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# Vegetation of the Glacier Lakes Ecosystem Experiments Site

Claudia M. Regan  
Robert C. Musselman  
June D. Haines



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## Abstract

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Vegetation at the Glacier Lakes Ecosystem Experiment Site, a 600 ha research site at 3200 to 3500 m elevation in the Snowy Range of southeastern Wyoming, was categorized and described from an intensive sampling of species abundances. A total of 304 vascular plant taxa were identified through collection and herbarium documentation. Plots with tree species were separated from those without tree species for ordination and classification analyses. Detrended correspondence analysis was used to order plots along major axes of composition variation, which are inferred moisture and topographic gradients. Cluster analysis was used to categorize plots based on composition similarity. The resulting groups were named according to species dominants. We identified and described in detail 4 meadow, 4 thicket or scrub, 3 krummholz, and 2 forest plant associations.

Key words: alpine vegetation, subalpine vegetation, plant associations, cluster analysis, floristics, Wyoming, Snowy Range, Medicine Bow Mountains

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## Contents

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Introduction .....	1
Study Area .....	2
Physiography and Geology .....	3
Climate .....	3
Landscape Characteristics .....	3
Wildlife and Domestic Grazers .....	3
Current Management .....	3
Methods .....	3
Field Methods .....	3
Floristics Documentation .....	4
Analytical Methods .....	4
Results and Discussion .....	5
Vegetation .....	9
Plant Associations .....	15
Conclusions .....	23
Literature Cited .....	24
Appendix 1 .....	26
Appendix 2 .....	32



# Vegetation of the Glacier Lakes Ecosystem Experiments Site

## Introduction

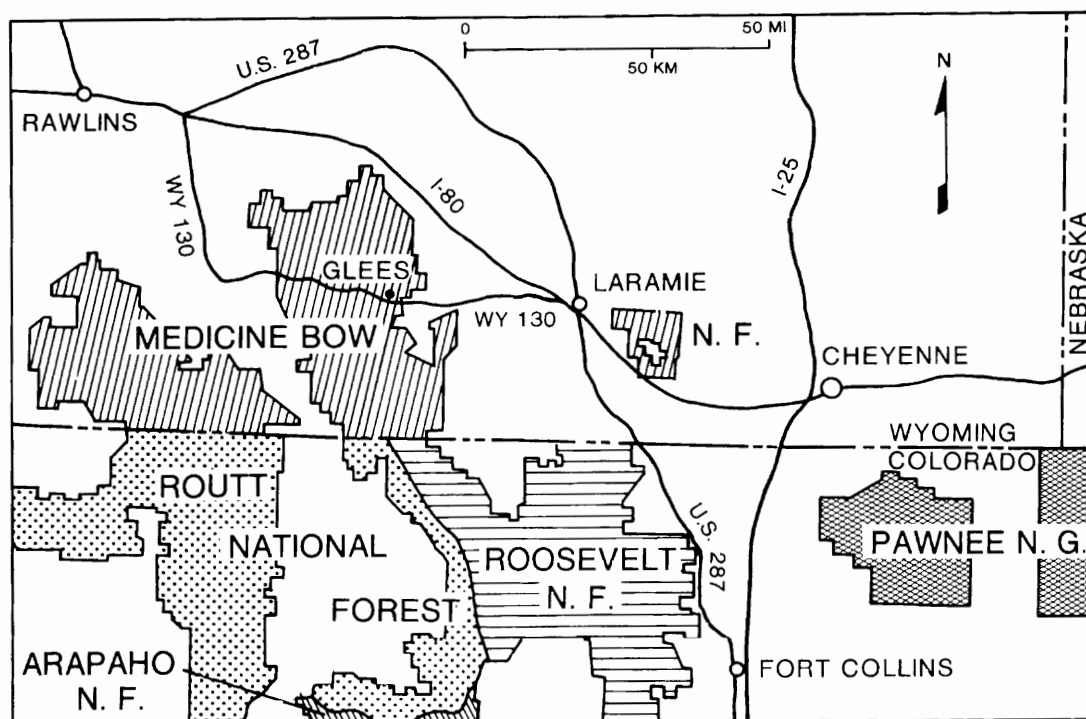
The Glacier Lakes Ecosystem Experiments Site (GLEES) (figure 1) was established in the Snowy Range of the Medicine Bow Mountains of Wyoming to study the effects of air pollution on the structure and function of subalpine and alpine ecosystems (Musselman 1994). Research at the site uses an integrated ecosystem approach to assess the environmental impact of human-induced atmospheric deposition and climate change in a landscape typical of high elevation wilderness systems. These assessments require baseline data to quantify the current environmental and biological status of the ecosystem and to study each biological and physical component. Our study documents the vascular flora of the entire GLEES and categorizes and describes the vegetation types based on quantitative data. This quantitative information is useful as a baseline for intensive studies of ecosystem processes at the site.

Several researchers have studied the vegetation of the Snowy Range. Oosting and Reed (1952) reported a phy-

tosociological survey of the spruce-fir forests of the Medicine Bow Mountains. Their study provides general information on the composition and structure of these forests. However, their study sites did not encompass the full range of environmental variability in subalpine forests, and their results do not indicate a comprehensive floristics survey because only 46 species of vascular plants were identified. Billings and Bliss (1959) studied snowbank environments and vegetation. They concluded that snowmelt in alpine areas greatly influences floristics and productivity. Several other studies investigated the relationship between productivity of the Medicine Bow alpine and the environment (Scott 1963; Smith and Johnson 1965; Smith 1969). Several species-level physiological studies have been done on alpine plants of the area (Mooney and Billings 1960, 1965; Mooney 1961; Scott et al. 1970).

The original vegetation classification (Wirsing 1973; Wirsing and Alexander 1975) focused on forest vegetation and identified 5 habitat types of the Medicine Bow Mountains. Alexander et al. (1986) strengthened the classification by again focusing on forested habitat types of this area. Although this study identifies 16 habitat types, it does not encompass all of the environmental variation

**Figure 1.** Geographic location of the Glacier Lakes Ecosystem Experiments Site.



present in the forests of the GLEES and does not include information on nonforested areas.

A preliminary assessment of the vegetation of part of the GLEES was conducted using a descriptive, qualitative approach (Simmons 1994). Landscape habitats of the Lost Lake, West Glacier Lake, and East Glacier Lake portions of the study area were identified using limited ground reconnaissance, air photo interpretation, and a physiognomic classification of the vegetation types. Twelve vegetation/landscape types were identified, mapped, and described based on interpretation of 1:6000 aerial photographs (Simmons 1994). Although the description does not include a comprehensive floristic documentation or a characterization of plant communities, it does provide a reference point and a baseline for the intensive study of the GLEES vegetation presented here.

The objectives of this study were to:

1. Provide a comprehensive, quantitative characterization of the GLEES flora;
2. Identify and describe the composition and structure of the plant associations of the GLEES;
3. Determine the similarity between the GLEES vegetation and the prevalent alpine and subalpine vegetation of the central Rocky Mountains; and
4. Provide baseline information for identifying future ecosystem change.

The floristics survey documents the occurrence of vascular plant species of the GLEES. The vegetation classification identifies vegetation types that are ecologically distinct and occupy a significant area. The plant community classification provides a framework to study the biotic components of the GLEES systems. In addition, the classification provides supplementary information to resource managers about subalpine and alpine meadow and shrub-dominated vegetation.

## Study Area

The GLEES is a 600 ha alpine and subalpine research study area in the Snowy Range of the Medicine Bow Mountains of southeastern Wyoming. The area is part of the Medicine Bow National Forest, which is 55 km west of Laramie, Wyoming, and 15 km northwest of Centennial, Wyoming, at 41° 22'30" latitude and 106° 15'30" longitude (figures 1 and 2). Portions of the GLEES are mapped on 4 U.S. Geological Survey (USGS) 7.5 minute series topographic quadrangles: the Medicine Bow Peak, Sand Lake, Morgan, and Centennial quads. The high elevation of the GLEES is defined by the watersheds of 3 glacial cirque lakes: Lost Lake, West Glacier Lake, and East Glacier Lake.

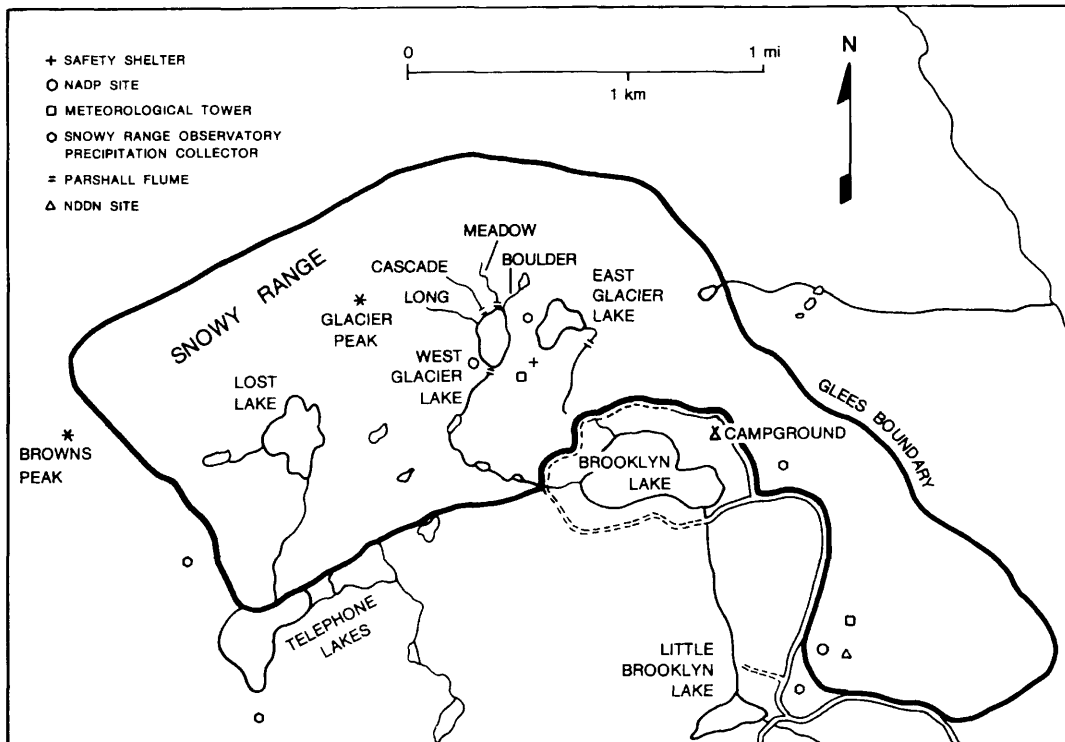


Figure 2. The Glacier Lakes Ecosystem Experiments Site research study area in southeast Wyoming (from Musselman 1994). The elevation of the GLEES ranges from 3180 m near Little Brooklyn Lake to 3494 m at Glacier Peak on the Snowy Range ridge.

The low elevation of the GLEES is east of Brooklyn Lake and Little Brooklyn Lake, within the Nash Fork watershed of the Little Laramie River. The GLEES elevation ranges from 3180 m near Little Brooklyn Lake to 3494 m at Glacier Peak on the Snowy Range ridge.

## Physiography and Geology

The Snowy Range is underlain by Precambrian gneiss and igneous rock (Thornbury 1965). The range rises from the western flank of the Laramie Basin and reaches its highest point on Medicine Bow Peak (3,658 m); the North Platte Valley is the western border of the range. The northern part of the range is characterized by Pleistocene glacial drift (Houston 1968) that results in numerous streams and lakes; the GLEES is within this glaciated portion. A predominant geologic feature of the GLEES is a ridge of Medicine Peak quartzite intruded by mafic dikes that compose 15 to 20 percent of the bedrock in the Glacier Lakes and Lost Lake drainage basins (Rochette 1994).

Typical of much of the GLEES area above the lakes, soils formed from the quartzite bedrock are extremely stony (Hopper and Walthall 1994) and are shallow and minimally developed in areas of rock outcrops, talus slopes, and below the permanent snowfield. High elevation soils are primarily Cryochrepts with some Cryorthents, and low elevation soils are Cryochrepts and Cryumbrepts. Cryoboralfs are associated with areas of glacial till.

## Climate

Minimum and maximum hourly average temperatures range from -23 °C to -1 °C in winter, and -7 °C to 21°C in summer. Most precipitation is snow that covers most of the study area from late October until July. Precipitation ranges from 90 to 125 cm; mean maximum snow accumulation is about 2 m. A predominant climatic feature of the study area is the high wind speed that averages 34 km/hr; winds are primarily northerly and westerly (Musselman 1994).

## Landscape Characteristics

The landscape is characterized by steep, highly dissected, rocky terrain. The complex terrain influences local wind patterns and snow distribution. Differing wind exposure and variable snow depth and duration create microhabitats of varying growing season duration and available moisture levels, which are the primary limiting factors for plant establishment and growth at high elevations (Billings and Bliss 1959; Johnson and Billings 1962; Bliss

1963). Much of the study area is at the subalpine to alpine transition. Many perennial and intermittent streams drain the watersheds, and the lower elevation portion of the study area is scattered with several perennial and ephemeral ponds. The forest/alpine, forest/subalpine, montane grassland, and terrestrial/aquatic ecotones dominate the GLEES landscape, which makes it an ideal location to study ecosystem dynamics resulting from climate change.

## Wildlife and Domestic Grazers

The GLEES, within the Libby Flats grazing allotment (USDA Forest Service 1985), has been grazed primarily by sheep since the late 1800s. Recently the area was restricted from further sheep grazing.

Several wildlife species also have an influence on the GLEES vegetation. The dominant ungulate in the area is the mule deer, and an occasional elk is sited. Pocket gophers create significant soil disturbance that influences plant community composition and structure. There have been no studies of the fauna at the GLEES.

## Current Management

The GLEES is part of the USDA Forest Service's Laramie Ranger District of the Medicine Bow National Forest. Recreation, the primary use of the area, includes fishing, hiking, overnight camping, motorized snow machines, and skiing. Recreational impacts include secondary trails and occasional campfire rings. Although closed to new mining claims, active claims exist. Most mining claims are unworked and the only evidence of past mining activity is an occasional old exploratory soil pit. There are no signs of recent mining activity at the GLEES. The study area is roadless but is bordered on the southwest by a Forest Service road; accessibility is provided by a Forest Service trail and several unimproved trails. Off-road vehicular travel is restricted to motorized snow machines.

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## Methods

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### Field Methods

A stratified, random approach was used to locate the sample sites. A 100 m<sup>2</sup> grid was drawn over a map of the study area. Within each grid cell, another grid of points at 10 m intervals was drawn resulting in 100 possible sample points per cell. One point from each 100 m<sup>2</sup> grid was

randomly selected and mapped as the sampling location for that grid cell. The sampling locations were physically located using the grid maps, aerial photography (1:24000), and an altimeter. Plot locations were marked on the aerial photographs. Markers labeled with the plot number were established as the center for circular macroplots. Plot centers were sometimes adjusted 1 to 3 m within the area to be sampled to ensure homogeneous environment and vegetation based on field observations. This adjustment avoided sample plot overlap of 2 distinct habitats. Less than 5 percent of the plots required such adjustment.

A 0.01 ha (11.28 m diameter) circular macroplot was used to measure tree and advanced regeneration strata, presence of all vascular plant species, and physical environment information. Trees (defined as woody plants  $\geq 1.4$  m tall) were measured for diameter at breast height and the species was recorded. Trees  $< 1.4$  m were tallied by species. All vascular plant species in the macroplot were listed. Physical environment information included elevation, aspect, slope position, and slope form.

A modified Daubenmire (1959) technique was used to measure the canopy cover of all vascular plant species. Transects originating from the plot center and extending to the perimeter of the plot were randomly located using azimuth corrected for declination ( $13^\circ$ ). Subplots ( $.1 \text{ m}^2$ ) were systematically placed at 1 m intervals along the transect. A canopy cover class for each species was determined for each subplot. The cover classes and associated percent cover quantities are: 0 ( $<1$ ), 1 (1 to 5), 2 (6 to 25), 3 (26 to 50), 4 (51 to 75), 5 (76 to 95), and 6 (96 to 100). Midpoints of the percent cover ranges were used as the species response value in data analysis. Initial assessment of the sample size requirements (pilot sampling and the construction of species area curves) revealed that 15 subplots were required for plots with low species diversity ( $<20$  species present) and 20 to 25 subplots were required for more diverse plots. A total of 125 macroplots and 2,040 subplots were established and sampled once during either the 1989, 1990, or 1991 growing season.

## Floristics Documentation

Vascular plant species collections were made and referenced for verification of species identifications and to document species occurrence. Identification and verification was done in cooperation with the Rocky Mountain Herbarium at the University of Wyoming. For purposes of plot sampling, species that were never collected while flowering or fruiting were identified to the genus. Nomenclature follows that used by the Rocky Mountain Herbarium (Nelson and Hartman 1992), with primary taxonomic references from Dorn (1988), Hitchcock et al. (1955, 1959, 1961, 1964, 1969), Harrington (1964), Hermann (1970),

and Moss (1983). Voucher specimens of all vascular plant species documented were deposited at the Rocky Mountain Herbarium.

