	0(0.0)	0(0.0)
FB_Senecio serra	0(0.0)	0(0.0)	8(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Senecio triangularis	0(0.0)	0(0.0)	25(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Sibbaldia procumbens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	28(0.1)	100(0.1)
FB_Silene acaulis var. subacaulescens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	50(0.5)
FB_Solidago canadensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Solidago multiradiata var. scopulorum	16(0.0)	100(0.1)	33(0.4)	50(0.0)	53(0.2)	50(0.0)
FB_Solidago velutina	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.1)	0(0.0)
FB_Stellaria monantha	0(0.0)	0(0.0)	0(0.0)	50(0.0)	0(0.0)	0(0.0)
FB_Stephanomeria runcinata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
FB_Streptopus amplexifolius	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Symphyotrichum foliaceum	0(0.0)	0(0.0)	8(0.0)	0(0.0)	6(0.0)	0(0.0)
FB_Symphyotrichum lanceolatum ssp. hesperium	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Taraxacum laevigatum	0(0.0)	0(0.0)	16(0.0)	50(0.0)	0(0.0)	0(0.0)
FB_Taraxacum officinale	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Telesonix heucheriformis	0(0.0)	0(0.0)	0(0.0)	50(1.0)	0(0.0)	0(0.0)
FB_Thalictrum occidentale	0(0.0)	0(0.0)	57(2.3)	0(0.0)	9(0.0)	0(0.0)
FB_Townsendia parryi	0(0.0)	0(0.0)	16(0.0)	50(0.0)	0(0.0)	0(0.0)
FB_Tragopogon dubius	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Trifolium fragiferum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Trifolium haydenii	0(0.0)	50(15.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Trifolium repens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Trollius albiflorus	0(0.0)	0(0.0)	8(0.8)	0(0.0)	3(0.0)	0(0.0)
FB_Valeriana dioica var. sylvatica	4(0.0)	50(1.0)	16(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Valeriana edulis	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Valeriana occidentalis	0(0.0)	0(0.0)	16(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Veronica wormskjoldii	0(0.0)	0(0.0)	8(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Viola adunca	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Viola nuttallii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Viola praemorsa	0(0.0)	0(0.0)	16(0.0)	0(0.0)	3(0.0)	0(0.0)
FB_Zigadenus elegans	0(0.0)	0(0.0)	25(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Zigadenus venenosus var. gramineus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FE_Cystopteris fragilis	4(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FE_Polystichum lonchitis	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
FE_Woodsia oregana	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Bromus tectorum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Calamagrostis inexpansa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
GR_Calamagrostis purpurascens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
GR_Calamagrostis rubescens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex backii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex capitata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex elynoides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
GR_Carex filifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex geyeri Boott	4(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
GR_Carex hoodii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex microptera	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
GR_Carex obtusata	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex paysonis	0(0.0)	0(0.0)	0(0.0)	50(0.0)	9(0.1)	100(2.0)
GR_Carex petasata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex phaeocephala	0(0.0)	0(0.0)	8(0.0)	0(0.0)	15(0.2)	50(1.5)
GR_Carex rossii	72(0.3)	100(0.1)	41(0.3)	0(0.0)	71(0.7)	100(0.1)
GR_Carex rupestris	0(0.0)	0(0.0)	0(0.0)	50(0.5)	0(0.0)	0(0.0)
GR_Carex sprengelii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Danthonia intermedia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	6(0.1)	50(1.0)
GR_Deschampsia cespitosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	6(0.1)	0(0.0)
GR_Elymus elymoides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	6(0.1)	0(0.0)
GR_Elymus glaucus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	6(0.0)	0(0.0)
GR_Elymus spicatus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Festuca brachyphylla	0(0.0)	0(0.0)	8(0.0)	50(1.0)	6(0.0)	50(0.0)
GR_Festuca campestris	0(0.0)	0(0.0)	0(0.0)	50(0.0)	0(0.0)	0(0.0)
GR_Festuca idahoensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Festuca pratensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Juncus parryi	0(0.0)	0(0.0)	8(0.0)	0(0.0)	34(0.1)	50(0.0)
GR_Koeleria macrantha	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
GR_Leucopoa kingii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Luzula parviflora	0(0.0)	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Luzula spicata	0(0.0)	0(0.0)	8(0.0)	50(0.0)	12(0.0)	100(0.1)
GR_Oryzopsis asperifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Phleum alpinum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
GR_Phleum pratense	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Piptatherum exiguum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa alpina	0(0.0)	0(0.0)	8(0.0)	50(0.0)	3(0.0)	0(0.0)
GR_Poa arctica var. arctica	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa cusickii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	18(0.1)	0(0.0)
GR_Poa fendleriana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.1)	0(0.0)
GR_Poa glauca var. rupicola	0(0.0)	50(2.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa interior	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa juncifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
GR_Poa palustris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa pattersonii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa pratensis	4(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa reflexa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Poa secunda	0(0.0)	0(0.0)	0(0.0)	0(0.0)	15(0.1)	50(0.0)
GR_Poa wheeleri	20(0.2)	50(0.5)	8(0.0)	0(0.0)	34(0.3)	50(0.0)
GR_Trisetum spicatum	0(0.0)	0(0.0)	0(0.0)	50(0.0)	18(0.0)	0(0.0)
SH_Acer glabrum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Alnus viridis ssp. sinuata	4(1.0)	0(0.0)	25(1.7)	0(0.0)	3(0.0)	0(0.0)
SH_Amelanchier alnifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Arctostaphylos uva-ursi	28(0.5)	100(0.6)	0(0.0)	50(0.5)	0(0.0)	100(3.0)
SH_Artemisia arbuscula	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Artemisia frigida	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
SH_Artemisia tridentata var. vaseyana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Ceanothus velutinus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Chimaphila umbellata var. occidentalis	12(0.0)	0(0.0)	16(0.2)	0(0.0)	6(0.0)	0(0.0)
SH_Chrysothamnus nauseosus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Chrysothamnus viscidiflorus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Dryas octopetala var. hookeriana	0(0.0)	0(0.0)	0(0.0)	50(0.0)	0(0.0)	0(0.0)
SH_Gaultheria humifusa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	9(0.1)	0(0.0)
SH_Juniperus communis var. depressa	68(0.9)	100(27.5)	16(0.3)	50(2.5)	25(0.2)	100(0.6)
SH_Juniperus horizontalis	8(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Juniperus scopulorum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Kalmia microphylla	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
SH_Ledum glandulosum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
SH_Linnaea borealis	4(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Lonicera utahensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Mahonia repens	4(0.2)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Penstemon fruticosus	24(0.0)	0(0.0)	8(0.2)	0(0.0)	3(0.0)	0(0.0)
SH_Pentaphylloides floribunda	8(0.1)	50(1.0)	8(0.0)	50(0.0)	6(0.0)	50(0.5)
SH_Phyllodoce empetriformis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.1)	0(0.0)
SH_Phyllodoce glanduliflora	0(0.0)	0(0.0)	0(0.0)	50(1.0)	0(0.0)	0(0.0)
SH_Physocarpus malvaceus	8(0.1)	50(1.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Prunus emarginata	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Prunus pensylvanica	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Prunus virginiana var. melanocarpa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Rhus aromatica var. trilobata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Ribes cereum var. pedicellare	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Ribes inerme	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Ribes lacustre	4(0.0)	0(0.0)	75(0.7)	0(0.0)	12(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
SH_Ribes montigenum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
SH_Ribes oxyacanthoides var. oxyacanthoides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
SH_Ribes oxyacanthoides var. setosum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Ribes viscosissimum	12(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Rosa nutkana var. hispida	4(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Rosa sayi	12(0.0)	100(0.6)	8(0.0)	0(0.0)	3(0.0)	0(0.0)
SH_Rosa woodsii	8(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Rubus idaeus	0(0.0)	0(0.0)	8(0.0)	0(0.0)	3(0.0)	0(0.0)
SH_Rubus parviflorus	0(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Salix arctica var. petraea	0(0.0)	0(0.0)	0(0.0)	50(1.0)	0(0.0)	0(0.0)
SH_Salix bebbiana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
SH_Salix glauca var. villosa	0(0.0)	0(0.0)	0(0.0)	50(0.5)	3(0.0)	50(3.5)
SH_Salix scouleriana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Sambucus racemosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Shepherdia canadensis	20(0.4)	50(0.0)	8(0.0)	50(0.0)	0(0.0)	0(0.0)
SH_Spiraea betulifolia	88(1.2)	50(0.5)	41(0.8)	0(0.0)	9(0.1)	0(0.0)
SH_Symphoricarpos albus	4(0.0)	0(0.0)	8(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Symphoricarpos occidentalis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Symphoricarpos oreophilus var. utahensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Vaccinium cespitosum	12(1.1)	0(0.0)	33(0.9)	0(0.0)	6(0.4)	0(0.0)
SH_Vaccinium membranaceum	12(1.6)	0(0.0)	33(1.3)	0(0.0)	6(0.0)	0(0.0)
SH_Vaccinium scoparium	28(6.1)	0(0.0)	66(3.0)	0(0.0)	93(26.9)	50(1.5)
TO_Abies lasiocarpa	28(1.9)	0(0.0)	91(23.8)	0(0.0)	62(6.4)	0(0.0)
TO_Picea engelmannii	0(0.0)	0(0.0)	83(13.9)	100(15.0)	81(5.3)	0(0.0)
TO_Pinus albicaulis	36(1.4)	50(2.5)	33(1.2)	50(1.5)	84(16.1)	0(0.0)
TO_Pinus contorta var. latifolia	100(43.0)	50(3.5)	25(1.8)	0(0.0)	28(3.9)	0(0.0)
TO_Pinus flexilis	8(0.4)	50(7.5)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table F.1. Cover and Constancy Table for Forested Associations of the Beartooth Mountains Study Area (continued).