## Analytical Methods

### *Floristics Summary and Biogeographic Analysis*

A species presence list was constructed after identifications were confirmed. Biogeographic affinities were determined by consulting standard regional floras (Haines et al. 1994). Several major biogeographic groups are represented in the GLEES flora; Alpine, Arctic-Alpine, Boreal-Montane, Great Plains, Montane, and ubiquitous. Secondary biogeographic groups were also identified; those of particular interest included Circumpolar, North America, Western North America, Rocky Mountain, and Southern Rocky Mountain. These groups are similar to those summarized by Thorne (1972) and discussed in Brown and Gibson (1983). We have added resolution in biogeographic group identification to address all biogeographic distributions cited in the regional floras. The percentage of flora falling into each biogeographic group was calculated.

### *Summary of Vegetation Data*

Detrended correspondence analysis (DCA) (Gauch 1982; Peet et al. 1988) was used to determine patterns in the vegetation data using the computer program CANOCO (version 2.1) (ter Braak 1988). CANOCO is a community ordination software package that is capable of indirect community ordination and multivariate direct gradient analysis. DCA is an ordination technique that searches for major gradients in species data. The procedure assumes a unimodal model for the relationship between species response and the ordination axes, assumed to represent theoretical environmental gradients, and fits the model using two-way weighted averaging. Species response data were mean percent cover values for each species at each site or macroplot. Ordination success was measured by the percent of variance that was accounted for by the ordination axes.

Ordinations of sites revealed patterns of dominant compositional gradients. Initial ordinations included all sites and species. Results from these analyses were used to eliminate outliers and to divide the data set into logical units for subsequent analysis; the subsets were ordinated for a more refined view of compositional patterns. A community classification was constructed using COMPAH (Combinatorial, Polythetic, Agglomerative, Hierarchical clustering) (Boesch 1977), which is a cluster analysis software package designed for ecological data classification. The cluster method used was a group averaging technique with unweighted pair-grouping (UPGMA) (Sneath and

Sokal 1973) and the resemblance function used was percent similarity (Bray and Curtis 1957). Cluster analysis results were summarized using dendrograms. The specific groups or communities were identified subjectively to achieve definable, interpretable, and repeatable associations based on our field observations and knowledge of the species characteristics (Ludwig and Reynolds 1988). The classification analyses were done on the individual data sets identified from the ordination results. Clustering was done by sites and species. Diversity measures were calculated and used to compare community structure (Ludwig and Reynolds 1988). Hill's indices (1973) were used to determine the total number of species in the sample (N0), the effective number of species including the number of abundant species (N1), and the number of very abundant species (N2). The modified Hill's ratio (Hill 1973; Alatalo 1981) was used as a measure of evenness.

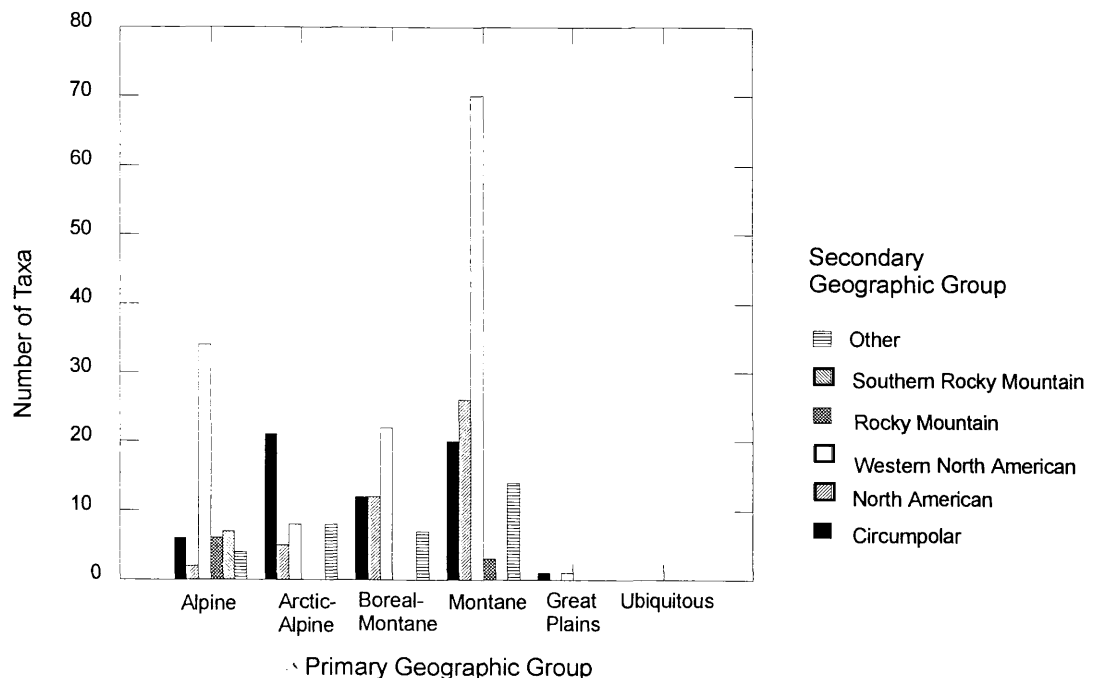
Plant community types or plant associations were named according to either dominant and codominant species for nonforested types or dominant overstory species and dominant shrub or herb layer species for forested types (those where tree species are present). Where possible, the terminology for types followed that used in other published reports. The potential for the use of species as indicators was analyzed by graphing the centroid distributions of individual species on the ordinations. Then, constancy and frequency data for each species in each type were evaluated to identify species with the highest constancy values for a dominance type and the lowest frequency values between dominance types. The classification results were field tested, refined, and synthesized to pro-

duce a classification system applicable to the entire GLEES study area.

## Results and Discussion

Vascular plant taxa present at the GLEES are listed in Appendix 1. A total of 289 species and 304 taxa were documented through collection and herbarium verification. Of the 304 taxa at the GLEES, 102 were not documented in the sample stands. Eleven taxa are present in >40 percent of the macroplots. They are, in order of frequency, *Abies lasiocarpa* var. *lasiocarpa*, *Erigeron peregrinus*, *Hieracium gracile* var. *gracile*, *Picea engelmannii*, *Vaccinium scoparium*, *Potentilla diversifolia* var. *diversifolia*, *Carex rossii*, *Polygonum bistortoides*, *Sibbaldia procumbens*, *Senecio dimorphophyllus* var. *dimorphophyllus*, and *Achillea millefolium* var. *lanulosa* (Appendix 2). Of the 304 taxa, 91 are present in < 5 percent of the total number of macroplots. Geographic distributions for species at the GLEES are summarized in table 1 and figure 3. Data on geographic distributions are missing for 7 of the 304 taxa because we were unable to find reference to their distributions in the literature. The GLEES species have predominantly Montane distributions with primarily western North America affinities. Alpine and Boreal-Montane geographic groups are approximately equally represented in the GLEES flora. Again, western North America affinities predominate.

Figure 3. Geographic distributions of the vascular plant taxa of the Glacier Lakes Ecosystem Experiments Site.



Only a minor portion of the GLEES flora (<5% of the total flora) is represented by species having a Rocky Mountain or southern Rocky Mountain range restriction.

The DCA ordination of all sites (figure 4) indicated the need to separate forested stands from all other stands for better resolution of the forest gradient. Since this analysis is based on floristic composition where the response variable is species cover, forested stands are those with tree species present. Stand structure is not considered in this initial data division; the forested data set includes areas dominated by erect trees and areas dominated by trees in the krummholz form. All subsequent analyses were performed on the forested and nonforested groups separately. The DCA ordination of meadow and shrub-dominated stands is in figure 5a; species are ordinated in figure 5b and the centroid locations of several key species, either those that are dominant or those that frequently occur, are indicated by arrows. Similarly, forested stands and species are ordinated in figures 6a and 6b, and key species centroids are indicated by arrows in both figures.

Ordinations of meadow and shrub-dominated plots have axis 1 and 2 eigenvalues of .92 and .65 (figures 5a and 5b), and ordinations of forest plots have axis 1 and 2 eigenvalues of .72 and .57 (figures 6a and 6b). The high eigenvalues for the ordinations of nonforested plots (figure 5a) indicate that these gradients account for more of the variation in floristic composition than in the forested plots. In addition, the length of the axis 1 gradient in figures 5a and 5b for the nonforested plots is over 2 times that of the forested plots (figure 6a and 6b). Finally, the pattern of sample distribution indicates that the nonforested plots (figure 5a and 5b) are related more clearly to 2 axes of variation than are the forested plots (figure 6a and 6b). In this paper, the ordinations are a backdrop for an overlay of the classification results and illustrate the pattern of vegetation distribution in ordination space.

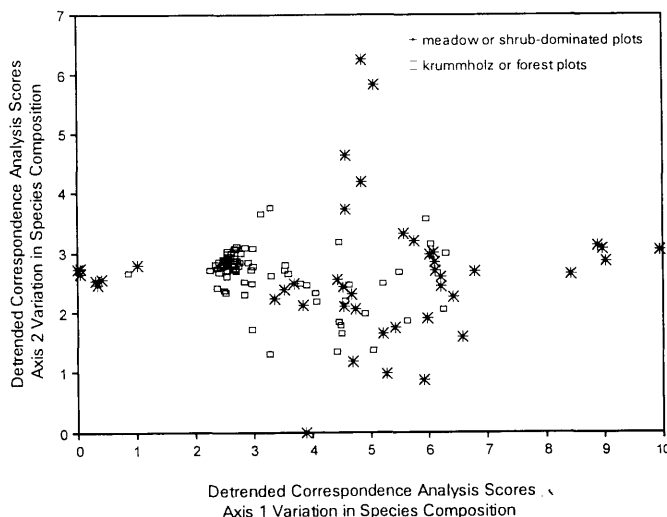


Table 1. Summary of the geographic distributions of the vascular plant taxa of the Glacier Lakes Ecosystem Experiments Site.

Geographic distribution		Number of taxa	% of total flora
<b>Major group</b>	<b>Secondary group</b>		
Alpine	Circumpolar	6	2
	North American	2	<1
	Western North American	34	11
	Rocky Mountain	6	2
	Southern Rocky Mountain	7	2
	Other	4	1
Arctic-Alpine	Circumpolar	21	7
	North American	5	2
	Western North American	8	3
	Rocky Mountain	0	0
	Southern Rocky Mountain	0	0
	Other	8	3
Boreal-Montane	Circumpolar	12	4
	North American	12	4
	Western North American	22	7
	Rocky Mountain	0	0
	Southern Rocky Mountain	0	0
	Other	7	2
Montane	Circumpolar	20	7
	North American	26	9
	Western North American	70	24
	Rocky Mountain	3	1
	Southern Rocky Mountain	0	0
	Other	14	5
Great Plains	Circumpolar	1	<1
	North American	0	0
	Western North American	1	<1
	Rocky Mountain	0	0
	Southern Rocky Mountain	0	0
	Other	0	0
Ubiquitous or disturbed		8	3

Figure 4. Detrended correspondence analysis ordination of all sample locations, Glacier Lakes Ecosystem Experiments Site. Axes 1 and 2 are the major axes of variation in sample composition. Eigenvalues are .87 for axis 1 and .62 for axis 2. The response variable is species mean cover so that the ordination is based on floristic composition and does not incorporate forest stand structure. Forested and krummholz plots are those where tree species are present. All other plots are either meadow or shrub-dominated associations.

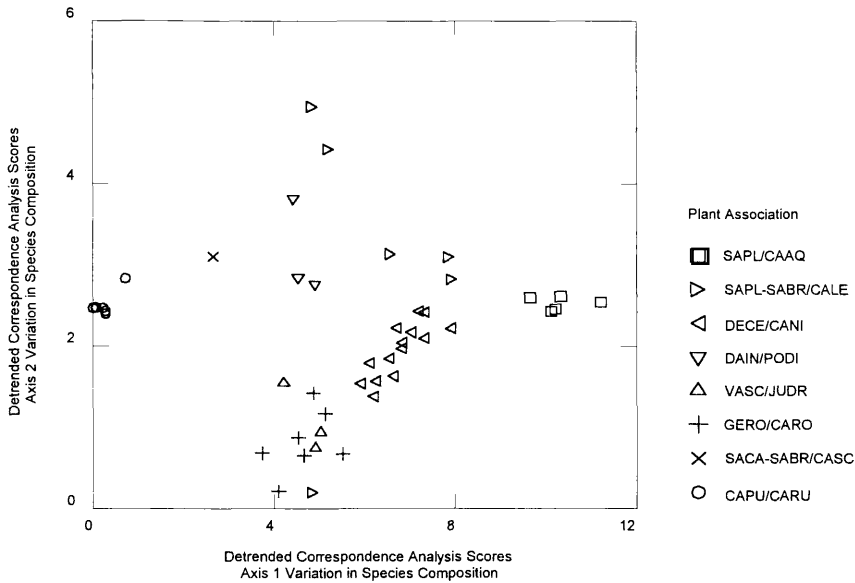


Figure 5a. Detrended correspondence analysis ordination of all meadow and shrub-dominated plots, Glacier Lakes Ecosystem Experiments Site. Axes 1 and 2 are major axes of species composition variation in the nonforested samples; axis 1 is an inferred moisture gradient, with samples occupying drier sites on the left and wetter sites on the right. Eigenvalues are .92 for axis 1 and .65 for axis 2. Plant associations are indicated. SAPL/CAAQ is the *Salix planifolia*/*Carex aquatilis* thicket. SAPL-SABR/CALE is the *Salix planifolia*-*S. brachycarpa*/*Caltha leptosepala* thicket. DECE/CANI is the *Deschampsia cespitosa*/*Carex nigricans* meadow. DAIN/PODI is the *Danthonia intermedia*/*Potentilla diversifolia* meadow. VASC/JUDR is the *Vaccinium scoparium*/*Juncus drummondii* dwarf scrub. GERO/CARO is the *Geum rossii*/*Carex rossii* meadow. SACA-SABR/CASC is the *Salix cascadiensis*-*S. brachycarpa*/*Carex scopulorum* thicket. CAPU/CARU is the *Calamagrostis purpurascens*/*Carex rupestris* meadow.

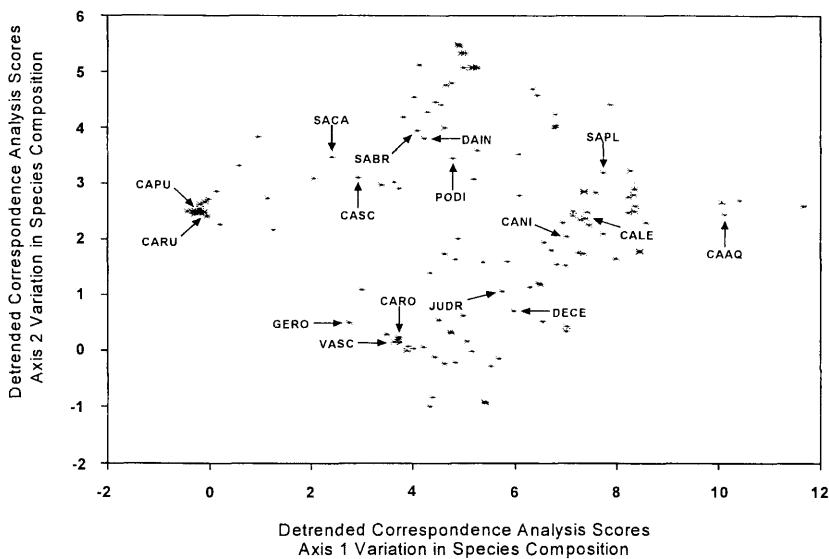


Figure 5b. Detrended correspondence analysis ordination of species in meadows and scrub or thicket vegetation, Glacier Lakes Ecosystem Experiments Site. Centroid locations of selected species, either those that are dominant or are frequently occurring, are indicated by arrows. Species are: CAAQ is *Carex aquatilis*, CALE is *Caltha leptosepala*, CANI is *Carex nigricans*, CAPU is *Calamagrostis purpurascens*, CARO is *Carex rossii*, CARU is *Carex rupestris*, CASC is *Carex scopulorum*, DAIN is *Danthonia intermedia*, DECE is *Deschampsia cespitosa*, GERO is *Geum rossii*, JUDR is *Juncus drummondii*, PODI is *Potentilla diversifolia*, SABR is *Salix brachycarpa*, SACA is *Salix cascadiensis*, SAPL is *Salix planifolia*, and VASC is *Vaccinium scoparium*. Axes 1 and 2 are major axes of species composition variation in the nonforested samples; axis 1 is an inferred moisture gradient, with the driest end of the gradient on the left.

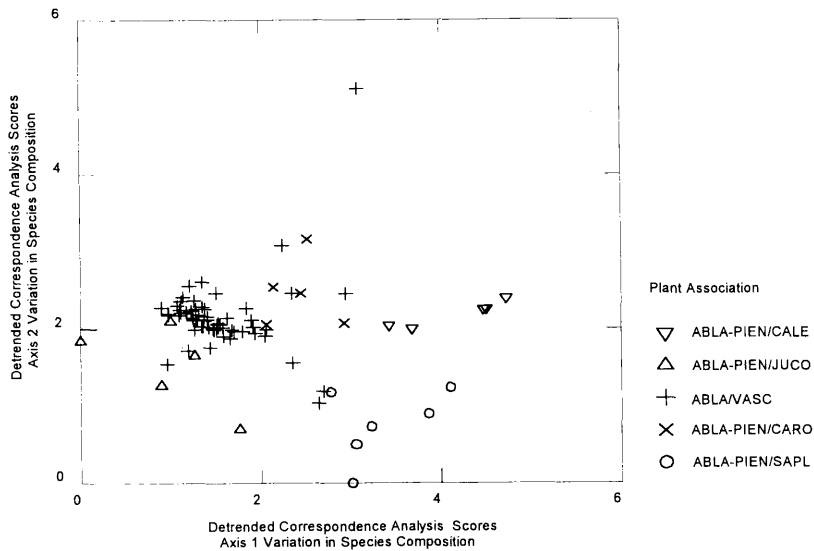


Figure 6a. Detrended correspondence analysis ordination of all forest and krummholz plots, Glacier Lakes Ecosystem Experiments Site. Axes 1 and 2 are major axes of species composition variation in the forested samples; axis 1 is an inferred moisture gradient, with drier sites on the left and wetter sites on the right. Eigenvalues are .72 for axis 1 and .57 for axis 2. Plant associations are indicated. ABLA-PIEN/CALE is the *Abies lasiocarpa-Picea engelmannii/Caltha leptosepala* forest. ABLA-PIEN/JUCO is the *Abies lasiocarpa-Picea engelmannii/Juniperus communis* krummholz. ABLA/VASC is the *Abies lasiocarpa/Vaccinium scoparium* forest. ABLA-PIEN/CARO is the *Abies lasiocarpa-Picea engelmannii/Carex rossii* krummholz. ABLA-PIEN/SAPL is the *Abies lasiocarpa-Picea engelmannii/Salix planifolia* krummholz.