STRATA_Species name	**PIFL / SYAL**	**PSME / ARCO9**	**PIFL / ARFR4**	**PIFL / AGGL**	**PICO / CEVE**	**PSME / mixed xeric shrub**
TO_Pinus ponderosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
TO_Pseudotsuga menziesii var. glauca	20(0.7)	100(20.0)	16(1.2)	0(0.0)	3(0.3)	0(0.0)
TR_Abies lasiocarpa	52(0.7)	50(0.0)	100(20.3)	0(0.0)	96(2.9)	50(5.0)
TR_Picea engelmannii	20(0.0)	50(0.0)	91(1.8)	100(20.0)	71(0.9)	50(0.5)
TR_Pinus albicaulis	56(2.3)	50(0.5)	33(0.1)	50(2.0)	96(2.7)	100(17.5)
TR_Pinus contorta var. latifolia	64(1.2)	50(0.0)	16(0.2)	0(0.0)	21(0.2)	50(0.5)
TR_Pinus flexilis	28(0.2)	50(0.0)	8(0.2)	50(3.0)	0(0.0)	0(0.0)
TR_Populus tremuloides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.0)	0(0.0)
TR_Pseudotsuga menziesii var. glauca	40(0.4)	100(0.1)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

APPENDIX G

KEY TO ALPINE VEGETATION ASSOCIATIONS

READ THESE INSTRUCTIONS FIRST!

1. Accurately identify and record canopy coverage of all species.
2. Check plot data in the field to verify that the plot is representative of the stand as a whole. If not, select another plot.
3. Use the definitions diagramed below for canopy coverage terms in the key. If you have difficulty deciding between types, refer to constancy and coverage data and the habitat type descriptions.
4. In stands where undergrowth is obviously depauperate (unusually sparse) because of dense shading or duff accumulations, adjust the definitions diagramed below to the next lower coverage class (for example, well represented >1%, common >0%.
5. Remember, the key is NOT the classification! Validate the determination made using the key by checking the written description.

INTERPRETATION OF CANOPY COVER TERMINOLOGY EMPLOYED IN KEY

Absent …..……...……..……..…… **0% canopy cover**
Present ……..…….. …… **.01 to 100% canopy cover**
Trace ……...……..…….. **< 1% canopy cover**
Common ……....……... **1 to 100% canopy cover**
Poorly Represented ……...……..……. **< 5% canopy cover**
Well Represented ……...…..…… **5 to 100% canopy cover**
Not Abundant ……...…….……..…….. **<25% canopy cover**
Abundant …… **25 to 100% canopy cover**

1a. Communities shrub dominated or having shrubby aspect …..…….…… 2
1b. Shrubs poorly represented ……..……..…….…… 5

2a. Shrub communities occurring in wetland areas. *Salix arctica*, *Salix reticulata* var. *nana* or *Salix planifolia* well represented …...…..……..……...…… 3

2b. Shrub communities not occurring in wetland areas ……...……..…… 4

3a. *Salix planifolia* well represented and dominating the shrub layer, *Carex scopulorum* also well represented and generally dominating the graminoid layer .....

……....…….…….. ***Salix planifolia/Carex scopulorum*** **association**

3b. *Salix reticulata* var. *nana* is well represented and more abundant than *Salix planifolia*, which is often present in low abundance ……..……...……
…….... ***Salix reticulata*** var. ***nana*** var. ***nana/Polygonum viviparum*** **association**

4a. *Salix glauca* well represented .....
.....***Salix glauca*** var. ***villosa/Geum rossii var. turbinatum*** **association**

4b. Not as above, *Dryas octopetala* dominating the shrub layer and *Carex rupestris* consistently present.....… ***Dryas octopetala*** var. ***hookeriana/Carex rupestris*** **association**

5a. Communities occurring in areas with late persisting snowpack (snowbed sites)…..… 6

5b. Communities not occurring in areas with late persisting snowpack ...……...……. 7

6a.Snowbed sites where snow persists and soils are saturated the longest. *Carex nigricans* the dominant graminoid and *Veronica wormskjoldii* consistently present, though often in low abundance …... ***Carex nigricans/Veronica wormskjoldii*** **association**

6b. Less saturated snowbed sites where *Antennaria lanata* dominates the forb layer, *Hieracium triste* var. *gracile* is consistently present, though often in low abundance and *Sibbaldia procumbens* var. *subacaulescens* is common to well represented. *Vaccinium scoparium* can become abundant on moist sites of this type ……...
…….....……. ***Antennaria lanata-Hieracium triste*** var. ***gracile*** **association**

7a.Communities dominated by either *Carex phaeochephala* or *Deschampsia cespitosa*. If stands are particularly depauperate (<5% total cover) the presence (0.1%) of *Carex phaeochephala* is enough to follow this break …….....8

7b. Communities dominated by forb species ……....11

8a. Community dominated by *Deschampsia cespitosa* …….…….....
…….... ***Deschampsia cespitosa-Carex microptera-Carex macloviana*** **association**

8b. Community not dominated by *Deschampsia cespitosa* ……...……...…… 9

9a. *Carex phaeochephala* dominant graminoid, generally having >10% total cover. Stands not depauperate. The most frequent forbs include: *Erigeron simplex, Hieracium triste* var. *gracile, Minuartia obtusiloba, Oreostemma alpigenum* var. *haydenii* and *Sibbaldia procumbens* extremely common in low abundance. *Juncus* spp. (*drummondii* and *parryi*) frequently present in low to moderate abundanc.....…… .....***Carex phaeochephala/Sibbaldia procumbens*** **association**

9b. *Carex phaeochephala* present but occurring in low abundance (< 10%) .....…….. 10

10a. Communities occurring on talus slopes with > 80% cobble and stone-sized rock fragments and minimal soil development. This is a depauperate stand with < 5% total cover. *Senecio fremontii* and *Draba incerta* are the dominant forbs. *Carex phaeochephala, Trisetum spicatum* and *Festuca brachyphylla* are the dominant graminoids..…….……..*****Senecio fremontii-Draba incerta*** **association**

10. Alpine fellfield community with slightly more soil development. This community occurs on exposed, wind-blasted slopes. *Abies lasiocarpa, Picea engelmannii* and *Pinus albicaulis* are extremely stunted and occur in very low abundance (< 1%). *Carex phaeochephala* and *Luzula spicata* occur in low abundance and are the most common graminoid species …… ***Picea engelmannii-Pinus albicaulis*/*Carex nardina*** **association**

11a. Community dominated by *Geum rossii* and *Carex rupestris*. Commonly associated forbs include: *Artemisia scopulorum, Bupleurum americanum, Minuartia obtusiloba, Phlox pulvinata, Polygonum bistortoides, Potentilla diversifolia* and *Silene acaulis* var. *subacaulescens*. *Festuca brachyphylla* and *Luzula spicata* are common graminoid species .....…… ***Geum rossii*** **var.** ***turbinatum/Carex rupestris*** **association**

11b. Not as above..…… 12

12a. Community occurring along seeps. *Senecio triangularis* and/or *Mertensia ciliata* are the dominant forbs ……. ***Senecio triangularis-Mertensia ciliata*** **association**

12b. Subalpine meadow community dominated by *Helianthella uniflora* (>30%). *Erigeron ursinus, Hydrophyllum capitatum, Lupinus argenteus, Pedicularis bracteosa* var. *paysoniana, Ranunculus eschscholtzii, Senecio crassulus, Collomia linearis, Delphinium glaucum* and *Astragalus alpinus* are commonly associated forbs ……..... ……...……..… ***Helianthella uniflora-Astragalus alpinus*** **association**

APPENDIX H

COVER/CONSTANCY TABLE FOR ALPINE VEGETATION ASSOCIATIONS

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations.