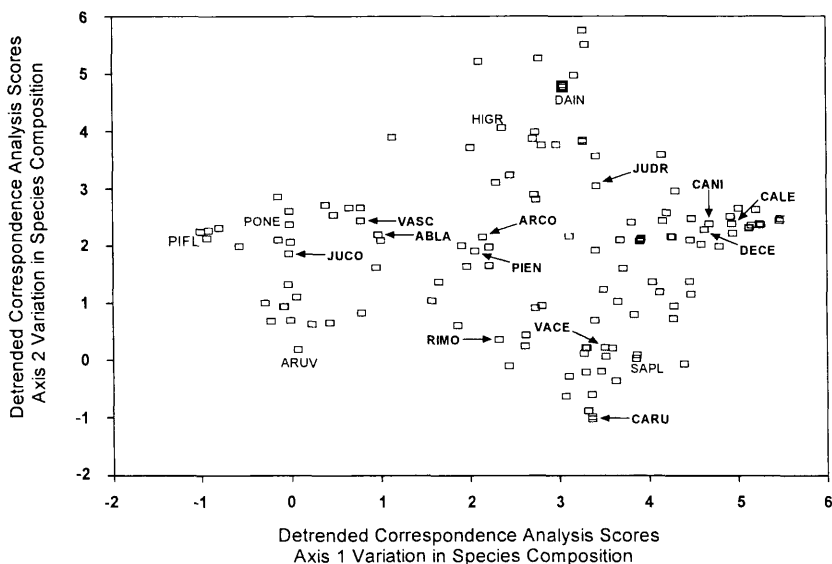


Figure 6b. Detrended correspondence analysis ordination of species occurring in forests or krummholz, Glacier Lakes Ecosystem Experiments Site. Centroid locations of dominant or frequently occurring species are indicated by arrows. Species are: ABLA is *Abies lasiocarpa*, ARCO is *Arnica cordifolia*, ARUV is *Arctostaphylos uva-ursi*, CALE is *Caltha leptosepala*, CANI is *Carex nigricans*, CARU is *Carex rupestris*, DAIN is *Danthonia intermedia*, DECE is *Deschampsia cespitosa*, HIGR is *Hieracium gracile*, JUCO is *Juniperus communis*, JUDR is *Juncus drummondii*, PIEN is *Picea engelmannii*, PIFL is *Pinus flexilis*, PONE is *Poa nervosa*, RIMO is *Ribes montigenum*, SAPL is *Salix planifolia*, VACE is *Vaccinium cespitosum*, and VASC is *Vaccinium scoparium*. Axis 1 and 2 are major axes of species composition variation in forested samples; axis 1 is an inferred moisture gradient, with the driest end of the gradient on the left.

The cluster analysis of the meadow and shrub-dominated plots is summarized in figure 7. Eight plant associations are recognized based on the degree of clustering, reflective of the degree of floristic similarity, field observations, and tabular comparisons. The associations are arranged in ordination space along inferred moisture and elevation gradients (figure 5a). High elevation associations are: *Calamagrostis purpurascens*/*Carex rupestris*, *Geum rossii*/*Carex rossii*, and *Salix cascadiensis*-*Salix brachycarpa*/*Carex scopulorum*. Mid to low elevation xeric to mesic associations are: *Vaccinium scoparium*/*Juncus drummondii* and *Danthonia intermedia*/*Potentilla diversifolia*. Mid to low elevation wet associations are: *Deschampsia cespitosa*/*Carex nigricans*, *Salix planifolia*-*Salix brachycarpa*/*Caltha leptosepala*, and *Salix planifolia*/*Carex aquatilis*. General characteristics and associated species are in table 2; mean percent cover and diversity estimates are in tables 3 and 4.

The forest and krummholz classification is illustrated in figure 8. Most of the forest plots are classified as the *Abies lasiocarpa*/*Vaccinium scoparium* type. High elevation mesic to xeric associations are: *Abies lasiocarpa*-*Picea engelmannii*/*Salix planifolia*, *Abies lasiocarpa*-*Picea engelmannii*/*Juniperus communis*, and *Abies lasiocarpa*-*Picea engelmannii*/*Carex rossi*. The mid to low elevation riparian or wetland association

is *Abies lasiocarpa*-*Picea engelmannii*/*Caltha leptosepala*. General characteristics and associated species are in table 5; mean percent cover or basal area for trees and diversity estimates are in tables 6 and 7.

## Vegetation

Vegetation of the GLEES and its spatial pattern on the landscape is typical of the subalpine/alpine ecotone in the central and southern Rocky Mountains. Coniferous forests dominate the landscape at the low portions of the study area and krummholz stands of these forests dominate at high elevations or exposed sites. The forests often occur as islands or ribbons and are interspersed with nonforested sites dominated by meadow or shrub-dominated communities. Drainages and topographic depressions have by willow shrub communities or graminoid dominated meadows. Areas of heavy snow accumulation and prolonged snow cover have willow shrub types or grass-sedge meadows. Alpine tundra vegetation occurs above treeline on exposed, windswept slopes. Much of the landscape is scree slopes and rock outcrops that are minimally vegetated, and water or permanent snowfields that are without vegetation.

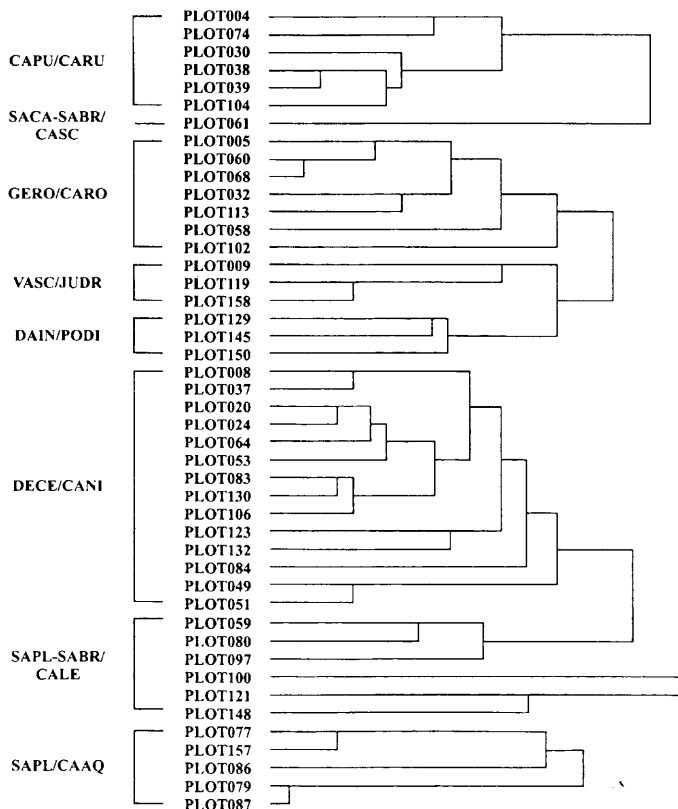


Figure 7. Dendrogram of meadow and shrub-dominated communities, Glacier Lakes Ecosystem Experiments Site. The dendrogram illustrates clusters of similar samples and is hierarchically arranged to reflect different degrees of similarity. Clustering is by weighted averages with unweighted pair-grouping, and the measure of resemblance is percent similarity. Plant associations identified with each cluster are indicated. SAPL/CAAQ is the *Salix planifolia*/*Carex aquatilis* thicket. SAPL-SABR/CALE is the *Salix planifolia*-*S. brachycarpa*/*Caltha leptosepala* thicket. DECE/CANI is the *Deschampsia cespitosa*/*Carex nigricans* meadow. DAIN/PODI is the *Danthonia intermedia*/*Potentilla diversifolia* meadow. VASC/JUDR is the *Vaccinium scoparium*/*Juncus drummondii* dwarf scrub. GERO/CARO is the *Geum rossii*/*Carex rossii* meadow. SACA-SABR/CASC is the *Salix cascadiensis*-*S. brachycarpa*/*Carex scopulorum* thicket. CAPU/CARU is the *Calamagrostis purpurascens*/*Carex rupestris* meadow.

Table 2. General characteristics of meadows and shrub dominated associations, Glacier Lakes Ecosystem Experiments Site.

Plant association	Associated species	Habitat characteristics
<i>Calamagrostis purpurascens</i> / <i>Carex rupestris</i> CAPU/CARU	<i>Erigeron pinnatisectus</i> <i>Festuca brachyphylla</i> <i>Geum rossii</i> <i>Haplopappus pygmaeus</i> <i>Minuartia rubella</i> <i>Paronychia pulvinata</i> <i>Phlox pulvinata</i> <i>Selaginella densa</i> <i>Trifolium dasyphyllum</i>	alpine sites, exposed rocky ridge tops and saddles, no persistent snowcover, shallow soils
<i>Salix cascadenis-</i> <i>Salix brachycarpa</i> / <i>Carex scopulorum</i> SACA-SABR/CASC	<i>Festuca brachyphylla</i> <i>Geum rossii</i> <i>Selaginella densa</i>	alpine sites, protected rocky ledges and depressions, prolonged snow cover
<i>Geum rossii</i> / <i>Carex rossii</i> GERO/CARO	<i>Artemesia scopulorum</i> <i>Erigeron melanocephalus</i> <i>Erigeron peregrinus</i> <i>Erigeron simplex</i> <i>Lewisia pygmaea</i> <i>Poa cusickii</i> <i>Poa reflexa</i> <i>Polygonum bistortoides</i> <i>Potentilla diversifolia</i> <i>Sibbaldia procumbens</i>	subalpine sites to near treeline, prolonged snow cover, well-drained soils
<i>Vaccinium scoparium</i> / <i>Juncus drummondii</i> VASC/JUDR	<i>Carex rossii</i> <i>Erigeron melanocephalus</i> <i>Erigeron peregrinus</i> <i>Erigeron simplex</i> <i>Erythronium grandiflorum</i> <i>Penstemon whippleanus</i> <i>Poa cusickii</i> <i>Senecio crassulus</i> <i>Sibbaldia procumbens</i>	subalpine upland sites, prolonged snow cover, very well-drained soils
<i>Danthonia intermedia</i> / <i>Potentilla diversifolia</i> DAIN/PODI	<i>Agoseris glauca</i> <i>Arenaria congesta</i> <i>Artemesia scopulorum</i> <i>Carex microptera</i> <i>Erigeron peregrinus</i> <i>Minuartia obtusiloba</i> <i>Phleum alpinum</i> <i>Poa reflexa</i> <i>Sibbaldia procumbens</i> <i>Trifolium parryi</i>	subalpine upland mesic sites, often in forest openings, prolonged snow cover
<i>Deschampsia cespitosa</i> / <i>Carex nigricans</i> DECE/CANI	<i>Arnica mollis</i> <i>Caltha leptosepala</i> <i>Carex aquatilis</i> <i>Carex scopulorum</i> <i>Erigeron peregrinus</i> <i>Festuca brachyphylla</i> <i>Juncus drummondii</i> <i>Kalmia microphylla</i> <i>Phleum alpinum</i> <i>Salix planifolia</i> <i>Vaccinium cespitosum</i>	subalpine wet sites, alluvial benches or protected areas with prolonged snow cover
<i>Salix planifolia-</i> <i>Salix brachycarpa</i> / <i>Caltha leptosepala</i> SAPL-SABR/CALE	<i>Calamagrostis canadensis</i> <i>Carex aquatilis</i> <i>Carex atrata</i> <i>Saxifraga odontoloma</i> <i>Sedum rhodanthum</i> <i>Senecio triangularis</i> <i>Trollius laxus</i>	subalpine wet sites, drainages, depressions, and seeps, poorly drained soils

Continued on next page

Table 2. ( Cont'd.)

Plant association	Associated species	Habitat characteristics
<i>Salix planifolia</i> <i>Carex aquatilis</i> SAPL/CAAQ	<i>Caltha leptosepala</i> <i>Carex canescens</i> <i>Eleocharis pauciflora</i> <i>Saxifraga odontoloma</i> <i>Sedum rhodanthum</i>	subalpine very wet sites, stream bottoms or depressions with the water table at or near the surface

Figure 8. Dendrogram of forest and krummholz communities, Glacier Lakes Ecosystem Experiments Site. The dendrogram illustrates clusters of similar samples and is hierarchically arranged to reflect different degrees of similarity. Clustering is by weighted averages with unweighted pair-grouping, and the measure of resemblance is percent similarity. Plant associations identified with each cluster are indicated. ABLA-PIEN/CALE is the *Abies lasiocarpa*-*Picea engelmannii*/*Caltha leptosepala* forest. ABLA-PIEN/JUCO is the *Abies lasiocarpa*-*Picea engelmannii*/*Juniperus communis* krummholz. ABLA/VASC is the *Abies lasiocarpa*/*Vaccinium scoparium* forest. ABLA-PIEN/CARO is the *Abies lasiocarpa*-*Picea engelmannii*/*Carex rossii* krummholz. ABLA-PIEN/SAPL is the *Abies lasiocarpa*-*Picea engelmannii*/*Salix planifolia* krummholz.

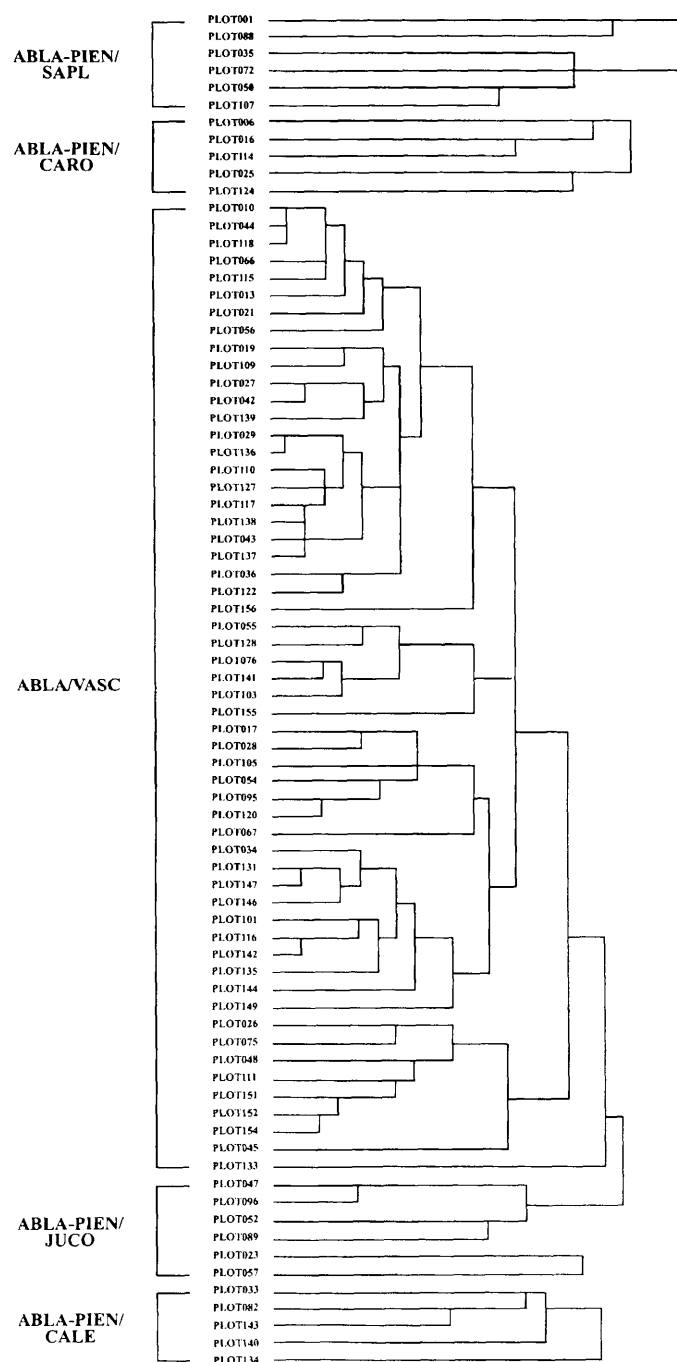


Table 3. Mean percent cover of major species by dominance types derived from COMPAH (Combinatorial, Polythetic, Agglomerative, Hierarchical clustering) (Boesch 1977), classification of meadows and shrub dominated associations of the Glacier Lakes Ecosystem Experiments Site.