STRATA_Species names	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIAC	CAPH2 / SIPR
CM_Selaginella sp. (densa or watsonii)	50(0.0)	0(0.0)	0(0.0)	81(2.7)	20(1.0)
FB_Achillea millefolium var. lanulosa	0(0.0)	0(0.0)	50(0.5)	9(0.0)	60(0.4)
FB_Adoxa moschatellina	0(0.0)	0(0.0)	25(0.0)	0(0.0)	0(0.0)
FB_Agoseris glauca	0(0.0)	100(0.1)	0(0.0)	45(0.6)	60(1.0)
FB_Agoseris lackschewitzii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Androsace chamaejasme var. carinata	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Androsace septentrionalis var. subulifera	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Anemone lithophila	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.0)
FB_Anemone patens var. multifida	0(0.0)	0(0.0)	0(0.0)	18(0.0)	0(0.0)
FB_Antennaria corymbosa	0(0.0)	0(0.0)	25(0.0)	0(0.0)	20(0.2)
FB_Antennaria lanata	0(0.0)	0(0.0)	0(0.0)	9(0.1)	40(0.4)
FB_Antennaria media	0(0.0)	0(0.0)	0(0.0)	18(0.0)	20(0.2)
FB_Antennaria microphylla	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Antennaria rosea	0(0.0)	0(0.0)	0(0.0)	9(0.0)	20(0.0)
FB_Antennaria umbrinella	50(0.0)	0(0.0)	0(0.0)	27(0.1)	40(0.8)
FB_Aquilegia jonesii	50(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Arenaria capillaris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Arnica fulgens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.8)
FB_Arnica latifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(1.0)
FB_Arnica mollis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Arnica rydbergii	0(0.0)	0(0.0)	0(0.0)	9(0.0)	20(0.4)
FB_Artemisia campestris	0(0.0)	0(0.0)	0(0.0)	18(0.0)	0(0.0)
FB_Artemisia scopulorum	0(0.0)	0(0.0)	0(0.0)	81(0.6)	20(0.4)
FB_Astragalus alpinus	0(0.0)	100(1.6)	0(0.0)	0(0.0)	0(0.0)
FB_Astragalus kentrophyta	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Besseya wyomingensis	0(0.0)	0(0.0)	0(0.0)	27(0.0)	0(0.0)
FB_Boechera angustifolia	0(0.0)	100(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Boechera lemmonii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	40(0.0)
FB_Boechera lyallii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Boechera nuttallii	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Bupleurum americanum	0(0.0)	0(0.0)	25(0.0)	81(0.2)	20(0.0)
FB_Caltha leptosepala	0(0.0)	0(0.0)	50(2.5)	9(0.1)	0(0.0)
FB_Campanula rotundifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.6)
FB_Campanula uniflora	0(0.0)	0(0.0)	0(0.0)	27(0.0)	0(0.0)
FB_Castilleja miniata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.0)
FB_Castilleja nivea	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Castilleja pulchella	50(0.0)	0(0.0)	0(0.0)	45(0.0)	40(0.0)
FB_Castilleja rhexiifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Castilleja sulphurea	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Cerastium arvense	0(0.0)	0(0.0)	0(0.0)	36(0.0)	20(0.8)
FB_Cerastium beeringianum var. capillare	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIAC	CAPH2 / SIPR
FB_Cerastium fontanum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Chamerion angustifolium	0(0.0)	100(4.5)	0(0.0)	0(0.0)	*20(0.0)*
FB_Cirsium scariosum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	*0(0.0)*
FB_Cirsium undulatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	*20(0.0)*
FB_Claytonia lanceolata	0(0.0)	50(0.0)	0(0.0)	9(0.0)	*0(0.0)*
FB_Collomia linearis	0(0.0)	100(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Delphinium bicolor	0(0.0)	100(0.1)	0(0.0)	0(0.0)	20(0.6)
FB_Delphinium glaucum	0(0.0)	100(1.5)	0(0.0)	0(0.0)	0(0.0)
FB_Descurainia incana	0(0.0)	50(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Dodecatheon pulchellum	0(0.0)	0(0.0)	25(0.2)	18(0.0)	0(0.0)
FB_Douglasia montana	0(0.0)	0(0.0)	0(0.0)	27(0.1)	0(0.0)
FB_Draba cana	0(0.0)	0(0.0)	0(0.0)	18(0.0)	0(0.0)
FB_Draba crassifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Draba incerta	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Epilobium anagallidifolium	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Epilobium ciliatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Epilobium clavatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	40(0.0)
FB_Epilobium glaberrimum var. fastigiatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Epilobium halleanum	0(0.0)	50(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Epilobium hornemannii	0(0.0)	50(0.5)	25(0.0)	0(0.0)	0(0.0)
FB_Eremogone congesta	0(0.0)	0(0.0)	0(0.0)	9(0.0)	60(0.6)
FB_Erigeron acris var. kamtschaticus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.0)
FB_Erigeron compositus var. discoideus	0(0.0)	0(0.0)	0(0.0)	9(0.0)	20(0.0)
FB_Erigeron grandiflorus	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Erigeron ochroleucus	0(0.0)	0(0.0)	0(0.0)	45(0.3)	40(0.0)
FB_Erigeron peregrinus var. scaposus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron radicatus	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Erigeron rydbergii	50(0.0)	0(0.0)	0(0.0)	45(0.4)	0(0.0)
FB_Erigeron simplex	0(0.0)	0(0.0)	0(0.0)	54(0.1)	80(0.3)
FB_Erigeron ursinus	0(0.0)	100(0.6)	0(0.0)	0(0.0)	20(0.2)
FB_Eriogonum flavum	50(0.0)	0(0.0)	0(0.0)	18(0.1)	0(0.0)
FB_Eriogonum umbellatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.8)
FB_Eritrichium howardii	50(0.5)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Eritrichium nanum var. elongatum	50(0.0)	0(0.0)	0(0.0)	72(0.4)	0(0.0)
FB_Erysimum asperum	0(0.0)	0(0.0)	0(0.0)	36(0.0)	0(0.0)
FB_Fragaria virginiana	0(0.0)	50(0.5)	0(0.0)	0(0.0)	0(0.0)
FB_Frasera speciosa	0(0.0)	50(0.0)	0(0.0)	0(0.0)	20(0.2)
FB_Galium bifolium	0(0.0)	0(0.0)	25(0.0)	0(0.0)	0(0.0)
FB_Gentiana algida	0(0.0)	0(0.0)	25(0.0)	18(0.0)	0(0.0)
FB_Gentiana prostrata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Geum rossii var. turbinatum	50(0.0)	0(0.0)	25(0.0)	100(12.9)	20(0.8)
FB_Hedysarum sulphurescens	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Helianthella uniflora	0(0.0)	100(40.0)	0(0.0)	0(0.0)	0(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIAC	CAPH2 / SIPR
FB_Heracleum sphondylium var. lanatum	0(0.0)	50(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Hieracium triste var. gracile	0(0.0)	0(0.0)	0(0.0)	0(0.0)	80(0.3)
FB_Hydrophyllum capitatum	0(0.0)	100(0.6)	0(0.0)	0(0.0)	0(0.0)
FB_Lewisia pygmaea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	40(0.0)
FB_Lloydia serotina	50(0.0)	0(0.0)	0(0.0)	27(0.1)	0(0.0)
FB_Lomatium cous	0(0.0)	0(0.0)	0(0.0)	27(0.0)	20(0.0)
FB_Lupinus argenteus	0(0.0)	100(9.5)	0(0.0)	54(2.4)	20(1.6)
FB_Mertensia alpina	0(0.0)	0(0.0)	0(0.0)	63(0.1)	0(0.0)
FB_Mertensia oblongifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Mimulus lewisii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Minuartia obtusiloba	50(0.0)	0(0.0)	0(0.0)	100(2.1)	80(0.1)
FB_Minuartia rubella	0(0.0)	0(0.0)	0(0.0)	36(0.0)	0(0.0)
FB_Myosotis alpestris	0(0.0)	0(0.0)	0(0.0)	27(0.0)	0(0.0)
FB_Myosotis arvensis	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Oreostemma alpigenum var. haydenii	0(0.0)	0(0.0)	0(0.0)	9(0.0)	80(0.8)
FB_Orobanche uniflora var. occidentalis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.0)
FB_Oxyria digyna	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.0)
FB_Oxytropis borealis var. viscida	0(0.0)	0(0.0)	0(0.0)	27(0.4)	0(0.0)
FB_Oxytropis campestris	0(0.0)	0(0.0)	0(0.0)	18(0.1)	0(0.0)
FB_Oxytropis lagopus	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Oxytropis sericea	50(1.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Packera cana	50(0.0)	0(0.0)	0(0.0)	63(0.3)	0(0.0)
FB_Packera dimorphophylla var. paysonii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.0)
FB_Packera subnuda	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.2)
FB_Parnassia fimbriata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Parnassia palustris var. montanensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Pedicularis bracteosa var. paysoniana	0(0.0)	100(0.6)	0(0.0)	0(0.0)	0(0.0)
FB_Pedicularis cystopteridifolia	0(0.0)	0(0.0)	0(0.0)	36(0.3)	20(0.2)
FB_Pedicularis groenlandica	0(0.0)	0(0.0)	50(0.5)	0(0.0)	0(0.0)
FB_Pedicularis oederi	0(0.0)	0(0.0)	25(0.0)	0(0.0)	0(0.0)
FB_Pedicularis pulchella	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Penstemon procerus	0(0.0)	0(0.0)	25(0.0)	18(0.1)	40(0.0)
FB_Phacelia hastata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Phleum alpinum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.0)
FB_Phlox pulvinata	0(0.0)	0(0.0)	0(0.0)	90(1.6)	20(0.6)
FB_Physaria didymocarpa	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Polemonium viscosum	0(0.0)	0(0.0)	0(0.0)	36(1.6)	0(0.0)
FB_Polygonum bistortoides	50(0.0)	0(0.0)	50(0.0)	100(1.2)	60(1.4)
FB_Polygonum viviparum	0(0.0)	0(0.0)	25(0.2)	0(0.0)	0(0.0)
FB_Potentilla diversifolia	50(0.0)	0(0.0)	100(0.8)	90(1.6)	60(1.0)
FB_Potentilla nivea	0(0.0)	0(0.0)	0(0.0)	36(0.1)	0(0.0)
FB_Ranunculus eschscholtzii	0(0.0)	100(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Rumex paucifolius	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.0)
FB_Saxifraga bronchialis var. austromantana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIAC	CAPH2 / SIPR
FB_Saxifraga occidentalis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Saxifraga odontoloma	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Saxifraga oppositifolia	50(0.5)	0(0.0)	0(0.0)	0(0.0)	20(0.0)
FB_Saxifraga rhomboidea	50(0.0)	0(0.0)	0(0.0)	45(0.0)	20(0.0)
FB_Saxifraga subapetala	0(0.0)	0(0.0)	25(0.2)	0(0.0)	0(0.0)
FB_Sedum integrifolium	50(0.0)	0(0.0)	75(0.8)	9(0.1)	0(0.0)
FB_Sedum lanceolatum	50(0.0)	50(0.0)	25(0.0)	90(0.1)	60(0.1)
FB_Sedum rhodanthum	0(0.0)	0(0.0)	50(0.0)	0(0.0)	0(0.0)
FB_Senecio crassulus	0(0.0)	100(2.5)	0(0.0)	0(0.0)	0(0.0)
FB_Senecio fremontii	50(0.0)	0(0.0)	25(0.5)	0(0.0)	0(0.0)
FB_Senecio integerrimus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Senecio lugens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Senecio triangularis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Sibbaldia procumbens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	80(2.4)
FB_Silene acaulis var. subacaulescens	50(0.0)	0(0.0)	0(0.0)	100(2.7)	40(0.4)
FB_Silene parryi	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Smelowskia calycina var. americana	0(0.0)	0(0.0)	0(0.0)	63(0.2)	20(0.0)
FB_Solidago multiradiata var. scopulorum	0(0.0)	100(2.5)	25(0.0)	45(0.5)	20(0.0)
FB_Stellaria calycantha	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Stellaria longipes	0(0.0)	0(0.0)	25(0.0)	0(0.0)	0(0.0)
FB_Stellaria monantha	0(0.0)	0(0.0)	25(0.0)	18(0.0)	0(0.0)
FB_Stellaria umbellata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Symphyotrichum foliaceum	0(0.0)	100(0.6)	25(1.0)	0(0.0)	40(0.2)
FB_Taraxacum ceratophorum	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
FB_Taraxacum laevigatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Taraxacum officinale	0(0.0)	50(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Tephroseris lindstroemii	0(0.0)	0(0.0)	0(0.0)	36(0.1)	0(0.0)
FB_Thalictrum occidentale	0(0.0)	0(0.0)	25(0.0)	0(0.0)	0(0.0)
FB_Trifolium dasyphyllum	0(0.0)	0(0.0)	0(0.0)	18(0.4)	0(0.0)
FB_Trifolium nanum	0(0.0)	0(0.0)	0(0.0)	63(2.0)	0(0.0)
FB_Trifolium parryi var. montanense	0(0.0)	0(0.0)	0(0.0)	9(0.1)	0(0.0)
FB_Trollius albiflorus	0(0.0)	0(0.0)	50(2.5)	0(0.0)	0(0.0)
FB_Valeriana dioica var. sylvatica	0(0.0)	50(2.5)	0(0.0)	0(0.0)	0(0.0)
FB_Valeriana occidentalis	0(0.0)	100(1.5)	0(0.0)	0(0.0)	0(0.0)
FB_Veronica wormskjoldii	0(0.0)	0(0.0)	50(0.3)	0(0.0)	40(0.0)
FB_Viola adunca	0(0.0)	0(0.0)	25(0.2)	0(0.0)	0(0.0)
FB_Viola palustris	0(0.0)	0(0.0)	25(0.0)	0(0.0)	0(0.0)
FB_Zigadenus elegans	50(0.0)	0(0.0)	0(0.0)	9(0.2)	0(0.0)
FE_Cryptogramma acrostichoides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.0)
GR_Agrostis humilis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Agrostis idahoensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Agrostis variabilis	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Bromus carinatus var. linearis	0(0.0)	100(0.1)	0(0.0)	0(0.0)	0(0.0)
GR_Calamagrostis canadensis	0(0.0)	0(0.0)	25(2.5)	0(0.0)	0(0.0)
GR_Calamagrostis purpurascens	0(0.0)	0(0.0)	25(0.0)	27(1.4)	0(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIAC	CAPH2 / SIPR
GR_Carex albonigra	0(0.0)	0(0.0)	0(0.0)	36(0.2)	0(0.0)
GR_Carex brunnescens	0(0.0)	0(0.0)	25(0.2)	0(0.0)	0(0.0)
GR_Carex capitata	0(0.0)	0(0.0)	50(0.0)	0(0.0)	0(0.0)
GR_Carex disperma	0(0.0)	0(0.0)	25(1.2)	0(0.0)	0(0.0)
GR_Carex elynoides	0(0.0)	0(0.0)	0(0.0)	36(0.4)	0(0.0)
GR_Carex gynocrates	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex illota	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex macloviana	0(0.0)	0(0.0)	25(0.0)	0(0.0)	0(0.0)
GR_Carex microptera	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex misandra	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex nardina	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Carex nigricans	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex obtusata	0(0.0)	0(0.0)	0(0.0)	27(1.6)	20(0.0)
GR_Carex paysonis	0(0.0)	0(0.0)	25(0.0)	9(0.0)	40(0.0)
GR_Carex petasata	0(0.0)	0(0.0)	25(0.0)	0(0.0)	0(0.0)
GR_Carex phaeocephala	0(0.0)	0(0.0)	0(0.0)	9(0.0)	100(13.0)
GR_Carex pyrenaica	0(0.0)	0(0.0)	0(0.0)	0(0.0)	40(1.0)
GR_Carex rossii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex rupestris	100(0.6)	0(0.0)	0(0.0)	72(7.4)	0(0.0)
GR_Carex scirpoidea	0(0.0)	0(0.0)	0(0.0)	18(1.4)	40(0.2)
GR_Carex scopulorum	0(0.0)	0(0.0)	100(14.3)	18(0.0)	0(0.0)
GR_Carex spectabilis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.6)
GR_Danthonia intermedia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(2.0)
GR_Deschampsia atropurpurea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Deschampsia cespitosa	0(0.0)	0(0.0)	50(0.8)	27(0.0)	60(0.4)
GR_Eleocharis quinqueflora	0(0.0)	0(0.0)	25(0.8)	0(0.0)	0(0.0)
GR_Elymus canadensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Elymus glaucus	0(0.0)	50(0.5)	0(0.0)	0(0.0)	0(0.0)
GR_Elymus scribneri	0(0.0)	0(0.0)	0(0.0)	27(0.1)	0(0.0)
GR_Elymus spicatus	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Elymus trachycaulus	0(0.0)	50(0.5)	0(0.0)	9(0.0)	0(0.0)
GR_Eriophorum callitrix	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Festuca brachyphylla	50(0.0)	0(0.0)	25(0.2)	90(0.4)	60(0.1)
GR_Festuca idahoensis	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Helictotrichon hookeri	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Juncus biglumis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Juncus drummondii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	40(0.4)
GR_Juncus ensifolius	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Juncus mertensianus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Juncus parryi	0(0.0)	0(0.0)	0(0.0)	0(0.0)	60(5.0)
GR_Juncus triglumis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Kobresia myosuroides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Koeleria macrantha	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Luzula parviflora	0(0.0)	0(0.0)	0(0.0)	9(0.0)	40(0.2)
GR_Luzula spicata	0(0.0)	0(0.0)	0(0.0)	72(0.3)	40(0.2)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIAC	CAPH2 / SIPR
GR_Melica spectabilis	0(0.0)	100(0.6)	0(0.0)	0(0.0)	0(0.0)
GR_Phleum alpinum	0(0.0)	100(0.6)	0(0.0)	0(0.0)	0(0.0)
GR_Poa alpina	50(0.0)	0(0.0)	25(0.0)	9(0.2)	40(0.2)
GR_Poa arctica var. arctica	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
GR_Poa cusickii	0(0.0)	0(0.0)	0(0.0)	9(0.2)	20(0.4)
GR_Poa fendleriana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(1.0)
GR_Poa glauca var. rupicola	0(0.0)	0(0.0)	0(0.0)	18(0.1)	0(0.0)
GR_Poa lettermanii	0(0.0)	0(0.0)	0(0.0)	18(0.2)	0(0.0)
GR_Poa pattersonii	0(0.0)	0(0.0)	0(0.0)	27(0.8)	0(0.0)
GR_Poa reflexa	0(0.0)	100(1.0)	0(0.0)	0(0.0)	20(0.0)
GR_Poa secunda	0(0.0)	0(0.0)	0(0.0)	45(0.2)	20(0.0)
GR_Trisetum spicatum	0(0.0)	100(0.1)	0(0.0)	45(0.1)	40(0.0)
SH_Arctostaphylos uva-ursi	0(0.0)	0(0.0)	0(0.0)	9(3.6)	0(0.0)
SH_Artemisia frigida	0(0.0)	0(0.0)	0(0.0)	9(0.2)	0(0.0)
SH_Betula glandulosa	0(0.0)	0(0.0)	75(1.5)	0(0.0)	0(0.0)
SH_Dryas octopetala var. hookeriana	100(15.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Gaultheria humifusa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Juniperus communis var. depressa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Kalmia microphylla	0(0.0)	0(0.0)	25(0.2)	0(0.0)	0(0.0)
SH_Pentaphylloides floribunda	50(0.5)	0(0.0)	75(2.0)	27(0.7)	0(0.0)
SH_Phyllodoce empetriformis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Phyllodoce glanduliflora	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Salix arctica var. petraea	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
SH_Salix glauca var. villosa	50(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Salix planifolia	0(0.0)	0(0.0)	100(66.2)	9(0.0)	0(0.0)
SH_Salix reticulata var. nana	50(0.0)	0(0.0)	25(0.5)	0(0.0)	0(0.0)
SH_Vaccinium scoparium	0(0.0)	0(0.0)	0(0.0)	0(0.0)	20(0.2)
TR_Abies lasiocarpa	0(0.0)	0(0.0)	0(0.0)	9(0.0)	0(0.0)
TR_Picea engelmannii	50(0.0)	0(0.0)	25(0.0)	9(0.1)	20(0.0)
TR_Pinus albicaulis	0(0.0)	0(0.0)	0(0.0)	18(0.1)	0(0.0)
TR_Pinus contorta var. latifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
CM_Selaginella sp. (densa or watsonii)	0(0.0)	0(0.0)	0(0.0)	14(2.8)	25(0.8)
FB_Achillea millefolium var. lanulosa	33(0.0)	0(0.0)	33(0.0)	28(0.1)	25(0.0)
FB_Adoxa moschatellina	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Agoseris glauca	33(0.0)	0(0.0)	33(1.7)	28(0.3)	0(0.0)
FB_Agoseris lackschewitzii	0(0.0)	0(0.0)	33(0.0)	14(0.6)	0(0.0)
FB_Androsace chamaejasme var. carinata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Androsace septentrionalis var. subulifera	0(0.0)	0(0.0)	0(0.0)	14(0.0)	25(0.0)
FB_Anemone lithophila	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Anemone patens var. multifida	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Antennaria corymbosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.5)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIAC	CAPH2 / SIPR
FB_Antennaria lanata	33(0.0)	0(0.0)	33(0.0)	100(12.2)	75(0.5)
FB_Antennaria media	0(0.0)	0(0.0)	33(0.0)	14(0.1)	25(0.5)