	Dominance types							
	CAPU/ CARU	SACA- SABR/ CASC	GERO/ CARO	VASC/ JUDR	DAIN/ PODI	DECE/ CANI	SAPL- SABR/ CALE	SAPL/ CAAQ
<i>Calamagrostis canadensis</i>	x <sup>1</sup>	x	x	x	x	x	0.4	* <sup>2</sup>
<i>Calamagrostis purpurascens</i>	4.6	x	x	x	x	x	x	x
<i>Caltha leptosepala</i>	x	x	x	x	x	19.9	12.2	1.6
<i>Carex aquatilis</i>	x	x	x	x	x	3.8	2.7	43.3
<i>Carex canescens</i>	x	x	x	x	x	x	x	11.7
<i>Carex nigricans</i>	x	x	x	x	x	32.8	11.2	x
<i>Carex rossii</i>	x	x	2.5	8.3	*	x	*	x
<i>Carex rupestris</i>	14.0	x	x	x	x	x	x	x
<i>Carex scopulorum</i>	x	2.5	x	x	x	*	x	x
<i>Danthonia intermedia</i>	x	x	0.4	2.2	26.3	*	2.1	x
<i>Deschampsia cespitosa</i>	x	x	0.5	0.7	1.7	6.3	12.0	x
<i>Eleocharis pauciflora</i>	x	x	x	x	x	x	x	18.6
<i>Erigeron peregrinus</i>	x	x	3.8	9.5	9.3	9.3	10.5	1.2
<i>Erigeron simplex</i>	x	x	*	0.6	*	x	x	x
<i>Festuca brachyphylla</i>	0.5	2.3	x	x	x	*	x	x
<i>Geum rossii</i>	1.0	4.6	*	4.8	*	x	*	x
<i>Juncus drummondii</i>	x	x	16.8	11.4	2.9	10.4	23.9	x
<i>Phlox pulvinata</i>	3.0	x	x	x	x	x	x	x
<i>Potentilla diversifolia</i>	x	x	*	7.6	13.1	2.3	3.5	x
<i>Salix brachycarpa</i>	x	6.7	x	x	x	x	x	x
<i>Salix cascadiensis</i>	x	20.3	x	x	x	x	x	x
<i>Salix planifolia</i>	*	x	x	x	x	13.3	3.7	1.3
<i>Senecio triangularis</i>	x	x	x	x	x	x	2.8	x
<i>Sibbaldia procumbens</i>	*	x	4.1	20.6	4.8	2.0	17.6	x
<i>Trifolium dasyphyllum</i>	1.2	x	x	x	x	x	x	x
<i>Trollius laxus</i>	x	x	x	x	x	8.3	2.1	*
<i>Vaccinium cespitosum</i>	x	*	x	*	x	2.9	16.9	x
<i>Vaccinium scoparium</i>	x	x	16.1	0.7	x	*	x	x
N <sup>3</sup>	6	1	7	3	4	9	5	5
n <sup>4</sup>	100	15	120	50	60	159	81	80

<sup>1</sup> species was absent

<sup>2</sup> mean cover < 0.5%

<sup>3</sup> number of stands

<sup>4</sup> number of subplots

CAPU/CARU = *Calamagrostis purpurascens*/*Carex rupestris*

SACA-SABR/CASC = *Salix cascadiensis*-*Salix brachycarpa*/*Carex scopulorum*

GERO/CARO = *Geum rossii*/*Carex rossii*

VASC/JUDR = *Vaccinium scoparium*/*Juncus drummondii*

DAIN/PODI = *Danthonia intermedia*/*Potentilla diversifolia*

DECE/CANI = *Deschampsia cespitosa*/*Carex nigricans*

SAPL-SABR/CALE = *Salix planifolia*-*Salix brachycarpa*/*Caltha leptosepala*

SAPL/CAAQ = *Salix planifolia*/*Carex aquatilis*

Table 4. Diversity estimates for each meadow and shrub dominated type of the Glacier Lakes Ecosystem Experiments Site.

Dominance type	N0 <sup>1</sup>	N1 <sup>2</sup>	N2 <sup>3</sup>	E <sup>4</sup>
CAPU/CARU	10.0	6.7	5.2	0.7
SACA-SABR/CASC	6.0	6.4	2.8	0.6
GERO/CARO	11.4	6.8	4.9	0.7
VASC/JUDR	18.3	12.3	9.7	0.8
DAIN/PODI	11.9	8.5	5.8	0.7
DECE/CANI	15.8	9.4	7.1	0.7
SAPL-SABR/CALE	12.2	6.4	4.8	0.7
SAPL/CAAQ	3.4	2.1	1.7	0.8

<sup>1</sup> average number of species occurring in the sample plots

<sup>2</sup> average number of abundant species

<sup>3</sup> average number of very abundant species

<sup>4</sup> evenness

CAPU/CARU = *Calamagrostis purpurascens*/*Carex rupestris*; SACA-SABR/CASC = *Salix cascadiensis*-*Salix brachycarpa*/*Carex scopulorum*; GERO/CARO = *Geum rossii*/*Carex rossii*; VASC/JUDR = *Vaccinium scoparium*/*Juncus drummondii*; DAIN/PODI = *Danthonia intermedia*/*Potentilla diversifolia*; DECE/CANI = *Deschampsia cespitosa*/*Carex nigricans*; SAPL-SABR/CALE = *Salix planifolia*-*Salix brachycarpa*/*Caltha leptosepala*; SAPL/CAAQ = *Salix planifolia*/*Carex aquatilis*

Table 5. General characteristics of forests and krummholz associations of the Glacier Lakes Ecosystem Experiments Site.

Plant association	Associated species	Habitat characteristics
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Salix planifolia</i>	<i>Carex rupestris</i> <i>Carex scopulorum</i>	krummholz forest in sheltered microsites on exposed windswept slopes, prolonged snow cover
ABLA-PIEN/SAPL <i>Kalmia microphylla</i> <i>Salix brachycarpa</i> <i>Vaccinium cespitosum</i>	<i>Erigeron peregrinus</i>	
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Juniperus communis</i>	<i>Calamagrostis purpurascens</i> <i>Carex rossii</i>	krummholz forest on dry, gentle slopes
ABLA-PIEN/JUCO <i>Salix brachycarpa</i> <i>Vaccinium cespitosum</i>	<i>Ribes montigenum</i>	
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Carex rossii</i>	<i>Carex rossii</i> <i>Hieracium gracile</i>	krummholz forest on dry, exposed steep slopes, sparse understory
ABLA-PIEN/CARO <i>Sibbaldia procumbens</i> <i>Vaccinium scoparium</i>	<i>Juncus drummondii</i>	
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Caltha leptosepala</i>	<i>Carex illota</i> <i>Carex microptera</i>	streambanks, terraces, and topographic depressions, moist to wet sites
ABLA-PIEN/CALE <i>Deschampsia cespitosa</i> <i>Saxifraga odontoloma</i> <i>Trollius laxus</i>	<i>Carex nigricans</i>	
<i>Abies lasiocarpa</i> / <i>Vaccinium scoparium</i>	<i>Arnica cordifolia</i> <i>Carex rossii</i>	widespread in a variety of upland sites, mesic to xeric with long snow duration
ABLA/VASC <i>Picea engelmannii</i> <i>Poa nervosa</i> <i>Ribes montigenum</i>	<i>Erigeron peregrinus</i>	

Table 6. Mean percent cover, or basal area (m<sup>2</sup>/ha) for trees, of major species by dominance types from COMPAH (Combinatorial, Polythetic, Agglomerative, Hierarchical clustering) (Boesch 1977), classification of forest and krummholz types of the Glacier Lakes Ecosystem Experiments Site.

	Dominance types				
	ABLA-PIEN/SAPL	ABLA-PIEN/CARO	ABLA-PIEN/JUCO	ABLA-PIEN/CALE	ABLA/VASC
<i>Abies lasiocarpa</i>	9.8	0.1	0.4	0.0	16.1
<i>Picea engelmannii</i>	8.9	1.4	* <sup>1</sup>	10.0	25.3
Total mean basal area	18.7	1.4	0.4	10.0	41.3
<i>Arnica cordifolia</i>	x <sup>2</sup>	*	*	0.5	*
<i>Calamagrostis purpurascens</i>	*	x	1.7	x	*
<i>Caltha leptosepala</i>	0.5	x	x	27.6	*
<i>Carex nigricans</i>	1.5	x	x	11.1	x
<i>Carex rossii</i>	1.4	4.7	1.8	x	1.4
<i>Carex rupestris</i>	0.9	0.7	*	x	x
<i>Deschampsia cespitosa</i>	1.2	0.5	x	12.2	*
<i>Erigeron peregrinus</i>	4.8	7.0	*	7.8	6.3
<i>Geum rossii</i>	1.3	*	*	x	*
<i>Hieracium gracile</i>	*	10.9	*	*	1.7
<i>Juncus drummondii</i>	*	28.3	x	1.8	*
<i>Juniperus communis</i>	x	x	10.5	x	0.6
<i>Kalmia microphylla</i>	2.1	x	x	*	*
<i>Poa cusickii</i>	0.9	*	x	x	*
<i>Poa nervosa</i>	x	*	3.7	x	1.0
<i>Poa reflexa</i>	x	x	x	x	0.6
<i>Ribes montigenum</i>	2.9	*	3.7	x	0.7
<i>Salix brachycarpa</i>	16.5	x	4.2	*	*
<i>Salix planifolia</i>	39.8	x	0.7	4.1	x
<i>Trifolium dasyphyllum</i>	x	x	0.7	x	*
<i>Trifolium parryi</i>	*	0.8	x	*	0.6
<i>Trisetum spicatum</i>	*	*	*	*	*
<i>Trollius laxus</i>	x	x	x	11.5	*
<i>Vaccinium cespitosum</i>	6.1	6.2	*	0.8	*
<i>Vaccinium scoparium</i>	4.3	4.3	1.5	2.4	21.2
N <sup>3</sup>	6	5	6	5	58
n <sup>4</sup>	105	100	80	93	898

<sup>1</sup> mean cover < 0.5%

<sup>2</sup> species was absent

<sup>3</sup> number of stands

<sup>4</sup> number of subplots

ABLA-PIEN/SAPL = *Abies lasiocarpa*-*Picea engelmannii*/*Salix planifolia*

ABLA-PIEN/CARO = *Abies lasiocarpa*-*Picea engelmannii*/*Carex rossii*

ABLA-PIEN/JUCO = *Abies lasiocarpa*-*Picea engelmannii*/*Juniperus communis*

ABLA-PIEN/CALE = *Abies lasiocarpa*-*Picea engelmannii*/*Caltha leptosepala*

ABLA/VASC = *Abies lasiocarpa*/*Vaccinium scoparium*

## Plant Associations

### *Calamagrostis purpurascens*/ *Carex rupestris* Meadows

The *Calamagrostis purpurascens*/*Carex rupestris* (CAPU/ CARU) plant association (figure 9) occurs at the highest elevations and on the most exposed sites at the GLEES. This is an alpine type that grows above timberline on rocky ridge tops and saddles in shallow soils without persistent snow cover. Environmentally adjacent associations are *Salix cascadensis*-*Salix brachycarpa*/*Carex scopulorum*, which occurs on protected sites with more snow cover, and *Geum rossii*/*Carex rossii*, which occurs at low elevations. This type is characterized by grasses, sedges, and forbs with tufted or cushion growth forms. Associated graminoids include *Festuca brachyphylla*, and associated forbs include: *Erigeron pinnatisectus*, *Geum rossii*, *Haplopappus pygmaeus*, *Minuartia rubella*, *Paronychia pulvinata*, *Phlox pulvinata*, and *Trifolium dasyphyllum*. *Selaginella densa* is very important in terms of total cover. The CAPU/ CARU association is included in the cushion plants/stone pavement landscape habitat described by Simmons (1994) for the GLEES.

The *Carex rupestris*/*Trifolium dasyphyllum* (CARU/ TRDA) plant association in north central Colorado (Hess 1981; Wasser and Hess 1982) is similar in species composition and topographic location to the above type. Species in the CARU/ TRDA type that do not occur at the GLEES

Table 7. Diversity estimates for each forest and krummholz type of the Glacier Lakes Ecosystem Experiments Site.

Dominance type	N0 <sup>1</sup>	N1 <sup>2</sup>	N2 <sup>3</sup>	E <sup>4</sup>
ABLA-PIEN/SAPL	14.0	7.2	5.0	0.6
ABLA-PIEN/CARO	11.4	7.7	6.1	0.8
ABLA-PIEN/JUCO	8.7	5.2	4.1	0.7
ABLA-PIEN/CALE	20.0	11.5	8.4	0.7
ABLA/VASC	6.4	3.6	2.9	0.7

<sup>1</sup> average number of species occurring in the sample plots

<sup>2</sup> average number of abundant species

<sup>3</sup> average number of very abundant species

<sup>4</sup> evenness

ABLA-PIEN/SAPL = *Abies lasiocarpa*-*Picea engelmannii*/  
*Salix planifolia*

ABLA-PIEN/CARO = *Abies lasiocarpa*-*Picea engelmannii*/  
*Carex rossii*

ABLA-PIEN/JUCO = *Abies lasiocarpa*-*Picea engelmannii*/  
*Juniperus communis*

ABLA-PIEN/CALE = *Abies lasiocarpa*-*Picea engelmannii*/  
*Caltha leptosepala*

ABLA/VASC = *Abies lasiocarpa*/*Vaccinium scoparium*

Figure 9. The *Calamagrostis purpurascens*/*Carex rupestris* (CAPU/ CARU) plant association occurs at the highest elevations and on the most exposed sites at the Glacier Lakes Ecosystem Experiments Sites.



are *Arenaria fendleri* (*Eremogone fendleri*), *Lidia biflora*, and *Oreoxis alpina*. Other floristically similar plant associations reported in the literature include *Carex rupestris*/*Lidia biflora* (Komarkova 1976, 1988; Baker 1983) in north central Colorado, west central Colorado, and north central New Mexico; *Carex rupestris*/*Kobresia myosuroides* (Komarkova 1988) in west central Colorado; and *Calamagrostis purpurascens*/*Helictotrichon mortonianum* (Komarkova 1988) in west central Colorado. Several species occur at the Colorado and New Mexico sites that do not occur at the GLEES including: *Helictotrichon mortonianum*, *Carex elynoides*, *Castilleja occidentalis*, *Trifolium nanum*, *Potentilla uniflora*, *Rydbergia grandiflora*, and *Kobresia myosuroides* (in addition to those listed previously).

### *Salix cascadenis*-*Salix brachycarpa*/ *Carex scopulorum* Thickets

The *Salix cascadenis*-*Salix brachycarpa*/*Carex scopulorum* (SACA-SABR/CASC) association is in the alpine environment on topographically protected depressions and on or near rocky ledges. Compared to the CAPU/CARU dominated sites, the SACA-SABR/CASC habitats are moister and have a shorter growing season due to snow accumulation and prolonged cover. The community is also not as diverse as CAPU/CARU, having only *Festuca brachyphylla*, *Geum rossii*, and *Selaginella densa* as important associates with the willow shrub and sedge dominants. This associa-

tion is included in the rock outcrop landscape habitat described by Simmons (1994). Although this landscape type represents over 8 percent of the area surveyed by Simmons, the area vegetated by the SACA-SABR/CASC type is much smaller since the type is limited to sheltered microsites.

The *Salix phylicifolia* spp. *planifolia*/*Carex scopulorum* (*Salix planifolia*/*Carex scopulorum*) plant association is a widespread type throughout central and western Colorado (Komarkova 1976, 1988; Webber et al. 1976; Hess 1981; Wasser and Hess 1982). This type, similar to the GLEES type floristically and in terms of elevation and topographic position where it occurs, is richer in species composition. In addition, the occurrence of *Salix cascadenis* and the absence of *Salix planifolia* in the GLEES type are conspicuous differences.

### *Geum rossii*/*Carex rossii* Meadows

The *Geum rossii*/*Carex rossii* (GERO/CARO) meadows (figure 10) occur over most of the alpine to subalpine transition environments at the GLEES. These habitats experience moderate snow accumulation and a slightly prolonged snow cover, but the soils are well-drained and the wind-exposed sites dry quickly. This type is characterized by grasses, sedges, and forbs without shrub or tree species. Associated graminoids include *Poa cusickii* and *Poa reflexa*; and associated forbs are: *Artemisia scopulorum*,



Figure 10. The *Geum rossii*/*Carex rossii* (GERO/CARO) meadows occur over most of the alpine to subalpine transitional environments at the Glacier Lakes Ecosystem Experiments Sites.

*Erigeron melanocephalus*, *Erigeron peregrinus*, *Erigeron simplex*, *Lewisia pygmaea*, *Polygonum bistortoides*, *Potentilla diversifolia*, and *Sibbaldia procumbens*. Simmons (1994) describes the GERO/CARO association in the diverse meadow landscape habitat.

Several *Geum rossii* dominated plant associations are documented in Colorado and Wyoming. The *Acomastylis rossii*/*Bistorta bistortoides* (*Geum rossii*/*Polygonum bistortoides*) type is widespread throughout central and western Colorado (Sheperd 1975; Spencer 1975; Komarkova 1976, 1988; Hess 1981; Hess and Wasser 1982). *Lloydia serotina* and *Castilleja occidentalis* occur in this type and are absent from the GLEES. The *Acomastylis rossii*/*Carex rupestris* plant association occurs in north central and west central Colorado (Hess and Wasser 1982). *Trifolium nanum* and *Lidia biflora* occur here but are absent from GLEES. At GLEES, *Carex rossii* has replaced *Carex rupestris* as the codominant graminoid. The *Acomastylis rossii*/*Trifolium dasyphyllum*



(ACRO/TRDA) plant association is documented on the Medicine Bow National Forest (Smith 1969). This association shares some floristic similarity to the minor components of the GLEES type but the dominant species are different. In addition, the ACRO/TRDA type is found on wind exposed sites with little snow accumulation, while the GLEES type is found on sites with prolonged snow cover.

### *Vaccinium scoparium*/*Juncus drummondii* Dwarf Scrub

The *Vaccinium scoparium*/*Juncus drummondii* (VASC/JUDR) association (figure 11) occurs across all elevations in the subalpine environments at the GLEES. This type is on upland sites with a late-melting snow cover where the soils are very rocky and well-drained, and the sites dry quickly. This association is floristically similar to the GERO/CARO type except for the shrub component dominated by *Vaccinium scoparium*, which does not occur in the meadow community. The VASC/JUDR association is also floristically similar to the *Abies lasiocarpa*/*Vaccinium scoparium* forest type. However, except for an occasional individual, trees are absent from the VASC/JUDR habitats. Also, most descriptions of ABLA/VASC lack *Juncus drummondii*, which is typically found in meadows. Associated graminoids of the VASC/JUDR association include *Carex rossii* and *Poa cusickii*; associated forbs are: *Erigeron melanocephalus*, *Erigeron peregrinus*, *Erigeron simplex*, *Erythronium grandiflorum*, *Penstemon whippleanus*, *Senecio crassulus*, and *Sibbaldia procumbens*. This type is included in the meadow landscape habitat described by Simmons (1994).

The *Vaccinium scoparium*-*Vaccinium cespitosum*/*Lidia biflora* plant association of north central and west central Colorado (Komarkova 1976, 1988) is very similar to the VASC/JUDR type at the GLEES. Both types occur on areas of prolonged snow cover. *Lidia biflora* does not occur at the GLEES and *Juncus drummondii* is a codominant with *Vaccinium scoparium* at GLEES.

Figure 11. The *Vaccinium scoparium*/*Juncus drummondii* (VASC/JUDR) association occurs across all elevations in the subalpine environments at the Glacier Lakes Ecosystem Experiments Sites.

### *Danthonia intermedia*/*Potentilla diversifolia* Meadow

The *Danthonia intermedia*/*Potentilla diversifolia* (DAIN/PODI) meadows are found throughout the subalpine and low alpine environments among krummholz islands at the GLEES. The association is generally on gentle, protected terrain with prolonged snow cover; it is often found in forest openings. These sites are more mesic than those occupied by the GERO/CARO and VASC/JUDR communities. Graminoid associates are *Carex microptera* and *Poa reflexa*. Important forbs in this community include: *Agoseris glauca*, *Arenaria congesta*, *Artemisia scopulorum*, *Erigeron peregrinus*, *Minuartia obtusiloba*, *Phleum alpinum*, *Sibbaldia procumbens*, and *Trifolium parryi*. Again, Simmons (1994) included this in the meadow landscape habitat. This association is documented in north central and west central Colorado (Komarkova 1976; Hess and Wasser 1982). The other locations are very similar floristically and topographically to the GLEES sites. A major difference is the occurrence of *Solidago spathulata* at the Colorado sites, which does not occur at the GLEES.

### *Deschampsia cespitosa*/*Carex nigricans* Meadow

*Deschampsia cespitosa*/*Carex nigricans* (DECE/CANI) wet meadows (figure 12) are found throughout the subalpine

environments at the GLEES on alluvial benches, protected areas, and gently sloping terrain with heavy snow accumulation and prolonged snow cover. Soils are flooded by the snow accumulation and are poorly-drained. This type is characterized by a dominance of graminoids including: *Carex aquatilis*, *Carex scopulorum*, *Festuca brachyphylla*, *Juncus drummondii*, and *Phleum alpinum*. Important forbs include *Arnica mollis*, *Caltha leptosepala*, and *Erigeron peregrinus*. Shrubs are of minor importance and are *Kalmia microphylla*, *Salix planifolia*, and *Vaccinium cespitosum*. These wet meadows are included in the wet meadow/willow shrub landscape habitat described by Simmons (1994).

The *Deschampsia cespitosa*/*Caltha leptosepala* (DECE/CALE) plant association is found throughout the Front Range and in west central Colorado. Except for the absence of *Carex nigricans* and the occurrence of *Senecio crocatus*, *Erigeron eximius*, and *Carex festivella*, DECE/CALE is floristically and topographically similar to the GLEES type. A widespread *Deschampsia cespitosa*/*Carex* spp. type has been documented on the Medicine Bow National Forest (Knight and Thilenius 1975). None of the descriptions document the codominance by *Carex nigricans*. However, *Carex nigricans* is a dominant associated with *Juncus drummondii* in a *Carex nigricans*/*Juncus drummondii* association, which is a widespread type that is somewhat similar to the DECE/CANI type at the GLEES (Johnson



Figure 12.  
*Deschampsia cespitosa*/*Carex nigricans* (DECE/CANI) wet meadows are found throughout the subalpine environments at the Glacier Lakes Ecosystem Experiments Sites.

and Billings 1962; Spencer 1975; Komarkova 1976, 1988; Rottman and Hartman 1985). *Juncus drummondii* is more important in the CANI/JUDR association than in the GLEES type.

### *Salix planifolia*-*Salix brachycarpa*/ *Caltha leptosepala* Thicket

The *Salix planifolia*-*Salix brachycarpa*/*Caltha leptosepala* (SAPL-SABR/CALE) association occurs throughout the subalpine range at the GLEES on wet sites in seeps, depressions, drainages, and valley bottoms. The soils are poorly drained and are moist to wet throughout the growing season. The type is shrub dominated and occurs as a mosaic of shrub patches interspersed with graminoid dominated meadows such as the DECE/CANI community. At a finer scale, the shrub patches occur on raised hummocks and alternate with poorly drained forb dominated patches. Important graminoid associates include *Calamagrostis canadensis*, *Carex aquatilis*, and *Carex atrata*. Associated forbs are: *Saxifraga odontoloma*, *Sedum rhodanthum*, *Senecio trinagularis*, and *Trollius laxus*. Simmons (1994) describes a wet meadow / willow shrub landscape habitat, which is comparable to the shrub dominated microsites, and a tall forb wet meadow, which is comparable to the forb dominated microsites.

The *Salix phylicifolia* spp. *planifolia*/*Caltha leptosepala* (*Salix planifolia*/*Caltha leptosepala*) plant association in west central Colorado (Wasser and Hess 1982; Komarkova 1988) is similar except for the occurrence of *Pseudocymopterus montanus* and *Carex festivella*, which are not present at the GLEES. The *Salix phylicifolia* spp. *planifolia*/*Deschampsia cespitosa* (*Salix planifolia*/*Deschampsia cespitosa*) plant association of northern Wyoming (Johnson and Billings 1962) and north central Colorado (Hess 1981; Wasser and Hess 1982) is also similar to the GLEES. However, *Deschampsia cespitosa* is a codominant in the SAPL/DECE type and is much less abundant in the willow dominated wetlands at the GLEES. Other floristic differences include the occurrence of *Castilleja septentrionalis* and *Senecio crocatus* in the SAPL/DECE type.

### *Salix planifolia*/*Carex aquatilis* Thicket

The *Salix planifolia*/*Carex aquatilis* (SAPL-CAAQ) association (figure 13) occurs throughout the subalpine range at the GLEES in depressions or stream bottoms. These are the wettest terrestrial sites at the GLEES, with very poorly drained soils and a water table at or near the surface most or all of the growing season. The shrub component of the community occurs patchily on slightly better drained microsites. Forbs associated with these shrub patches include *Caltha leptosepala*, *Saxifraga odontoloma*, and *Sedum rhodanthum*. Interspersed among the shrub patches are microsites with standing water that are vegetated with only a few graminoid species. In addition to *Carex aquatilis*, *Carex canescens* and *Eleocharis pauciflora* are found on these very wet microsites.

The *Salix planifolia*/*Carex aquatilis* plant association (may be *Salix phylicifolia* spp. *planifolia*/*Carex aquatilis* in the literature) is widespread in Colorado and Wyoming

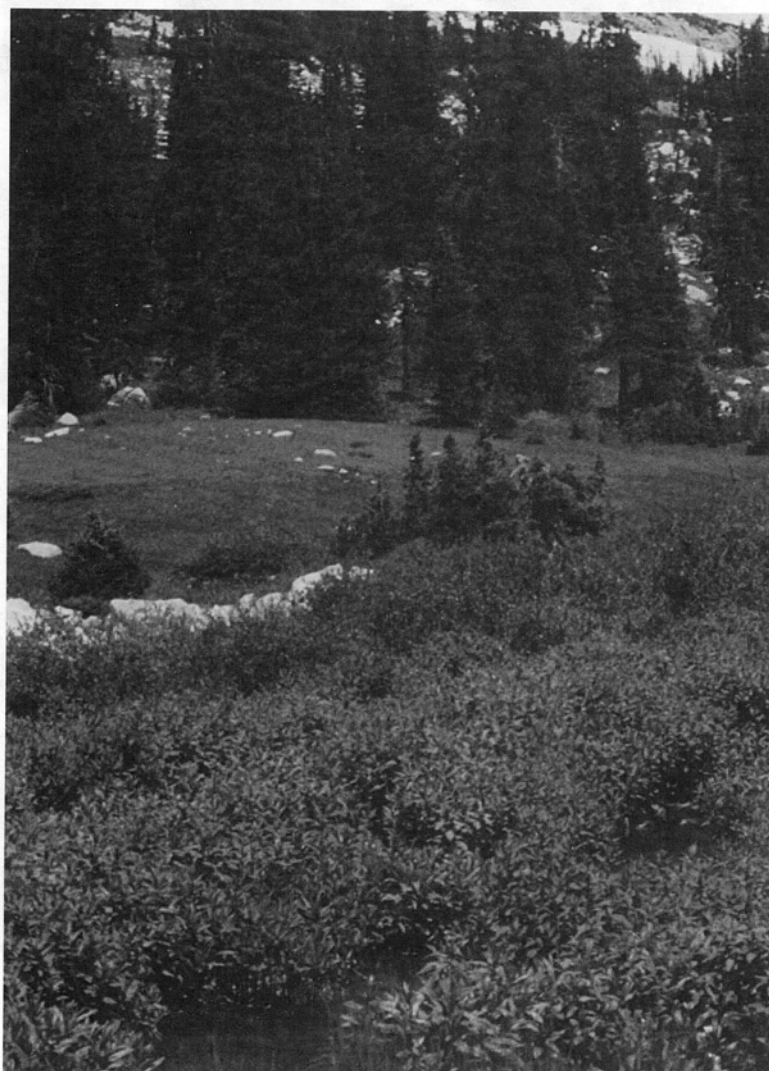


Figure 13. The *Salix planifolia*/*Carex aquatilis* (SAPL-CAAQ) association occurs throughout the subalpine range at the Glacier Lakes Ecosystem Experiments Sites.

(Hanna 1934; Bierly 1982; Hess 1981; Wasser and Hess 1982; Komarkova 1988; Cooper 1990). *Betula glandulosa* occurs in this type in several other locations but was not recorded at the GLEES.

#### *Abies lasiocarpa*-*Picea engelmannii*/*Salix planifolia* Krummholz

The *Abies lasiocarpa*-*Picea engelmannii*/*Salix planifolia* (ABLA-PIEN/SAPL) krummholz association (figure 14) is common in the alpine range at the GLEES. These forests occur in sheltered microsites with prolonged snow cover on exposed windswept slopes. The stands occur as patches surrounded by more exposed areas that are dominated by CAPU/CARU or GERO/CARO associations. Tree species and shrubs are both dominant and reflect a matted, stunted growth form. *Salix brachycarpa* is a codominant

shrub with *Salix planifolia*. Other important shrubs are *Kalmia microphylla* and *Vaccinium cespitosum*. Associated species include *Carex rupestris*, *Carex scopulorum*, and *Erigeron peregrinus*. Simmons (1994) includes all krummholz associations as krummholz conifer landscape habitat.

The *Abies lasiocarpa*-*Picea engelmannii*/*Salix planifolia* association is a common timberline type. This type is similar to vegetation identified as *Abies lasiocarpa*-*Picea engelmannii*/*Salix glauca*, *Picea engelmannii*/*Salix pseudolapponum*, or *Picea engelmannii*-*Abies lasiocarpa*/*Salix pseudolapponum* in the literature (Sheperd 1975; Hess 1981; Hess and Wasser 1982; Komarkova 1988). Species that are common or characteristic of the type in other areas but are absent at the GLEES include *Vaccinium myrtillus*, *Betula glandulosa*, and *Polemonium pulcherrimum*. In addition, the GLEES stands differ in their dominance by *Salix*



Figure 14. The *Abies lasiocarpa*-*Picea engelmannii*/*Salix planifolia* (ABLA-PIEN/SAPL) krummholz association is common in the alpine ranges at the Glacier Lakes Ecosystem Experiments Sites.

*planifolia*, *Salix brachycarpa*, and *Vaccinium cespitosum* in the shrub layer.

### *Abies lasiocarpa*-*Picea engelmannii*/*Juniperus communis* Krummholz

The *Abies lasiocarpa*-*Picea engelmannii*/*Juniperus communis* (ABLA-PIEN/JUCO) krummholz association (figure 15) is physiognomically similar to the ABLA-PIEN/SAPL type, but it occurs in drier environments on gentle slopes. *Juniperus communis* replaces willow as the shrub layer dominant. *Salix brachycarpa* and *Vaccinium cespitosum* are still important shrub associates; in addition, *Ribes montigenum* occurs in these stands. *Calamagrostis purpurascens* and *Carex rossii* are important graminoid associates, and forbs are a minor component of the community.

An *Abies lasiocarpa*-*Picea engelmannii*/*Juniperus communis* forest type is documented in the literature, but it seems to occur at elevations lower than those at the GLEES and has forest tree structure (Moir and Ludwig 1979). The cited type has a richer shrub layer, with *Shepherdia canadensis*, *Symphoricarpos oreophilus*, *Mahonia repens*, *Rosa* spp., and *R. wolfii* commonly occurring in some or all of the other locations. Another low elevation type similar to ABLA-PIEN/JUCO is the *Abies lasiocarpa*-*Picea engelmannii*/*Vaccinium cespitosum* association (Mauk and Henderson 1984), which has been documented in the Medicine Bow Mountains (Wirsing 1973). Again, there are floristic differences in both the shrub and grass layers. Since each of the similar types found in the literature have major floristic differences from the GLEES type, this krummholz community at the GLEES may not have been well described before the current study.



Figure 15. The *Abies lasiocarpa*-*Picea engelmannii*/*Juniperus communis* (ABLA-PIEN/JUCO) krummholz association is physiognomically similar to the ABLA-PIEN/SAPL type, but it occurs in drier environments on gentle slopes at the Glacier Lakes Ecosystem Experiments Sites.

*Abies lasiocarpa-Picea engelmannii/Carex rossii*  
Krummholz

A third krummholz association at the GLEES is *Abies lasiocarpa-Picea engelmannii/Carex rossii* (ABLA-PIEN/CARO) (figure 16). These stands occur in the driest of the krummholz environments; on steep, exposed slopes. The understory is usually very sparse and associated species include: *Hieracium gracile*, *Juncus drummondii*, *Sibbaldia procumbens*, and *Vaccinium scoparium*.

The *Abies lasiocarpa-Picea engelmannii/Carex rossii* type documented in the literature (DeVilice et al. 1986) is also found at elevations lower than those at the GLEES. In addition, there are some floristic differences between the GLEES sites and other locations, with *Paxistima myrsinites* found in the shrub layer and *Osmorhiza chilensis* and *Ciliaria austromontana* in the forb layer. There are a number of species found in this type at the GLEES that are not

documented in the same type elsewhere. Again, we feel that the ABLA-PIEN/CARO that we have described at the GLEES differs substantially from what is in the literature and may not have been well described before the current study.