FB_Antennaria microphylla	33(0.3)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Antennaria rosea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Antennaria umbrinella	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
FB_Aquilegia jonesii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Arenaria capillaris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Arnica fulgens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Arnica latifolia	0(0.0)	0(0.0)	0(0.0)	56(0.3)	0(0.0)
FB_Arnica mollis	0(0.0)	0(0.0)	0(0.0)	14(0.7)	0(0.0)
FB_Arnica rydbergii	33(0.0)	0(0.0)	0(0.0)	28(2.1)	25(0.0)
FB_Artemisia campestris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Artemisia scopulorum	100(0.7)	50(0.0)	33(0.3)	0(0.0)	75(1.3)
FB_Astragalus alpinus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Astragalus kentrophyta	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.2)
FB_Besseya wyomingensis	0(0.0)	0(0.0)	0(0.0)	14(0.0)	0(0.0)
FB_Boechera angustifolia	0(0.0)	0(0.0)	33(0.0)	14(0.0)	0(0.0)
FB_Boechera lemmonii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Boechera lyallii	0(0.0)	0(0.0)	0(0.0)	42(0.0)	0(0.0)
FB_Boechera nuttallii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Bupleurum americanum	33(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Caltha leptosepala	33(0.7)	50(0.5)	0(0.0)	14(0.4)	0(0.0)
FB_Campanula rotundifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Campanula uniflora	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Castilleja miniata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Castilleja nivea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Castilleja pulchella	33(0.0)	0(0.0)	0(0.0)	14(0.0)	50(0.0)
FB_Castilleja rhexiifolia	0(0.0)	0(0.0)	0(0.0)	14(0.0)	0(0.0)
FB_Castilleja sulphurea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Cerastium arvense	0(0.0)	0(0.0)	33(0.0)	0(0.0)	25(0.2)
FB_Cerastium beeringianum var. capillare	33(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Cerastium fontanum	0(0.0)	0(0.0)	33(0.3)	0(0.0)	0(0.0)
FB_Chamerion angustifolium	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Cirsium scariosum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Cirsium undulatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Claytonia lanceolata	33(0.0)	0(0.0)	33(0.0)	71(1.3)	0(0.0)
FB_Collomia linearis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Delphinium bicolor	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Delphinium glaucum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Descurainia incana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Dodecatheon pulchellum	66(0.1)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Douglasia montana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIAC	CAPH2 / SIPR
FB_Draba cana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Draba crassifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Draba incerta	0(0.0)	0(0.0)	33(0.0)	0(0.0)	75(0.1)
FB_Epilobium anagallidifolium	0(0.0)	0(0.0)	0(0.0)	14(0.0)	0(0.0)
FB_Epilobium ciliatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Epilobium clavatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Epilobium glaberrimum var. fastigiatum	33(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Epilobium halleanum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Epilobium hornemannii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Eremogone congesta	0(0.0)	0(0.0)	0(0.0)	28(0.0)	25(0.2)
FB_Erigeron acris var. kamtschaticus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron compositus var. discoideus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Erigeron grandiflorus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron ochroleucus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.2)
FB_Erigeron peregrinus var. scaposus	0(0.0)	0(0.0)	0(0.0)	42(0.7)	0(0.0)
FB_Erigeron radicatus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron rydbergii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron simplex	33(0.0)	0(0.0)	0(0.0)	14(0.0)	75(0.3)
FB_Erigeron ursinus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Eriogonum flavum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Eriogonum umbellatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Eritrichium howardii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Eritrichium nanum var. elongatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Erysimum asperum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Fragaria virginiana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Frasera speciosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Galium bifolium	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Gentiana algida	66(0.1)	100(0.1)	33(0.0)	0(0.0)	0(0.0)
FB_Gentiana prostrata	0(0.0)	50(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Geum rossii var. turbinatum	100(2.3)	50(1.5)	66(5.0)	0(0.0)	75(1.3)
FB_Hedysarum sulphurescens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Helianthella uniflora	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Heracleum sphondylium var. lanatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Hieracium triste var. gracile	0(0.0)	0(0.0)	33(0.0)	85(1.6)	25(0.0)
FB_Hydrophyllum capitatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Lewisia pygmaea	0(0.0)	0(0.0)	0(0.0)	42(0.2)	25(0.2)
FB_Lloydia serotina	66(0.1)	50(0.0)	0(0.0)	14(0.0)	50(0.3)
FB_Lomatium cous	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Lupinus argenteus	33(1.0)	0(0.0)	0(0.0)	28(0.4)	25(0.2)
FB_Mertensia alpina	0(0.0)	0(0.0)	33(0.3)	0(0.0)	50(0.0)
FB_Mertensia oblongifolia	33(0.3)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIAC	CAPH2 / SIPR
FB_Mimulus lewisii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Minuartia obtusiloba	100(0.1)	0(0.0)	0(0.0)	28(0.1)	100(0.6)
FB_Minuartia rubella	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Myosotis alpestris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Myosotis arvensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Oreostemma alpigenum var. haydenii	33(0.0)	0(0.0)	0(0.0)	100(0.1)	50(0.3)
FB_Orobanche uniflora var. occidentalis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Oxyria digyna	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Oxytropis borealis var. viscida	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Oxytropis campestris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Oxytropis lagopus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Oxytropis sericea	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Packera cana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Packera dimorphophylla var. paysonii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Packera subnuda	33(0.3)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Parnassia fimbriata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Parnassia palustris var. montanensis	0(0.0)	0(0.0)	0(0.0)	14(0.0)	0(0.0)
FB_Pedicularis bracteosa var. paysoniana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Pedicularis cystopteridifolia	33(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Pedicularis groenlandica	0(0.0)	0(0.0)	33(0.0)	28(0.1)	0(0.0)
FB_Pedicularis oederi	66(0.1)	100(2.0)	33(0.0)	0(0.0)	0(0.0)
FB_Pedicularis pulchella	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Penstemon procerus	66(0.7)	0(0.0)	33(0.0)	14(0.0)	25(0.5)
FB_Phacelia hastata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Phleum alpinum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Phlox pulvinata	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Physaria didymocarpa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Polemonium viscosum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Polygonum bistortoides	100(0.1)	0(0.0)	66(0.1)	100(0.8)	75(0.3)
FB_Polygonum viviparum	0(0.0)	100(5.0)	66(0.1)	0(0.0)	25(0.0)
FB_Potentilla diversifolia	100(0.4)	50(0.0)	100(4.0)	71(2.9)	75(0.3)
FB_Potentilla nivea	0(0.0)	100(0.1)	0(0.0)	0(0.0)	0(0.0)
FB_Ranunculus eschscholtzii	33(0.0)	0(0.0)	33(0.0)	28(0.0)	50(0.0)
FB_Rumex paucifolius	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Saxifraga bronchialis var. austromantana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
FB_Saxifraga occidentalis	0(0.0)	0(0.0)	33(0.0)	14(0.0)	0(0.0)
FB_Saxifraga odontoloma	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Saxifraga oppositifolia	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Saxifraga rhomboidea	66(0.1)	0(0.0)	0(0.0)	14(0.0)	25(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIAC	CAPH2 / SIPR
FB_Saxifraga subapetala	0(0.0)	50(0.0)	33(0.0)	14(0.0)	25(0.0)
FB_Sedum integrifolium	0(0.0)	100(0.6)	33(0.0)	0(0.0)	25(0.2)
FB_Sedum lanceolatum	100(0.1)	0(0.0)	0(0.0)	42(0.0)	100(0.1)
FB_Sedum rhodanthum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Senecio crassulus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Senecio fremontii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.0)
FB_Senecio integerrimus	33(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Senecio lugens	33(0.0)	50(0.0)	0(0.0)	14(0.0)	0(0.0)
FB_Senecio triangularis	0(0.0)	0(0.0)	0(0.0)	14(0.3)	0(0.0)
FB_Sibbaldia procumbens	33(0.0)	0(0.0)	33(0.0)	100(3.3)	100(1.5)
FB_Silene acaulis var. subacaulescens	33(0.0)	0(0.0)	33(0.0)	0(0.0)	100(1.3)
FB_Silene parryi	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Smelowskia calycina var. americana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	75(0.1)
FB_Solidago multiradiata var. scopulorum	33(0.3)	50(0.0)	66(0.1)	28(0.1)	75(0.6)
FB_Stellaria calycantha	0(0.0)	0(0.0)	0(0.0)	14(0.0)	0(0.0)
FB_Stellaria longipes	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Stellaria monantha	33(0.0)	50(0.0)	33(1.3)	14(0.0)	0(0.0)
FB_Stellaria umbellata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Symphyotrichum foliaceum	0(0.0)	0(0.0)	33(1.3)	28(0.0)	0(0.0)
FB_Taraxacum ceratophorum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Taraxacum laevigatum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
FB_Taraxacum officinale	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Tephroseris lindstroemii	66(0.1)	50(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Thalictrum occidentale	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Trifolium dasyphyllum	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Trifolium nanum	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
FB_Trifolium parryi var. montanense	0(0.0)	50(0.0)	33(0.3)	0(0.0)	0(0.0)
FB_Trollius albiflorus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Valeriana dioica var. sylvatica	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Valeriana occidentalis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Veronica wormskjoldii	0(0.0)	0(0.0)	33(0.0)	28(0.1)	0(0.0)
FB_Viola adunca	0(0.0)	0(0.0)	0(0.0)	14(0.0)	0(0.0)
FB_Viola palustris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FB_Zigadenus elegans	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
FE_Cryptogramma acrostichoides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Agrostis humilis	0(0.0)	0(0.0)	0(0.0)	28(0.0)	50(0.0)
GR_Agrostis idahoensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
GR_Agrostis variabilis	0(0.0)	0(0.0)	0(0.0)	14(0.1)	50(0.0)
GR_Bromus carinatus var. linearis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Calamagrostis canadensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Calamagrostis purpurascens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIAC	CAPH2 / SIPR
GR_Carex albonigra	0(0.0)	0(0.0)	33(0.3)	0(0.0)	25(0.5)
GR_Carex brunnescens	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex capitata	0(0.0)	50(1.0)	33(0.0)	0(0.0)	0(0.0)
GR_Carex disperma	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex elynoides	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex gynocrates	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(1.2)
GR_Carex illota	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex macloviana	0(0.0)	0(0.0)	66(0.7)	0(0.0)	0(0.0)
GR_Carex microptera	0(0.0)	0(0.0)	66(5.0)	0(0.0)	0(0.0)
GR_Carex misandra	0(0.0)	100(1.6)	0(0.0)	0(0.0)	0(0.0)
GR_Carex nardina	0(0.0)	0(0.0)	0(0.0)	0(0.0)	50(0.5)
GR_Carex nigricans	0(0.0)	0(0.0)	0(0.0)	14(0.8)	0(0.0)
GR_Carex obtusata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex paysonis	66(2.4)	0(0.0)	66(4.3)	100(5.9)	75(2.2)
GR_Carex petasata	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex phaeocephala	33(3.0)	0(0.0)	0(0.0)	71(4.0)	100(2.0)
GR_Carex pyrenaica	0(0.0)	0(0.0)	0(0.0)	28(1.4)	0(0.0)
GR_Carex rossii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
GR_Carex rupestris	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Carex scirpoidea	66(0.4)	0(0.0)	66(0.4)	14(0.4)	0(0.0)
GR_Carex scopulorum	33(1.7)	100(20.0)	33(2.7)	0(0.0)	0(0.0)
GR_Carex spectabilis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Danthonia intermedia	0(0.0)	0(0.0)	0(0.0)	14(0.1)	0(0.0)
GR_Deschampsia atropurpurea	0(0.0)	0(0.0)	0(0.0)	14(0.0)	0(0.0)
GR_Deschampsia cespitosa	66(2.3)	50(0.5)	100(50.0)	71(1.6)	50(0.0)
GR_Eleocharis quinqueflora	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Elymus canadensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Elymus glaucus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Elymus scribneri	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
GR_Elymus spicatus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Elymus trachycaulus	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Eriophorum callitrix	0(0.0)	50(4.0)	0(0.0)	0(0.0)	0(0.0)
GR_Festuca brachyphylla	100(0.7)	100(0.1)	66(0.4)	14(0.3)	75(1.5)
GR_Festuca idahoensis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Helictotrichon hookeri	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Juncus biglumis	0(0.0)	50(0.5)	0(0.0)	0(0.0)	0(0.0)
GR_Juncus drummondii	0(0.0)	0(0.0)	33(0.0)	56(0.7)	50(0.0)
GR_Juncus ensifolius	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Juncus mertensianus	0(0.0)	0(0.0)	0(0.0)	14(0.0)	0(0.0)
GR_Juncus parryi	33(0.0)	0(0.0)	33(0.0)	71(2.7)	25(0.5)
GR_Juncus triglumis	0(0.0)	50(2.5)	0(0.0)	0(0.0)	0(0.0)
GR_Kobresia myosuroides	0(0.0)	50(2.0)	0(0.0)	0(0.0)	0(0.0)
GR_Koeleria macrantha	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	DROC / CARU3	HEUN / ASAL7	SAPL2 / CASC12	GERO2 / SIAC	CAPH2 / SIPR
GR_Luzula parviflora	0(0.0)	0(0.0)	0(0.0)	42(0.2)	0(0.0)
GR_Luzula spicata	66(0.4)	100(0.1)	66(0.4)	71(2.0)	100(1.0)
GR_Melica spectabilis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Phleum alpinum	0(0.0)	0(0.0)	33(0.3)	28(0.0)	0(0.0)
GR_Poa alpina	66(0.1)	50(0.0)	66(1.7)	14(0.0)	50(0.8)
GR_Poa arctica var. arctica	0(0.0)	0(0.0)	33(0.0)	0(0.0)	0(0.0)
GR_Poa cusickii	0(0.0)	0(0.0)	33(0.0)	85(4.7)	25(0.0)
GR_Poa fendleriana	33(0.3)	0(0.0)	0(0.0)	14(0.3)	0(0.0)
GR_Poa glauca var. rupicola	0(0.0)	50(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa lettermanii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa pattersonii	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
GR_Poa reflexa	0(0.0)	0(0.0)	0(0.0)	14(0.0)	0(0.0)
GR_Poa secunda	0(0.0)	0(0.0)	0(0.0)	28(0.3)	75(0.3)
GR_Trisetum spicatum	66(0.1)	50(0.0)	66(0.4)	71(0.1)	75(1.0)
SH_Arctostaphylos uva-ursi	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Artemisia frigida	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Betula glandulosa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Dryas octopetala var. hookeriana	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
SH_Gaultheria humifusa	0(0.0)	0(0.0)	0(0.0)	14(0.1)	0(0.0)
SH_Juniperus communis var. depressa	0(0.0)	0(0.0)	0(0.0)	0(0.0)	25(1.2)
SH_Kalmia microphylla	0(0.0)	0(0.0)	0(0.0)	14(0.1)	0(0.0)
SH_Pentaphylloides floribunda	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Phyllodoce empetriformis	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
SH_Phyllodoce glanduliflora	0(0.0)	0(0.0)	0(0.0)	14(0.3)	25(0.0)
SH_Salix arctica var. petraea	33(1.0)	0(0.0)	33(0.3)	0(0.0)	50(1.3)
SH_Salix glauca var. villosa	100(65.0)	50(1.5)	0(0.0)	0(0.0)	0(0.0)
SH_Salix planifolia	0(0.0)	50(2.5)	0(0.0)	0(0.0)	0(0.0)
SH_Salix reticulata var. nana	66(0.7)	100(25.0)	0(0.0)	0(0.0)	0(0.0)
SH_Vaccinium scoparium	0(0.0)	0(0.0)	0(0.0)	42(5.1)	25(0.0)
TR_Abies lasiocarpa	33(0.0)	0(0.0)	0(0.0)	0(0.0)	25(0.0)
TR_Picea engelmannii	66(0.1)	0(0.0)	0(0.0)	28(0.0)	75(0.3)
TR_Pinus albicaulis	33(0.0)	0(0.0)	0(0.0)	14(0.0)	75(0.1)
TR_Pinus contorta var. latifolia	0(0.0)	0(0.0)	0(0.0)	28(0.0)	0(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	CANI2 - VEWO2	SETR / MECI3	SEFR3 - DRIN2
CM_Selaginella sp. (densa or watsonii)	22(0.6)	0(0.0)	0(0.0)
FB_Achillea millefolium var. lanulosa	0(0.0)	0(0.0)	0(0.0)
FB_Adoxa moschatellina	0(0.0)	0(0.0)	0(0.0)
FB_Agoseris glauca	0(0.0)	0(0.0)	0(0.0)
FB_Agoseris lackschewitzii	11(0.1)	0(0.0)	0(0.0)
FB_Androsace chamaejasme var. carinata	0(0.0)	0(0.0)	0(0.0)
FB_Androsace septentrionalis var. subulifera	0(0.0)	0(0.0)	0(0.0)
FB_Anemone lithophila	0(0.0)	0(0.0)	0(0.0)
FB_Anemone patens var. multifida	0(0.0)	0(0.0)	0(0.0)
FB_Antennaria corymbosa	11(0.3)	0(0.0)	0(0.0)
FB_Antennaria lanata	77(2.8)	0(0.0)	0(0.0)
FB_Antennaria media	0(0.0)	0(0.0)	0(0.0)
FB_Antennaria microphylla	11(0.0)	0(0.0)	0(0.0)
FB_Antennaria rosea	0(0.0)	0(0.0)	0(0.0)
FB_Antennaria umbrinella	11(0.1)	0(0.0)	0(0.0)
FB_Aquilegia jonesii	0(0.0)	0(0.0)	0(0.0)
FB_Arenaria capillaris	0(0.0)	0(0.0)	0(0.0)
FB_Arnica fulgens	0(0.0)	0(0.0)	0(0.0)
FB_Arnica latifolia	11(0.8)	100(0.1)	0(0.0)
FB_Arnica mollis	33(2.0)	0(0.0)	0(0.0)
FB_Arnica rydbergii	22(0.6)	0(0.0)	0(0.0)
FB_Artemisia campestris	0(0.0)	0(0.0)	0(0.0)
FB_Artemisia scopulorum	0(0.0)	0(0.0)	0(0.0)
FB_Astragalus alpinus	0(0.0)	0(0.0)	0(0.0)
FB_Astragalus kentrophyta	0(0.0)	0(0.0)	0(0.0)
FB_Besseya wyomingensis	0(0.0)	0(0.0)	0(0.0)
FB_Boechera angustifolia	0(0.0)	0(0.0)	0(0.0)
FB_Boechera lemmonii	0(0.0)	0(0.0)	0(0.0)
FB_Boechera lyallii	0(0.0)	0(0.0)	0(0.0)
FB_Boechera nuttallii	0(0.0)	0(0.0)	0(0.0)
FB_Bupleurum americanum	0(0.0)	0(0.0)	0(0.0)
FB_Caltha leptosepala	55(8.3)	0(0.0)	0(0.0)
FB_Campanula rotundifolia	0(0.0)	0(0.0)	0(0.0)
FB_Campanula uniflora	0(0.0)	0(0.0)	0(0.0)
FB_Castilleja miniata	11(0.0)	0(0.0)	0(0.0)
FB_Castilleja nivea	0(0.0)	0(0.0)	0(0.0)
FB_Castilleja pulchella	0(0.0)	0(0.0)	0(0.0)