*Abies lasiocarpa-Picea engelmannii/*  
*Caltha leptosepala* Forest

The *Picea engelmannii/Caltha leptosepala* (PIEN/CALE) forests (figure 17) occur in mesic to wet subalpine environments at the GLEES. They are found in topographic depressions as patches in a landscape characterized as a mosaic of forest with sedge meadow (DECE/CANI) openings in the most poorly drained areas. They are also in drainages on streambanks and alluvial terraces. The soils are saturated most or all of the growing season and surface water may be present early in the summer. The most

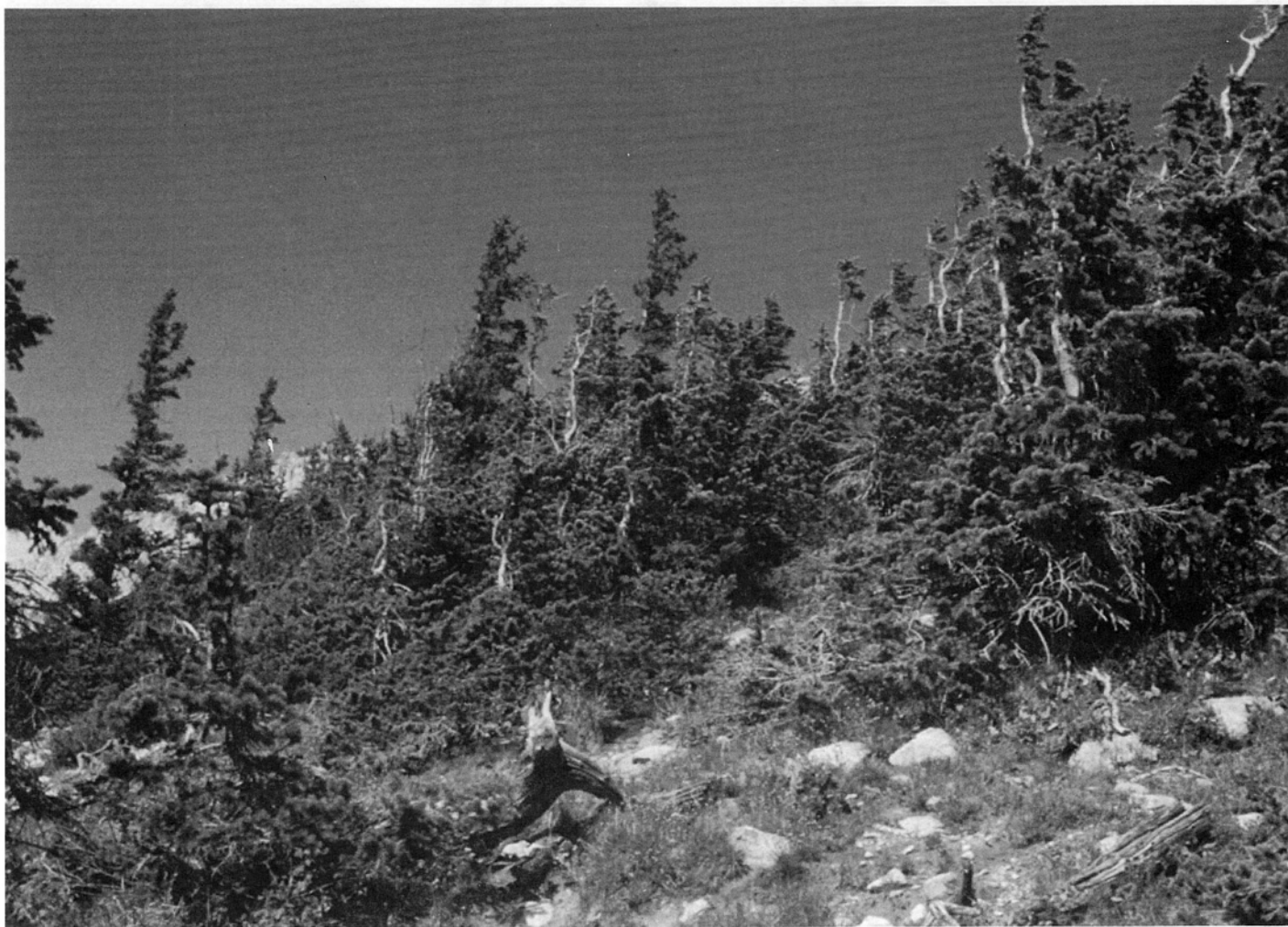


Figure 16. The *Abies lasiocarpa-Picea engelmannii/Carex rossii* (ABLA-PIEN/CARO) krummholz association occurs on steep, exposed slopes at the Glacier Lakes Ecosystem Experiments Sites.

important associated species are graminoids and include *Carex illota*, *Carex microptera*, *Carex nigricans*, and *Deschampsia cespitosa*. Important associated forbs are *Saxifraga odontoloma* and *Trollius laxis*. These wet forests are included in the conifer forest landscape type described by Simmons (1994).

The *Picea engelmannii*/*Caltha leptosepala* association is documented in northwestern Wyoming and northeastern Utah (Steele et al. 1983; Mauk and Henderson 1984). This type is very similar to the GLEES association except for the presence of *Picea pungens* in the overstory and *Kalmia polifolia* and *Phyllodoce empetrififormis* in the shrub and herb layer in the PIEN/CALE stands. In addition, at the GLEES *Abies lasiocarpa* is a codominant and is absent from some of the other stands, which tend to occur at low elevations. Peet (1981) describes a *Picea-Abies* bog forest that is comparable to our ABLA-PIEN/CALE type. The *Abies lasiocarpa-Picea engelmannii*/*Calamagrostis canadensis* is a widely dis-

tributed forest type that is also found on poorly drained soils (Hess 1981; Wasser and Hess 1982; Hess and Alexander 1986; Alexander et al. 1986). The ABLA-PIEN/CALE type at the GLEES seems to occur on even wetter sites. Where *Calamagrostis canadensis* is dominant in the herb layer, there is a rich forb community with *Dodecatheon* spp., *Veratrum tenuipetalum*, and *Thalictrum occidentale* important at other locations but not occurring at the GLEES. In addition, more species of *Carex* occur in the wetter GLEES site.

The *Abies lasiocarpa-Picea engelmannii*/*Mertensia ciliata* association of southern and southwestern Colorado is also similar but again is found on slightly dryer sites. The southern association has a much richer forb layer with *Oxypolis fendleri*, *Cardamine cordifolia*, *Ligularia bigelovii*, *Heracleum sphondylium*, *Erigeron coulteri*, *Moneses uniflora*, *Polemonium pulcherrimum*, *Geranium richardsonii*, and *Streptopus fassettii*. A third association that is similar to the



Figure 17. The *Picea engelmannii*/*Caltha leptosepala* (PEIN/CALE) forests occur in mesic to wet subalpine environments at the Glacier Lakes Ecosystem Experiments Sites.

ABLA-PIEN/CALE type at the GLEES is *Abies lasiocarpa*-*Picea engelmannii*/*Senecio triangularis* (Hess 1981; Peet 1981; Wasser and Hess 1982; Crouch 1985; Komarkova 1988), which again occupies drier sites and is more species rich. Species that occur in this type but do not occur at the GLEES include: *Vaccinium myrtillus* in the shrub layer, *Carex disperma*, *Eleocharis quinqueflora*, *Scirpus microcarpus*, *Cardamine cordifolia*, *Smilacina stellata*, *Streptopus fassettii*, *Veronica nutans*, *Moneses uniflora*, and *Polemonium pulcherrimum*.

### *Abies lasiocarpa*/*Vaccinium scoparium* Forest

*Abies lasiocarpa*/*Vaccinium scoparium* (ABLA-VASC) forests cover much of the subalpine forested landscape at the GLEES. These forest occur in a variety of upland sites in mesic to xeric environments. The most mesic of these forests have a heavy snow accumulation and a prolonged snow cover. The ground layer vegetation is lush in the most mesic sites and is dominated by *Vaccinium scoparium*. In drier environments, the ground layer may be very sparse. Associated species occurring across the full range of these forests include: *Arnica cordifolia*, *Carex rossii*, *Erigeron peregrinus*, *Poa nervosa*, and *Ribes montigenum*. *Picea engelmannii* is present as a codominant in all the GLEES stands. These stands are included in the coniferous forest landscape type described by Simmons (1994).

This type is one of the most widely distributed in the subalpine zone and is well documented in the Medicine Bow Mountains (Oosting and Reed 1952; Wirsing 1973; Wirsing and Alexander 1975; Knight and Thilenius 1975; Alexander et al. 1986). Our *Abies lasiocarpa*/*Vaccinium scoparium* type may include some stands similar to the *Abies lasiocarpa*-*Picea engelmannii*/*Ribes* spp. plant association in the literature (Sheperd 1975; Boyce 1977; Moir and Ludwig 1979; Peet 1981; DeVelice et al. 1986; Komarkova 1988; Allen et al. 1991). *Ribes* is never a dominant component of the shrub layer of GLEES forests and the *Ribes* dominated association tends to occur at low elevations. There is a rich shrub layer in the ABLA-PIEN/*Ribes* association with the importance of several species including: *Distegia involucrata*, *Ribes wolfii*, *R. inerme*, *Rubus parviflorus*, and *Vaccinium myrtillus*, which do not occur at the GLEES.

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## Conclusions

We have documented the occurrence of 304 vascular plant taxa at the GLEES. The flora of the GLEES is typical of western North America and reflects Montane, Alpine, and Boreal-Montane geographic affinities. The vegeta-

tion of the GLEES can be classified into 4 meadow, 4 shrubland, 3 krummholz, and 2 forest associations that differ in floristic composition and community structure, and that occur repeatedly on the GLEES landscape. Our description of types reflects variability in composition and structure of nonforested types that is not well documented in the literature. In addition, 2 krummholz associations, *Abies lasiocarpa*-*Picea engelmannii*/*Juniperus communis* krummholz and *Abies lasiocarpa*-*Picea engelmannii* krummholz, were not well documented before this study and the *Abies lasiocarpa*-*Picea engelmannii*/*Caltha leptosepala* wet forests were not well described for this geographic region.

These results provide additional information on the vegetation of subalpine/alpine ecotones in general, and specifically they provide a baseline for future studies of the vegetation of the GLEES. The plant community classification provides an organizational framework for designing future studies of the functional characteristics of communities or systems and species-environment relationships at the GLEES.

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## Appendix 1

### Vascular plant taxa of the Glacier Lakes Ecosystem Experiments Site.

Family	Species
Equisetaceae	<i>Equisetum arvense</i> L.
Isoetaceae	<i>Isoetes bolanderi</i> Engelm. var. <i>bolanderi</i>
Ophioglossaceae	<i>Botrychium lunaria</i> (L.) Sw. var. <i>lunaria</i>
Polypodiaceae	<i>Cryptogramma acrostichoides</i> R. Br.
Polypodiaceae	<i>Cystopteris fragilis</i> (L.) Bernh. var. <i>fragilis</i>
Polypodiaceae	<i>Woodsia scopulina</i> D. C. Eat.
Selaginellaceae	<i>Selaginella densa</i> Rydb.
Cupressaceae	<i>Juniperus communis</i> L. var. <i>depressa</i> Pursh
Pinaceae	<i>Abies lasiocarpa</i> (Hook.) Nutt. var. <i>lasiocarpa</i>
Pinaceae	<i>Picea engelmannii</i> Parry ex Englem.
Pinaceae	<i>Pinus contorta</i> Dougl. ex Loud. var. <i>latifolia</i> Engelm. ex Wats.
Pinaceae	<i>Pinus flexilis</i> James
Apiaceae	<i>Angelica grayi</i> (Coul. & Rose) Coul. & Rose
Apiaceae	<i>Conioselinum scopulorum</i> (Gray) Coul. & Rose
Apiaceae	<i>Ligusticum porteri</i> Coul. & Rose var. <i>porteri</i>
Apiaceae	<i>Osmorhiza depauperata</i> Phil.
Asteraceae	<i>Achillea millefolium</i> L. var. <i>lanulosa</i> (Nutt.) Piper
Asteraceae	<i>Agoseris aurantiaca</i> (Hook.) Greene
Asteraceae	<i>Agoseris glauca</i> (Pursh) Raf. var. <i>dasycephala</i> (T. & G.) Jeps.
Asteraceae	<i>Anaphalis margaritacea</i> (L.) Benth. & Hook.
Asteraceae	<i>Antennaria aromatica</i> Evert
Asteraceae	<i>Antennaria corymbosa</i> E. Nels.
Asteraceae	<i>Antennaria media</i> Greene
Asteraceae	<i>Antennaria microphylla</i> Rydb.
Asteraceae	<i>Antennaria parvifolia</i> Nutt.
Asteraceae	<i>Antennaria rosea</i> Greene
Asteraceae	<i>Antennaria umbrinella</i> Rydb.
Asteraceae	<i>Arnica cordifolia</i> Hook.
Asteraceae	<i>Arnica latifolia</i> Bong.
Asteraceae	<i>Arnica mollis</i> Hook.
Asteraceae	<i>Arnica ovata</i> Greene
Asteraceae	<i>Arnica parryi</i> Gray var. <i>parryi</i>
Asteraceae	<i>Arnica rydbergii</i> Greene
Asteraceae	<i>Artemisia scopulorum</i> Gray
Asteraceae	<i>Aster foliaceus</i> Lindl. ex DC. var. <i>apricus</i> Gray
Asteraceae	<i>Cirsium centaureae</i> (Rydb.) K. Schum.
Asteraceae	<i>Erigeron compositus</i> Pursh var. <i>discoideus</i> Gray
Asteraceae	<i>Erigeron melanocephalus</i> (A. Nels.) A. Nels.
Asteraceae	<i>Erigeron peregrinus</i> (Banks ex Pursh) Greene ssp. <i>callianthemus</i> (Greene) Cronq.
Asteraceae	<i>Erigeron pinnatisectus</i> (Gray) A. Nels.
Asteraceae	<i>Erigeron simplex</i> Greene
Asteraceae	<i>Erigeron ursinus</i> D. C. Eat.
Asteraceae	<i>Haplopappus pygmaeus</i> (T. & G.) Gray
Asteraceae	<i>Hieracium gracile</i> Hook. var. <i>gracile</i>
Asteraceae	<i>Hymenoxys grandiflora</i> (T. & G. ex Gray) Parker
Asteraceae	<i>Senecio canus</i> Hook.
Asteraceae	<i>Senecio crassulus</i> Gray
Asteraceae	<i>Senecio dimorphophyllus</i> Greene var. <i>dimorphophyllus</i>
Asteraceae	<i>Senecio fremontii</i> T. & G. var. <i>blitoides</i> (Greene) Cronq.
Asteraceae	<i>Senecio integerrimus</i> Nutt. var. <i>exaltatus</i> (Nutt.) Cronq.
Asteraceae	<i>Senecio streptanthifolius</i> Greene

## Appendix 1 (Cont'd.)

Family	Species
Asteraceae	<i>Senecio triangularis</i> Hook.
Asteraceae	<i>Solidago multiradiata</i> Ait var. <i>scopulorum</i> Gray
Asteraceae	<i>Solidago parryi</i> (Gray) Greene
Asteraceae	<i>Solidago simplex</i> Kunth
Asteraceae	<i>Taraxacum ceratophorum</i> (Ledeb.) DC.
Asteraceae	<i>Taraxacum eriophorum</i> Rydb.
Asteraceae	<i>Taraxacum laevigatum</i> (Willd.) DC.
Asteraceae	<i>Taraxacum officinale</i> Weber
Boraginaceae	<i>Eritrichium nanum</i> (Vill.) Schrad. ex Gaudin var. <i>elongatum</i> (Rydb.) Cronq.
Boraginaceae	<i>Mertensia ciliata</i> (James ex Torr.) G. Don var. <i>ciliata</i>
Boraginaceae	<i>Mertensia viridis</i> (A. Nels.) A. Nels.
Brassicaceae	<i>Arabis drummondii</i> Gray
Brassicaceae	<i>Draba albertina</i> Greene
Brassicaceae	<i>Draba apiculata</i> C.L. Hitchc.
Brassicaceae	<i>Draba aurea</i> Vahl ex Hornem. var. <i>aurea</i>
Brassicaceae	<i>Draba cana</i> Rydb.
Brassicaceae	<i>Draba crassifolia</i> Grah.
Brassicaceae	<i>Draba oligosperma</i> Hook.
Brassicaceae	<i>Rorippa curvipes</i> Greene var. <i>alpina</i> (Wats.) Stuckey
Brassicaceae	<i>Thlaspi montanum</i> L. var. <i>montanum</i>
Callitricheaceae	<i>Callitriche palustris</i> L.
Campanulaceae	<i>Campanula rotundifolia</i> L.
Campanulaceae	<i>Campanula uniflora</i> L.
Caprifoliaceae	<i>Sambucus racemosa</i> L. var. <i>microbotrys</i> (Rydb.) Kearney & Peebles
Caryophyllaceae	<i>Arenaria congesta</i> Nutt. var. <i>congesta</i>
Caryophyllaceae	<i>Cerastium arvense</i> L.
Caryophyllaceae	<i>Minuartia obtusiloba</i> (Rydb.) House
Caryophyllaceae	<i>Minuartia rubella</i> (Wahlenb.) Hiern
Caryophyllaceae	<i>Paronychia pulvinata</i> Gray
Caryophyllaceae	<i>Sagina saginoides</i> (L.) Karst.
Caryophyllaceae	<i>Silene acaulis</i> (L.) Jacq. var. <i>subacaulescens</i> (F. N. Williams) Fern. & St. John
Caryophyllaceae	<i>Silene drummondii</i> Hook. var. <i>drummondii</i>
Caryophyllaceae	<i>Silene drummondii</i> Hook. var. <i>striata</i> (Rydb.) Bocq.
Caryophyllaceae	<i>Silene parryi</i> (Wats.) Hitchc. & Maguire
Caryophyllaceae	<i>Spergularia rubra</i> (L.) J. & K. Presl
Caryophyllaceae	<i>Stellaria borealis</i> Bigel. ssp. <i>borealis</i>
Caryophyllaceae	<i>Stellaria calycantha</i> (Ledeb.) Bong.
Caryophyllaceae	<i>Stellaria longipes</i> Goldie var. <i>longipes</i>
Caryophyllaceae	<i>Stellaria monantha</i> Hult.
Caryophyllaceae	<i>Stellaria umbellata</i> Turcz. ex Kar. & Kir.
Chenopodiaceae	<i>Chenopodium atrovirens</i> Rydb.
Chenopodiaceae	<i>Chenopodium leptophyllum</i> (Moq.) Nutt. ex Wats.
Crassulaceae	<i>Sedum integrifolium</i> (Raf.) A. Nels. ssp. <i>integrifolium</i>
Crassulaceae	<i>Sedum lanceolatum</i> Torr. var. <i>lanceolatum</i>
Crassulaceae	<i>Sedum rhodanthum</i> Gray
Cyperaceae	<i>Carex albonigra</i> Mack.
Cyperaceae	<i>Carex aquatilis</i> Wahlenb. var. <i>aquatilis</i>
Cyperaceae	<i>Carex atrata</i> L.
Cyperaceae	<i>Carex atrata</i> L. var. <i>chalciolepis</i> (Holm) Kuek.
Cyperaceae	<i>Carex atrata</i> L. var. <i>erecta</i> Boott
Cyperaceae	<i>Carex aurea</i> Nutt.
Cyperaceae	<i>Carex bipartita</i> All.
Cyperaceae	<i>Carex canescens</i> L. var. <i>cancescens</i>
Cyperaceae	<i>Carex capillaris</i> L.
Cyperaceae	<i>Carex ebenea</i> Rydb.