FB_Castilleja rhexiifolia	33(0.6)	50(1.0)	0(0.0)
FB_Castilleja sulphurea	0(0.0)	0(0.0)	0(0.0)
FB_Cerastium arvense	0(0.0)	0(0.0)	0(0.0)
FB_Cerastium beeringianum var. capillare	0(0.0)	0(0.0)	0(0.0)
FB_Cerastium fontanum	0(0.0)	0(0.0)	0(0.0)
FB_Chamerion angustifolium	0(0.0)	50(0.0)	0(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	CANI2 - VEWO2	SETR / MECI3	SEFR3 - DRIN2
FB_Cirsium scariosum	0(0.0)	0(0.0)	0(0.0)
FB_Cirsium undulatum	0(0.0)	0(0.0)	0(0.0)
FB_Claytonia lanceolata	55(0.5)	50(0.0)	0(0.0)
FB_Collomia linearis	0(0.0)	0(0.0)	0(0.0)
FB_Delphinium bicolor	0(0.0)	0(0.0)	0(0.0)
FB_Delphinium glaucum	0(0.0)	0(0.0)	0(0.0)
FB_Descurainia incana	0(0.0)	0(0.0)	0(0.0)
FB_Dodecatheon pulchellum	0(0.0)	50(0.0)	0(0.0)
FB_Douglasia montana	0(0.0)	0(0.0)	0(0.0)
FB_Draba cana	0(0.0)	0(0.0)	0(0.0)
FB_Draba crassifolia	0(0.0)	0(0.0)	0(0.0)
FB_Draba incerta	0(0.0)	0(0.0)	100(0.1)
FB_Epilobium anagallidifolium	0(0.0)	0(0.0)	0(0.0)
FB_Epilobium ciliatum	11(0.1)	0(0.0)	0(0.0)
FB_Epilobium clavatum	22(0.0)	0(0.0)	0(0.0)
FB_Epilobium glaberrimum var. fastigiatum	0(0.0)	0(0.0)	0(0.0)
FB_Epilobium halleanum	0(0.0)	0(0.0)	0(0.0)
FB_Epilobium hornemannii	0(0.0)	100(2.0)	0(0.0)
FB_Eremogone congesta	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron acris var. kamtschaticus	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron compositus var. discoideus	0(0.0)	0(0.0)	50(0.0)
FB_Erigeron grandiflorus	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron ochroleucus	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron peregrinus var. scaposus	66(1.9)	100(1.0)	0(0.0)
FB_Erigeron radicatus	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron rydbergii	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron simplex	0(0.0)	0(0.0)	0(0.0)
FB_Erigeron ursinus	0(0.0)	0(0.0)	0(0.0)
FB_Eriogonum flavum	0(0.0)	0(0.0)	0(0.0)
FB_Eriogonum umbellatum	0(0.0)	0(0.0)	0(0.0)
FB_Eritrichium howardii	0(0.0)	0(0.0)	0(0.0)
FB_Eritrichium nanum var. elongatum	0(0.0)	0(0.0)	0(0.0)
FB_Erysimum asperum	0(0.0)	0(0.0)	0(0.0)
FB_Fragaria virginiana	0(0.0)	0(0.0)	0(0.0)
FB_Frasera speciosa	0(0.0)	0(0.0)	0(0.0)
FB_Galium bifolium	0(0.0)	0(0.0)	0(0.0)
FB_Gentiana algida	0(0.0)	0(0.0)	0(0.0)
FB_Gentiana prostrata	0(0.0)	0(0.0)	0(0.0)
FB_Geum rossii var. turbinatum	0(0.0)	0(0.0)	0(0.0)
FB_Hedysarum sulphurescens	0(0.0)	0(0.0)	0(0.0)
FB_Helianthella uniflora	0(0.0)	0(0.0)	0(0.0)
FB_Heracleum sphondylium var. lanatum	0(0.0)	50(3.5)	0(0.0)
FB_Hieracium triste var. gracile	77(0.9)	50(0.0)	0(0.0)
FB_Hydrophyllum capitatum	0(0.0)	0(0.0)	0(0.0)
FB_Lewisia pygmaea	0(0.0)	0(0.0)	0(0.0)
FB_Lloydia serotina	0(0.0)	0(0.0)	0(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	CANI2 - VEWO2	SETR / MECI3	SEFR3 - DRIN2
FB_Lomatium cous	0(0.0)	0(0.0)	0(0.0)
FB_Lupinus argenteus	0(0.0)	0(0.0)	0(0.0)
FB_Mertensia alpina	0(0.0)	0(0.0)	0(0.0)
FB_Mertensia oblongifolia	0(0.0)	0(0.0)	0(0.0)
FB_Mimulus lewisii	0(0.0)	50(0.5)	0(0.0)
FB_Minuartia obtusiloba	0(0.0)	0(0.0)	50(0.0)
FB_Minuartia rubella	0(0.0)	0(0.0)	0(0.0)
FB_Myosotis alpestris	0(0.0)	0(0.0)	0(0.0)
FB_Myosotis arvensis	0(0.0)	0(0.0)	0(0.0)
FB_Oreostemma alpigenum var. haydenii	11(0.0)	0(0.0)	0(0.0)
FB_Orobanche uniflora var. occidentalis	0(0.0)	0(0.0)	0(0.0)
FB_Oxyria digyna	0(0.0)	0(0.0)	50(0.0)
FB_Oxytropis borealis var. viscida	0(0.0)	0(0.0)	0(0.0)
FB_Oxytropis campestris	0(0.0)	0(0.0)	0(0.0)
FB_Oxytropis lagopus	0(0.0)	0(0.0)	0(0.0)
FB_Oxytropis sericea	0(0.0)	0(0.0)	0(0.0)
FB_Packera cana	11(3.3)	0(0.0)	0(0.0)
FB_Packera dimorphophylla var. paysonii	22(0.6)	0(0.0)	0(0.0)
FB_Packera subnuda	55(0.8)	0(0.0)	0(0.0)
FB_Parnassia fimbriata	11(0.2)	0(0.0)	0(0.0)
FB_Parnassia palustris var. montanensis	0(0.0)	0(0.0)	0(0.0)
FB_Pedicularis bracteosa var. paysoniana	22(0.0)	0(0.0)	0(0.0)
FB_Pedicularis cystopteridifolia	0(0.0)	0(0.0)	0(0.0)
FB_Pedicularis groenlandica	55(0.1)	0(0.0)	0(0.0)
FB_Pedicularis oederi	0(0.0)	0(0.0)	0(0.0)
FB_Pedicularis pulchella	0(0.0)	0(0.0)	0(0.0)
FB_Penstemon procerus	0(0.0)	0(0.0)	0(0.0)
FB_Phacelia hastata	0(0.0)	0(0.0)	0(0.0)
FB_Phleum alpinum	0(0.0)	0(0.0)	0(0.0)
FB_Phlox pulvinata	0(0.0)	0(0.0)	0(0.0)
FB_Physaria didymocarpa	0(0.0)	0(0.0)	0(0.0)
FB_Polemonium viscosum	0(0.0)	0(0.0)	50(0.0)
FB_Polygonum bistortoides	44(0.2)	50(0.0)	0(0.0)
FB_Polygonum viviparum	0(0.0)	0(0.0)	0(0.0)
FB_Potentilla diversifolia	11(0.0)	0(0.0)	0(0.0)
FB_Potentilla nivea	0(0.0)	0(0.0)	0(0.0)
FB_Ranunculus eschscholtzii	44(0.8)	100(0.6)	0(0.0)
FB_Rumex paucifolius	0(0.0)	0(0.0)	0(0.0)
FB_Saxifraga bronchialis var. austromantana	0(0.0)	0(0.0)	50(0.0)
FB_Saxifraga occidentalis	0(0.0)	50(0.0)	0(0.0)
FB_Saxifraga odontoloma	11(0.0)	0(0.0)	0(0.0)
FB_Saxifraga oppositifolia	0(0.0)	0(0.0)	0(0.0)
FB_Saxifraga rhomboidea	0(0.0)	0(0.0)	0(0.0)
FB_Saxifraga subapetala	0(0.0)	0(0.0)	0(0.0)
FB_Sedum integrifolium	0(0.0)	0(0.0)	0(0.0)
FB_Sedum lanceolatum	0(0.0)	0(0.0)	0(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	CANI2 - VEWO2	SETR / MECI3	SEFR3 - DRIN2
FB_Sedum rhodanthum	0(0.0)	0(0.0)	0(0.0)
FB_Senecio crassulus	0(0.0)	0(0.0)	0(0.0)
FB_Senecio fremontii	0(0.0)	0(0.0)	100(1.0)
FB_Senecio integerrimus	0(0.0)	0(0.0)	0(0.0)
FB_Senecio lugens	0(0.0)	0(0.0)	0(0.0)
FB_Senecio triangularis	77(0.8)	100(50.0)	0(0.0)
FB_Sibbaldia procumbens	33(0.3)	0(0.0)	0(0.0)
FB_Silene acaulis var. subacaulescens	0(0.0)	0(0.0)	0(0.0)
FB_Silene parryi	0(0.0)	0(0.0)	0(0.0)
FB_Smelowskia calycina var. americana	0(0.0)	0(0.0)	0(0.0)
FB_Solidago multiradiata var. scopulorum	0(0.0)	0(0.0)	0(0.0)
FB_Stellaria calycantha	11(0.0)	50(0.5)	0(0.0)
FB_Stellaria longipes	0(0.0)	0(0.0)	0(0.0)
FB_Stellaria monantha	11(0.3)	0(0.0)	0(0.0)
FB_Stellaria umbellata	22(0.3)	50(0.0)	0(0.0)
FB_Symphyotrichum foliaceum	44(1.8)	50(0.0)	0(0.0)
FB_Taraxacum ceratophorum	0(0.0)	0(0.0)	0(0.0)
FB_Taraxacum laevigatum	0(0.0)	0(0.0)	0(0.0)
FB_Taraxacum officinale	0(0.0)	0(0.0)	0(0.0)
FB_Tephroseris lindstroemii	0(0.0)	0(0.0)	0(0.0)
FB_Thalictrum occidentale	0(0.0)	0(0.0)	0(0.0)
FB_Trifolium dasyphyllum	0(0.0)	0(0.0)	0(0.0)
FB_Trifolium nanum	0(0.0)	0(0.0)	0(0.0)
FB_Trifolium parryi var. montanense	0(0.0)	0(0.0)	0(0.0)
FB_Trollius albiflorus	22(0.7)	0(0.0)	0(0.0)
FB_Valeriana dioica var. sylvatica	0(0.0)	0(0.0)	0(0.0)
FB_Valeriana occidentalis	0(0.0)	0(0.0)	0(0.0)
FB_Veronica wormskjoldii	100(1.6)	100(0.1)	0(0.0)
FB_Viola adunca	0(0.0)	0(0.0)	0(0.0)
FB_Viola palustris	0(0.0)	0(0.0)	0(0.0)
FB_Zigadenus elegans	0(0.0)	0(0.0)	0(0.0)
FE_Cryptogramma acrostichoides	0(0.0)	0(0.0)	0(0.0)
GR_Agrostis humilis	33(0.7)	0(0.0)	50(0.5)
GR_Agrostis idahoensis	0(0.0)	0(0.0)	0(0.0)
GR_Agrostis variabilis	11(0.2)	50(0.0)	0(0.0)
GR_Bromus carinatus var. linearis	0(0.0)	0(0.0)	0(0.0)
GR_Calamagrostis canadensis	0(0.0)	0(0.0)	0(0.0)
GR_Calamagrostis purpurascens	0(0.0)	0(0.0)	0(0.0)
GR_Carex albonigra	0(0.0)	0(0.0)	0(0.0)
GR_Carex brunnescens	0(0.0)	0(0.0)	0(0.0)
GR_Carex capitata	0(0.0)	0(0.0)	0(0.0)
GR_Carex disperma	0(0.0)	0(0.0)	0(0.0)
GR_Carex elynoides	0(0.0)	0(0.0)	0(0.0)
GR_Carex gynocrates	0(0.0)	0(0.0)	0(0.0)
GR_Carex illota	11(0.0)	0(0.0)	0(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	CANI2 - VEWO2	SETR / MECI3	SEFR3 - DRIN2
GR_Carex macloviana	0(0.0)	0(0.0)	0(0.0)
GR_Carex microptera	0(0.0)	50(0.5)	0(0.0)
GR_Carex misandra	0(0.0)	0(0.0)	0(0.0)
GR_Carex nardina	0(0.0)	0(0.0)	0(0.0)
GR_Carex nigricans	100(45.3)	100(1.0)	0(0.0)
GR_Carex obtusata	0(0.0)	0(0.0)	0(0.0)
GR_Carex paysonis	77(1.8)	0(0.0)	0(0.0)
GR_Carex petasata	0(0.0)	0(0.0)	0(0.0)
GR_Carex phaeocephala	0(0.0)	0(0.0)	100(1.0)
GR_Carex pyrenaica	11(0.1)	0(0.0)	0(0.0)
GR_Carex rossii	0(0.0)	0(0.0)	0(0.0)
GR_Carex rupestris	0(0.0)	0(0.0)	0(0.0)
GR_Carex scirpoidea	0(0.0)	0(0.0)	0(0.0)
GR_Carex scopulorum	11(0.2)	0(0.0)	0(0.0)
GR_Carex spectabilis	0(0.0)	100(0.6)	0(0.0)
GR_Danthonia intermedia	22(0.2)	0(0.0)	0(0.0)
GR_Deschampsia atropurpurea	22(0.4)	0(0.0)	0(0.0)
GR_Deschampsia cespitosa	77(1.8)	50(1.0)	50(0.0)
GR_Eleocharis quinqueflora	0(0.0)	0(0.0)	0(0.0)
GR_Elymus canadensis	0(0.0)	50(0.0)	0(0.0)
GR_Elymus glaucus	0(0.0)	0(0.0)	0(0.0)
GR_Elymus scribneri	0(0.0)	0(0.0)	0(0.0)
GR_Elymus spicatus	0(0.0)	0(0.0)	0(0.0)
GR_Elymus trachycaulus	0(0.0)	0(0.0)	0(0.0)
GR_Eriophorum callitrix	0(0.0)	0(0.0)	0(0.0)
GR_Festuca brachyphylla	0(0.0)	0(0.0)	100(0.1)
GR_Festuca idahoensis	0(0.0)	0(0.0)	0(0.0)
GR_Helictotrichon hookeri	0(0.0)	0(0.0)	0(0.0)
GR_Juncus biglumis	0(0.0)	0(0.0)	0(0.0)
GR_Juncus drummondii	55(1.3)	100(0.6)	0(0.0)
GR_Juncus ensifolius	11(0.0)	0(0.0)	0(0.0)
GR_Juncus mertensianus	44(0.5)	100(0.1)	0(0.0)
GR_Juncus parryi	11(0.1)	0(0.0)	0(0.0)
GR_Juncus triglumis	0(0.0)	0(0.0)	0(0.0)
GR_Kobresia myosuroides	0(0.0)	0(0.0)	0(0.0)
GR_Koeleria macrantha	0(0.0)	0(0.0)	0(0.0)
GR_Luzula parviflora	33(0.9)	0(0.0)	0(0.0)
GR_Luzula spicata	0(0.0)	50(0.0)	50(0.0)
GR_Melica spectabilis	0(0.0)	0(0.0)	0(0.0)
GR_Phleum alpinum	77(0.3)	50(0.0)	0(0.0)
GR_Poa alpina	0(0.0)	0(0.0)	0(0.0)
GR_Poa arctica var. arctica	0(0.0)	0(0.0)	0(0.0)
GR_Poa cusickii	77(4.6)	100(0.1)	0(0.0)
GR_Poa fendleriana	0(0.0)	0(0.0)	0(0.0)
GR_Poa glauca var. rupicola	0(0.0)	0(0.0)	0(0.0)
GR_Poa lettermanii	0(0.0)	0(0.0)	50(0.0)

Table H.1. Cover/Constancy Table for Alpine Vegetation Associations (continued).

STRATA_Species names	CANI2 - VEWO2	SETR / MECI3	SEFR3 - DRIN2
GR_Poa pattersonii	0(0.0)	0(0.0)	0(0.0)
GR_Poa reflexa	33(0.3)	100(1.6)	0(0.0)
GR_Poa secunda	11(0.0)	0(0.0)	0(0.0)
GR_Trisetum spicatum	0(0.0)	0(0.0)	100(0.6)
SH_Arctostaphylos uva-ursi	0(0.0)	0(0.0)	0(0.0)
SH_Artemisia frigida	0(0.0)	0(0.0)	0(0.0)
SH_Betula glandulosa	0(0.0)	0(0.0)	0(0.0)
SH_Dryas octopetala var. hookeriana	0(0.0)	0(0.0)	0(0.0)
SH_Gaultheria humifusa	33(0.3)	0(0.0)	0(0.0)
SH_Juniperus communis var. depressa	0(0.0)	0(0.0)	0(0.0)
SH_Kalmia microphylla	44(2.8)	0(0.0)	0(0.0)
SH_Pentaphylloides floribunda	0(0.0)	0(0.0)	0(0.0)
SH_Phyllodoce empetriformis	33(0.2)	0(0.0)	0(0.0)
SH_Phyllodoce glanduliflora	11(0.1)	0(0.0)	0(0.0)
SH_Salix arctica var. petraea	0(0.0)	0(0.0)	0(0.0)
SH_Salix glauca var. villosa	0(0.0)	0(0.0)	0(0.0)
SH_Salix planifolia	0(0.0)	0(0.0)	0(0.0)
SH_Salix reticulata var. nana	0(0.0)	0(0.0)	0(0.0)
SH_Vaccinium scoparium	22(0.6)	0(0.0)	0(0.0)
TR_Abies lasiocarpa	11(0.0)	0(0.0)	0(0.0)
TR_Picea engelmannii	11(0.0)	0(0.0)	0(0.0)
TR_Pinus albicaulis	0(0.0)	0(0.0)	0(0.0)
TR_Pinus contorta var. latifolia	0(0.0)	0(0.0)	0(0.0)