## Appendix 1 (Cont'd.)

Family	Species
Cyperaceae	<i>Carex egglestonii</i> Mack.
Cyperaceae	<i>Carex foetida</i> All. var. <i>vernacula</i> (Bailey) Kuek.
Cyperaceae	<i>Carex geyeri</i> Boott
Cyperaceae	<i>Carex haydeniana</i> Olney
Cyperaceae	<i>Carex hoodii</i> Boott
Cyperaceae	<i>Carex illota</i> Bailey
Cyperaceae	<i>Carex macloviana</i> Urv.
Cyperaceae	<i>Carex microptera</i> Mack. var. <i>limnophilia</i> (F.J. Herm.) Dorn
Cyperaceae	<i>Carex microptera</i> Mack. var. <i>microptera</i>
Cyperaceae	<i>Carex nardina</i> Fries var. <i>hepburnii</i> (Boott) Kukenth.
Cyperaceae	<i>Carex nelsonii</i> Mack.
Cyperaceae	<i>Carex nigricans</i> C. A. Mey.
Cyperaceae	<i>Carex norvegica</i> Retz. var. <i>stevenii</i> (Holm) Dorn
Cyperaceae	<i>Carex nova</i> Bailey var. <i>nova</i>
Cyperaceae	<i>Carex pachystachya</i> Cham. ex Steud.
Cyperaceae	<i>Carex phaeocephala</i> Piper
Cyperaceae	<i>Carex praeceptorum</i> Mack.
Cyperaceae	<i>Carex pyrenaica</i> Wahlenb.
Cyperaceae	<i>Carex raynoldsii</i> Dewey
Cyperaceae	<i>Carex rossii</i> Boott
Cyperaceae	<i>Carex rostrata</i> Stokes ex With. var. <i>rostrata</i>
Cyperaceae	<i>Carex rupestris</i> All.
Cyperaceae	<i>Carex saxatilis</i> L. var. <i>major</i> Olney
Cyperaceae	<i>Carex scopulorum</i> var. <i>bracteosa</i>
Cyperaceae	<i>Carex scopulorum</i> Holm var. <i>scopulorum</i>
Cyperaceae	<i>Carex vesicaria</i> L. var. <i>vesicaria</i>
Cyperaceae	<i>Eleocharis pauciflora</i> (Lightf.) Link
Ericaceae	<i>Arctostaphylos uva-ursi</i> (L.) Spreng. ssp. <i>uva-ursi</i> var. <i>stipitata</i> (Packer ex Denford)
Ericaceae	<i>Arctostaphylos uva-ursi</i> (L.) Spreng. ssp. <i>uva-ursi</i> var. <i>uva-ursi</i>
Ericaceae	<i>Gaultheria humifusa</i> (Grah.) Rydb.
Ericaceae	<i>Kalmia microphylla</i> (Hook.) Heller var. <i>microphylla</i>
Ericaceae	<i>Monotropa hypopithys</i> L.
Ericaceae	<i>Orthilia secunda</i> (L.) House
Ericaceae	<i>Pyrola minor</i> L.
Ericaceae	<i>Vaccinium cespitosum</i> Michx.
Ericaceae	<i>Vaccinium scoparium</i> Leib. ex Cov.
Fabaceae	<i>Astragalus alpinus</i> L. var. <i>alpinus</i>
Fabaceae	<i>Lupinus argenteus</i> Pursh var. <i>argenteus</i>
Fabaceae	<i>Oxytropis campestris</i> var. (L.) DC. var. <i>gracilis</i> (A. Nels.) Barneby
Fabaceae	<i>Trifolium dasyphyllum</i> T. & G.
Fabaceae	<i>Trifolium parryi</i> Gray
Gentianaceae	<i>Gentiana algida</i> Pall.
Gentianaceae	<i>Gentiana parryi</i> Engelm.
Gentianaceae	<i>Gentianella amarella</i> (L.) Boerner var. <i>amarella</i>
Gentianaceae	<i>Gentianopsis detonsa</i> (Rottb.) Ma var. <i>elegans</i> (A. Nels.) N. Holmgren
Gentianaceae	<i>Swertia perennis</i> L.
Grossulariaceae	<i>Ribes lacustre</i> (Pers.) Poir.
Grossulariaceae	<i>Ribes montigenum</i> McClat.
Hydrocharitaceae	<i>Elodea canadensis</i> Michx.
Hydrophyllaceae	<i>Phacelia sericea</i> (Grah. ex Hook.) Gray var. <i>ciliosa</i> Rydb.
Hydrophyllaceae	<i>Phacelia sericea</i> (Grah. ex Hook.) Gray var. <i>sericea</i>
Iridaceae	<i>Iris missouriensis</i> Nutt.
Juncaceae	<i>Juncus castaneus</i> Sm.
Juncaceae	<i>Juncus confusus</i> Cov.

## Appendix 1 (Cont'd.)

Family	Species
Juncaceae	<i>Juncus drummondii</i> E. Mey
Juncaceae	<i>Juncus drummondii</i> E. Mey. var. <i>drummondii</i>
Juncaceae	<i>Juncus drummondii</i> E. Mey. var. <i>subtriflorus</i> (E. Mey.) C. L. Hitchc.
Juncaceae	<i>Juncus hallii</i> Engelm.
Juncaceae	<i>Juncus mertensianus</i> Bong.
Juncaceae	<i>Juncus parryi</i> Engelm.
Juncaceae	<i>Juncus triglumis</i> L. var. <i>albescens</i> Lange
Juncaceae	<i>Luzula multiflora</i> (Ehrh.) Lej.
Juncaceae	<i>Luzula parviflora</i> (Ehrh.) Desv.
Juncaceae	<i>Luzula spicata</i> (L.) DC.
Liliaceae	<i>Allium brevistylum</i> Wats.
Liliaceae	<i>Erythronium grandiflorum</i> Pursh var. <i>grandiflorum</i>
Liliaceae	<i>Streptopus amplexifolius</i> (L.) DC.
Liliaceae	<i>Zigadenus elegans</i> Pursh
Onagraceae	<i>Epilobium anagallidifolium</i> Lam.
Onagraceae	<i>Epilobium angustifolium</i> L. var. <i>angustifolium</i>
Onagraceae	<i>Epilobium angustifolium</i> L. var. <i>canescens</i> Wood
Onagraceae	<i>Epilobium ciliatum</i> Raf. var. <i>ciliatum</i>
Onagraceae	<i>Epilobium ciliatum</i> var. <i>glandulosum</i>
Onagraceae	<i>Epilobium clavatum</i> Trel.
Onagraceae	<i>Epilobium halleianum</i> Hausskn.
Onagraceae	<i>Epilobium hornemannii</i> Reichenb. ssp. <i>hornemannii</i>
Onagraceae	<i>Epilobium lactiflorum</i> Hausskn.
Onagraceae	<i>Epilobium saximontanum</i> Hausskn.
Onagraceae	<i>Gayophytum decipiens</i> Lewis & Szweyk.
Onagraceae	<i>Gayophytum diffusum</i> T. & G. var. <i>strictipes</i> (Hook) Dorn
Onagraceae	<i>Gayophytum racemosum</i> T. & G.
Orchidaceae	<i>Platanthera dilatata</i> (Pursh) Lindl. ex Beck var. <i>albiflora</i> (Cham.) Ledeb.
Orchidaceae	<i>Platanthera dilatata</i> (Pursh) Lindl. ex Beck var. <i>dilatata</i>
Orobanchaceae	<i>Orobanche uniflora</i> L. var. <i>occidentalis</i> (Greene) Taylor & MacBryde
Plantaginaceae	<i>Plantago tweedyi</i> Gray
Poaceae	<i>Agropyron subsecundum</i> (Link) Hitchc.
Poaceae	<i>Agrostis humilis</i> Vasey
Poaceae	<i>Agrostis scabra</i> Willd. var. <i>scabra</i>
Poaceae	<i>Agrostis thurberiana</i> Hitchc.
Poaceae	<i>Agrostis variabilis</i> Rydb.
Poaceae	<i>Bromus ciliatus</i> L.
Poaceae	<i>Bromus inermis</i> Leyss. var. <i>inermis</i>
Poaceae	<i>Calamagrostis canadensis</i> (Michx.) Beauv.
Poaceae	<i>Calamagrostis purpurascens</i> R. Br. var. <i>purpurascens</i>
Poaceae	<i>Danthonia intermedia</i> Vasey
Poaceae	<i>Deschampsia atropurpurea</i> (Wahlenb.) Scheele var. <i>latifolia</i> (Hook.) Scribn. ex Macoun
Poaceae	<i>Deschampsia cespitosa</i> (L.) Beauv. var. <i>cespitosa</i>
Poaceae	<i>Elymus glaucus</i> Buckl. var. <i>glaucus</i>
Poaceae	<i>Elymus scribneri</i> (Vasey) Jones
Poaceae	<i>Elymus trachycaulus</i> (Link) Gould ex Shinnery var. <i>trachycaulus</i>
Poaceae	<i>Festuca brachyphylla</i> Schult. & Schult. ssp. <i>coloradensis</i> Frederiksen
Poaceae	<i>Festuca saximontana</i> Rydb. var. <i>saximontana</i>
Poaceae	<i>Hierochloa odorata</i> (L.) Beauv.
Poaceae	<i>Oryzopsis exigua</i> Thurber.
Poaceae	<i>Phleum alpinum</i> L. var. <i>alpinum</i>
Poaceae	<i>Poa alpina</i> L.
Poaceae	<i>Poa arctica</i> R. Br. var. <i>grayana</i> (Vasey) Dorn
Poaceae	<i>Poa compressa</i> L.

## Appendix 1 (Cont'd.)

Family	Species
Poaceae	<i>Poa cusickii</i> Vasey var. <i>epilis</i> (Scribn.) C. L. Hitchc.
Poaceae	<i>Poa fendleriana</i> (Steud.) Vasey
Poaceae	<i>Poa interior</i> Rydb.
Poaceae	<i>Poa leptocoma</i> Trin.
Poaceae	<i>Poa nervosa</i> (Hook.) Vasey var. <i>wheeleri</i> (Vasey) C. L. Hitchc.
Poaceae	<i>Poa pattersonii</i> Vasey
Poaceae	<i>Poa pratensis</i> L.
Poaceae	<i>Poa reflexa</i> Vasey & Scribn.
Poaceae	<i>Poa rupicola</i> Nash ex Rydb.
Poaceae	<i>Poa secunda</i> Presl var. <i>elongata</i> (Vasey) Dorn
Poaceae	<i>Poa secunda</i> Presl var. <i>incurva</i> (Scribn. & Williams ex Scribn.) Beetle
Poaceae	<i>Stipa lettermanii</i> Vasey
Poaceae	<i>Torreyochloa pallida</i> (Torr.) Church var. <i>pauciflora</i> (J. Presl) J. Davis
Poaceae	<i>Trisetum spicatum</i> (L.) Richt.
Poaceae	<i>Trisetum wolfii</i> Vasey
Polemoniaceae	<i>Collomia linearis</i> Nutt.
Polemoniaceae	<i>Phlox multiflora</i> A. Nels.
Polemoniaceae	<i>Phlox pulvinata</i> (Wherry) Cronq.
Polemoniaceae	<i>Polemonium brandegei</i> (Gray) Greene
Polemoniaceae	<i>Polemonium viscosum</i> Nutt.
Polygonaceae	<i>Eriogonum umbellatum</i> Torr. var. <i>majus</i> Hook.
Polygonaceae	<i>Oxyria digyna</i> (L.) Hill
Polygonaceae	<i>Polygonum bistortoides</i> Pursh
Polygonaceae	<i>Polygonum douglasii</i> var. <i>douglasii</i>
Polygonaceae	<i>Polygonum sawatchense</i> Sm.
Polygonaceae	<i>Polygonum viviparum</i> L.
Polygonaceae	<i>Rumex densiflorus</i> Osterh.
Polygonaceae	<i>Rumex utahenses</i> Rech. f.
Portulacaceae	<i>Claytonia lanceolata</i> Pursh var. <i>lanceolata</i>
Portulacaceae	<i>Lewisia pygmaea</i> (Gray) Robins. var. <i>pygmaea</i>
Portulacaceae	<i>Lewisia triphylla</i> (Wats.) Robins.
Primulaceae	<i>Androsace septentrionalis</i> L. var. <i>subulifera</i> Gray
Primulaceae	<i>Primula parryi</i> Gray
Ranunculaceae	<i>Aconitum columbianum</i> Nutt. var. <i>columbianum</i>
Ranunculaceae	<i>Anemone multifida</i> Poir. var. <i>multifida</i>
Ranunculaceae	<i>Anemone patens</i> L. var. <i>multifida</i> Pritz.
Ranunculaceae	<i>Aquilegia coerulea</i> James var. <i>coerulea</i>
Ranunculaceae	<i>Caltha leptosepala</i> DC. ssp. <i>leptosepala</i> var. <i>leptosepala</i>
Ranunculaceae	<i>Delphinium barbeyi</i> (Huth) Huth
Ranunculaceae	<i>Ranunculus alismifolius</i> Geyer ex Benth. var. <i>montanus</i> Wats.
Ranunculaceae	<i>Ranunculus eschscholtzii</i> Schlect. var. <i>eschscholtzii</i>
Ranunculaceae	<i>Ranunculus flammula</i> L.
Ranunculaceae	<i>Ranunculus flammula</i> L. var. <i>filiformis</i> (Michx.) Hook.
Ranunculaceae	<i>Ranunculus inamoenus</i> Greene var. <i>alpeophilus</i> (A. Nels.) Benson
Ranunculaceae	<i>Ranunculus uncinatus</i> D. Don ex G. Don
Ranunculaceae	<i>Trollius laxus</i> Salisb. var. <i>albiflorus</i> Gray
Rosaceae	<i>Geum rossii</i> (R. Br.) Ser. var. <i>turbinatum</i> (Rydb.) C. L. Hitchc.
Rosaceae	<i>Potentilla concinna</i> Richards. var. <i>concinna</i>
Rosaceae	<i>Potentilla diversifolia</i> Lehm. var. <i>diversifolia</i>
Rosaceae	<i>Poteneilla fruticosa</i> L.
Rosaceae	<i>Potentilla gracilis</i> Dougl. ex Hook. var. <i>nuttallii</i> (Lehm.) Sheld
Rosaceae	<i>Potentilla gracilis</i> Dougl. ex Hook. var. <i>pulcherrima</i> (Lehm.) Fern
Rosaceae	<i>Potentilla hookeriana</i> Lehm.
Rosaceae	<i>Potentilla nivea</i> L.

## Appendix 1 (Cont'd.)

Family	Species
Rosaceae	<i>Potentilla plattensis</i> Nutt.
Rosaceae	<i>Potentilla rubricaulis</i> Lehm.
Rosaceae	<i>Rubus idaeus</i> L. var. <i>aculeatissimus</i> Regel & Tiling
Rosaceae	<i>Sibbaldia procumbens</i> L.
Rubiaceae	<i>Galium trifidum</i> L. var. <i>trifidum</i>
Salicaceae	<i>Populus tremuloides</i> Michx.
Salicaceae	<i>Salix arctica</i> Pall. var. <i>petraea</i> Anderss.
Salicaceae	<i>Salix bebbiana</i> Sarg. var. <i>bebbiana</i>
Salicaceae	<i>Salix brachycarpa</i> Nutt. var. <i>brachycarpa</i>
Salicaceae	<i>Salix cascadiensis</i> Ckll.
Salicaceae	<i>Salix glauca</i> L. var. <i>villosa</i> (Hook.) Anderss.
Salicaceae	<i>Salix lasiandra</i> Benth. var. <i>caudata</i> (Nutt.) Sudw.
Salicaceae	<i>Salix planifolia</i> Pursh var. <i>planifolia</i>
Saxifragaceae	<i>Heuchera parvifolia</i> Nutt. ex T. & G.
Saxifragaceae	<i>Lithophragma glabrum</i> Nutt. var. <i>ramulosum</i> (Suksd.) Boivin
Saxifragaceae	<i>Mitella pentandra</i> Hook.
Saxifragaceae	<i>Parnassia fimbriata</i> Konig var. <i>fimbriata</i>
Saxifragaceae	<i>Saxifraga odontoloma</i> Piper
Saxifragaceae	<i>Saxifraga rhomboidea</i> Greene
Saxifragaceae	<i>Saxifraga rivularis</i> Greene
Saxifragaceae	<i>Saxifraga rivularis</i> L. ssp. <i>hyperborea</i> (R. Br.) Dorn var. <i>debilis</i> (Engelm ex Gray) Dorn
Scrophulariaceae	<i>Castilleja rhexifolia</i> Rydb.
Scrophulariaceae	<i>Castilleja sulphurea</i> Rydb.
Scrophulariaceae	<i>Chionophila jamesii</i> Benth.
Scrophulariaceae	<i>Pedicularis bracteosa</i> Benth. var. <i>paysoniana</i> (Penn.) Cronq.
Scrophulariaceae	<i>Pedicularis groenlandica</i> Retz.
Scrophulariaceae	<i>Pedicularis parryi</i> Gray ssp. <i>parryi</i>
Scrophulariaceae	<i>Pedicularis racemosa</i> Dougl. ex Hook. var. <i>alba</i> (Penn.) Cronq.
Scrophulariaceae	<i>Penstemon procerus</i> Dougl. ex Grah. var. <i>procerus</i>
Scrophulariaceae	<i>Penstemon rydbergii</i> A. Nels. var. <i>rydbergii</i>
Scrophulariaceae	<i>Penstemon whippleanus</i> Gray
Scrophulariaceae	<i>Veronica serpyllifolia</i> L. var. <i>humifusa</i> (Dickson) Vahl
Scrophulariaceae	<i>Veronica wormskjoldii</i> R. & S.
Violaceae	<i>Viola adunca</i> Sm.
Violaceae	<i>Viola palustris</i> L.
Violaceae	<i>Viola praemorsa</i> Dougl. ex Lindl.

## Appendix 2

**Vascular plant taxa of the Glacier Lakes Ecosystem Experiments Site ranked by presence (the number of stands where the species occurred) and percent occurrence (the proportion of stands where present). Taxa present at the GLEES but not occurring in the sample stands are not included.**

Species occurrence	Presence	%
<i>Abies lasiocarpa</i> (Hook.) Nutt. var. <i>lasiocarpa</i>	83	64
<i>Erigeron peregrinus</i> (Banks ex Pursh) Greene spp. <i>callianthemus</i> (Greene) Cronq.	83	64
<i>Hieracium gracile</i> Hook. var. <i>gracile</i>	81	62
<i>Picea engelmannii</i> Parry ex Englem.	81	62
<i>Vaccinium scoparium</i> Leib. ex Cov.	74	57
<i>Potentilla diversifolia</i> Lehm. var. <i>diversifolia</i>	70	54
<i>Carex rossii</i> Boott	68	52
<i>Polygonum bistortoides</i> Pursh	64	49
<i>Sibbaldia procumbens</i> L.	61	47
<i>Senecio dimorphophyllus</i> Greene var. <i>dimorphophyllus</i>	60	46
<i>Achillea millefolium</i> L. var. <i>lanulosa</i> (Nutt.) Piper	58	45
<i>Juncus drummondii</i> E. Mey	48	37
<i>Phleum alpinum</i> L. var. <i>alpinum</i>	48	37
<i>Penstemon whippleanus</i> Gray	45	35
<i>Trisetum spicatum</i> (L.) Richt.	44	34
<i>Lewisia pygmaea</i> (Gray) Robins. var. <i>pygmaea</i>	43	33
<i>Erythronium grandiflorum</i> Pursh var. <i>grandiflorum</i>	42	32
<i>Selaginella densa</i> Rydb.	41	32
<i>Veronica wormskjoldii</i> R. & S.	41	32
<i>Deschampsia cespitosa</i> (L.) Beauv. var. <i>cespitosa</i>	39	30
<i>Ribes montigenum</i> McClat.	38	29
<i>Senecio crassulus</i> Gray	30	23
<i>Antennaria umbrinella</i> Rydb.	29	22
<i>Artemisia scopulorum</i> Gray	29	22
<i>Sedum lanceolatum</i> Torr. var. <i>lanceolatum</i>	29	22
<i>Arnica cordifolia</i> Hook.	28	22
<i>Caltha leptosepala</i> DC. ssp. <i>leptosepala</i> var. <i>leptosepala</i>	28	22
<i>Minuartia obtusiloba</i> (Rydb.) House	28	22
<i>Poa nervosa</i> (Hook.) Vasey var. <i>wheeleri</i> (Vasey) C. L. Hitchc.	28	22
<i>Poa reflexa</i> Vasey & Scribn.	28	22
<i>Poa cusickii</i> Vasey var. <i>epilis</i> (Scribn.) C. L. Hitchc.	27	21
<i>Geum rossii</i> (R. Br.) Ser. var. <i>turbinatum</i> (Rydb.) C. L. Hitchc.	25	19
<i>Thlaspi montanum</i> L. var. <i>montanum</i>	25	19
<i>Carex nigricans</i> C. A. Mey.	24	18
<i>Salix planifolia</i> Pursh var. <i>planifolia</i>	24	18
<i>Pedicularis racemosa</i> Dougl. ex Hook. var. <i>alba</i> (Penn.) Cronq.	23	18
<i>Sedum rhodanthum</i> Gray	23	18
<i>Vaccinium cespitosum</i> Michx.	23	18
<i>Danthonia intermedia</i> Vasey	22	17
<i>Erigeron pinnatisectus</i> (Gray) A. Nels.	22	17
<i>Epilobium angustifolium</i> L. var. <i>canescens</i> Wood	21	16
<i>Agoseris glauca</i> (Pursh) Raf. var. <i>dasycephala</i> (T. & G.) Jeps.	20	15
<i>Festuca brachyphylla</i> Schult. & Schult. spp. <i>coloradensis</i> Frederiksen	20	15
<i>Pedicularis bracteosa</i> Benth. var. <i>paysoniana</i> (Penn.) Cronq.	20	15
<i>Pedicularis groenlandica</i> Retz.	20	15
<i>Arenaria congesta</i> Nutt. var. <i>congesta</i>	19	15
<i>Erigeron melanocephalus</i> (A. Nels.) A. Nels.	19	15

## Appendix 2 (Cont'd.)

Species occurrence	Presence	%
<i>Arnica mollis</i> Hook.	18	14
<i>Luzula spicata</i> (L.) DC.	18	14
<i>Poa alpina</i> L.	18	14
<i>Agrostis thurberiana</i> Hitchc.	17	13
<i>Arnica latifolia</i> Bong.	16	12
<i>Carex aquatilis</i> Wahlenb. var. <i>aquatilis</i>	16	12
<i>Viola adunca</i> Sm.	16	12
<i>Aquilegia coerulea</i> James var. <i>coerulea</i>	15	12
<i>Gentianella amarella</i> (L.) Boerner var. <i>amarella</i>	15	12
<i>Minuartia rubella</i> (Wahlenb.) Hiern	15	12
<i>Trifolium parryi</i> Gray	15	12
<i>Conioselinum scopulorum</i> (Gray) Coult. & Rose	14	11
<i>Juniperus communis</i> L. var. <i>depressa</i> Pursh	14	11
<i>Solidago simplex</i> Kunth	14	11
<i>Carex microptera</i> Mack. var. <i>microptera</i>	13	10
<i>Phlox pulvinata</i> (Wherry) Cronq.	13	10
<i>Arabis drummondii</i> Gray	12	9
<i>Carex rupestris</i> All.	12	9
<i>Pedicularis parryi</i> Gray ssp. <i>parryi</i>	12	9
<i>Polemonium viscosum</i> Nutt.	12	9
<i>Antennaria media</i> Greene	11	8
<i>Epilobium hornemannii</i> Reichenb. spp. <i>hornemannii</i>	11	8
<i>Juncus mertensianus</i> Bong.	11	8
<i>Luzula parviflora</i> (Ehrh.) Desv.	11	8
<i>Salix brachycarpa</i> Nutt. var. <i>brachycarpa</i>	11	8
<i>Angelica grayi</i> (Coult. & Rose) Coult. & Rose	10	8
<i>Erigeron simplex</i> Greene	10	8
<i>Juncus parryi</i> Engelm.	10	8
<i>Poa fendleriana</i> (Steud.) Vasey	10	8
<i>Potentilla nivea</i> L.	10	8
<i>Ranunculus alismifolius</i> Geyer ex Benth. var. <i>montanus</i> Wats.	10	8
<i>Calamagrostis purpurascens</i> R. Br. var. <i>purpurascens</i>	9	7
<i>Cerastium arvense</i> L.	9	7
<i>Kalmia microphylla</i> (Hook.) Heller var. <i>microphylla</i>	9	7
<i>Senecio triangularis</i> Hook.	9	7
<i>Silene acaulis</i> (L.) Jacq. var. <i>subacaulescens</i> (F. N. Williams) Fern. & St. John	9	7
<i>Taraxacum officinale</i> Weber	9	7
<i>Agrostis humilis</i> Vasey	8	6
<i>Calamagrostis canadensis</i> (Michx.) Beauv.	8	6
<i>Carex illota</i> Bailey	8	6
<i>Carex scopulorum</i> Holm var. <i>scopulorum</i>	8	6
<i>Draba oligosperma</i> Hook.	8	6
<i>Eritrichium nanum</i> (Vill.) Schrad. ex Gaudin var. <i>elongatum</i> (Rydb.) Cronq.	8	6
<i>Festuca saximontana</i> Rydb. var. <i>saximontana</i>	8	6
<i>Arctostaphylos uva-ursi</i> (L.) Spreng. spp. <i>uva-ursi</i> var. <i>stipitata</i> (Packer ex Denford) Dorn	7	5
<i>Castilleja rhexifolia</i> Rydb.	7	5
<i>Mertensia ciliata</i> (James ex Torr.) G. Don var. <i>ciliata</i>	7	5
<i>Paronychia pulvinata</i> Gray	7	5
<i>Trifolium dasyphyllum</i> T. & G.	7	5
<i>Androsace septentrionalis</i> L. var. <i>subulifera</i> Gray	6	
<i>Arnica rydbergii</i> Greene	6	5
<i>Carex ebenea</i> Rydb.	6	5

## Appendix 2 (Cont'd.)

Species occurrence	Presence	%
<i>Deschampsia atropurpurea</i> (Wahlenb.) Scheele		
var. <i>latifolia</i> (Hook.) Scribn. ex Macoun	6	5
<i>Draba aurea</i> Vahl ex Hornem. var. <i>aurea</i>	6	5
<i>Hymenoxys grandiflora</i> (T. & G. ex Gray) Parker	6	5
<i>Platanthera dilatata</i> (Pursh) Lindl. ex Beck var. <i>albiflora</i> (Cham.) Ledeb.	6	5
<i>Poa interior</i> Rydb.	6	5
<i>Poa pattersonii</i> Vasey	6	5
<i>Poa secunda</i> Presl var. <i>elongata</i> (Vasey) Dorn	6	5
<i>Polygonum viviparum</i> L.	6	5
<i>Saxifraga odontoloma</i> Piper	6	5
<i>Saxifraga rhomboidea</i> Greene	6	5
<i>Stellaria umbellata</i> Turcz. ex Kar. & Kir.	6	5
<i>Trisetum wolfii</i> Vasey	6	5
<i>Antennaria rosea</i> Greene	5	4
<i>Aster foliaceus</i> Lindl. ex DC. var. <i>apricus</i> Gray	5	4
<i>Epilobium halleianum</i> Hausskn.	5	4
<i>Haplopappus pygmaeus</i> (T. & G.) Gray	5	4
<i>Plantago tweedyi</i> Gray	5	4
<i>Poa leptocoma</i> Trin.	5	4
<i>Ranunculus eschscholtzii</i> Schlect. var. <i>eschscholtzii</i>	5	4
<i>Ranunculus inamoenus</i> Greene var. <i>alpeophilus</i> (A. Nels.) Benson	5	4
<i>Agrostis variabilis</i> Rydb.	4	3
<i>Carex atrata</i> L. var. <i>erecta</i> Boott	4	3
<i>Carex foetida</i> All. var. <i>vernacula</i> (Bailey) Kuek.	4	3
<i>Carex pyrenaica</i> Wahlenb.	4	3
<i>Carex scopulorum</i> var. <i>bracteosa</i>	4	3
<i>Elymus scribneri</i> (Vasey) Jones	4	3
<i>Erigeron ursinus</i> D. C. Eat.	4	3
<i>Gentiana algida</i> Pall.	4	3
<i>Mitella pentandra</i> Hook.	4	3
<i>Pinus flexilis</i> James	4	3
<i>Salix cascadiensis</i> Ckll.	4	3
<i>Solidago multiradiata</i> Ait var. <i>scopulorum</i> Gray	4	3
<i>Carex albonigra</i> Mack.	3	2
<i>Carex haydeniana</i> Olney	3	2
<i>Cystopteris fragilis</i> (L.) Bernh. var. <i>fragilis</i>	3	2
<i>Elymus trachycaulus</i> (Link) Gould ex Shinnars var. <i>trachycaulus</i>	3	2
<i>Mertensia viridis</i> (A. Nels.) A. Nels.	3	2
<i>Astragalus alpinus</i> L. var. <i>alpinus</i>	2	2
<i>Carex atrata</i> L. var. <i>chalciolepis</i> (Holm) Kuek.	2	2
<i>Carex canescens</i> L. var. <i>cancescens</i>	2	2
<i>Carex pachystachyha</i> Cham. ex Steud.	2	2
<i>Carex phaeocephala</i> Piper	2	2
<i>Chionophila jamesii</i> Benth.	2	2
<i>Draba crassifolia</i> Grah.	2	2
<i>Eleocharis pauciflora</i> (Lightf.) Link	2	2
<i>Epilobium lactiflorum</i> Hausskn.	2	2
<i>Gentiana parryi</i> Engelm.	2	2
<i>Oxyria digyna</i> (L.) Hill	2	2
<i>Phacelia sericea</i> (Grah. ex Hook.) Gray var. <i>sericea</i>	2	2
<i>Pinus contorta</i> Dougl. ex Loud. var. <i>latifolia</i> Engelm. ex Wats.	2	2
<i>Poa rupicola</i> Nash ex Rydb.	2	2
<i>Rumex densiflorus</i> Osterh.	2	2
<i>Sagina saginoides</i> (L.) Karst.	2	2

## Appendix 2 (Cont'd.)

Species occurrence	Presence	%
<i>Senecio fremontii</i> T. & G. var. <i>blitoides</i> (Greene) Cronq.	2	2
<i>Stellaria borealis</i> Bigel. spp. <i>borealis</i>	2	2
<i>Swertia perennis</i> L.	2	2
<i>Viola praemorsa</i> Dougl. ex Lindl.	2	2
<i>Agoseris aurantiaca</i> (Hook.) Greene	1	1
<i>Agrostis scabra</i> Willd. var. <i>scabra</i>	1	1
<i>Antennaria microphylla</i> Rydb.	1	1
<i>Botrychium lunaria</i> (L.) Sw. var. <i>lunaria</i>	1	1
<i>Callitriche palustris</i> L.	1	1
<i>Carex hoodii</i> Boott	1	1
<i>Carex microptera</i> Mack. var. <i>limnophila</i> (F.J. Herm.) Dorn	1	1
<i>Carex nelsonii</i> Mack.	1	1
<i>Carex nova</i> Bailey var. <i>nova</i>	1	1
<i>Carex praeceptorum</i> Mack.	1	1
<i>Carex raynoldsii</i> Dewey	1	1
<i>Carex vesicaria</i> L. var. <i>vesicaria</i>	1	1
<i>Draba albertina</i> Greene	1	1
<i>Elymus glaucus</i> Buckl. var. <i>glaucus</i>	1	1
<i>Epilobium ciliatum</i> Raf. var. <i>ciliatum</i>	1	1
<i>Epilobium clavatum</i> Trel.	1	1
<i>Epilobium saximontanum</i> Hausskn.	1	1
<i>Equisetum arvense</i> L.	1	1
<i>Gaultheria humifusa</i> (Grah.) Rydb.	1	1
<i>Hierochloa odorata</i> (L.) Beauv.	1	1
<i>Juncus confusus</i> Cov.	1	1
<i>Lupinus argenteus</i> Pursh var. <i>argenteus</i>	1	1
<i>Monotropa hypopithys</i> L.	1	1
<i>Oryzopsis exigua</i> Thurb.	1	1
<i>Osmorhiza depauperata</i> Phil.	1	1
<i>Oxytropis campestris</i> var. (L.) DC. var. <i>gracilis</i> (A. Nels.) Barneby	1	1
<i>Parnassia fimbriata</i> Konig var. <i>fimbriata</i>	1	1
<i>Poa compressa</i> L.	1	1
<i>Polygonum douglasii</i> var. <i>douglasii</i>	1	1
<i>Populus tremuloides</i> Michx.	1	1
<i>Pyrola minor</i> L.	1	1
<i>Ranunculus flammula</i> L. var. <i>filiformis</i> (Michx.) Hook.	1	1
<i>Rorippa curvipes</i> Greene var. <i>alpina</i> (Wats.) Stuckey	1	1
<i>Sambucus racemosa</i> L. var. <i>microbotrys</i> (Rydb.) Kearney & Peebles	1	1
<i>Saxifraga rivularis</i> Greene	1	1
<i>Senecio streptanthifolius</i> Greene	1	1
<i>Silene drummondii</i> Hook. var. <i>striata</i> (Rydb.) Bocq.	1	1
<i>Solidago parryi</i> (Gray) Greene	1	1
<i>Stellaria calycantha</i> (Ledeb.) Bong.	1	1
<i>Stellaria longipes</i> Goldie var. <i>longipes</i>	1	1
<i>Stellaria monantha</i> Hult.	1	1
<i>Streptopus amplexifolius</i> (L.) DC.	1	1
<i>Taraxacum ceratophorum</i> (Ledeb.) DC.	1	1
<i>Taraxacum laevigatum</i> (Willd.) DC.	1	1
<i>Woodsia scopulina</i> D. C. Eat.	1	1
<i>Zigadenus elegans</i> Pursh	1	1







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