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Mary Lou Rottman
University of Colorado, Denver

Emily L. Hartman
University of Colorado, Denver

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TUNDRA VEGETATION OF THREE CIRQUE BASINS IN THE NORTHERN SAN JUAN MOUNTAINS, COLORADO

Mary Lou Rottman¹ and Emily L. Hartman¹

ABSTRACT.— The vegetation of three alpine cirque basins in the northern San Juan Mountains of southwestern Colorado was inventoried and analyzed for the degree of specificity shown by vascular plant communities for certain types of habitats identified as representative of the basins. A total of 197 vascular plant species representing 31 families was inventoried. Growth forms of all species were noted and a growth form spectrum for all of the communities was derived. The caespitose monocot and erect dicot growth forms are the most important growth forms among the community dominants. The most common growth form among all species is the rosette dicot.

Since the early 1900s a number of ecological studies have been undertaken in the alpine tundra of the Front Range of Colorado (Cooper 1908, Holm 1923, Cox 1933, Osburn 1958, Marr 1961, Willard 1963, Komarkova 1976, Flock 1978, May and Webber 1982). However, the alpine tundra of central and southwestern Colorado remains relatively unknown (Langenheim 1962, Johnson 1969). A floristic study was done by Michener (1964) in the subalpine and alpine zones of the Needle Mountains in the southern San Juan Mountains. Another major study in the southern San Juan Mountains, an analysis of snowpack augmentation by Steinhoff and Ives (1976), included the alpine zone as well as the forest ecosystems below. There is no published botanical work on the alpine vegetation of the northern San Juan Mountains. In this study the vegetation of three alpine cirque basins in the northern San Juans was inventoried and analyzed for the degree of specificity shown by individual species and aggregations of species for certain types of habitats.

STUDY AREA

The San Juan Mountains are a discontinuous section of the Southern Rocky Mountains situated along the Continental Divide in southwestern Colorado. They are located between 106 and 108 degrees west longitude and 36 degrees 30 minutes and 38 degrees 15 minutes north latitude (Atwood

and Mather 1932). Sharp pinnacles, rounded crests, serrate ridges, and broad upland erosional surfaces characterize the alpine zone of these mountains. The elevation of the San Juans ranges from 1524 m in the southwest corner to 4358 m at the summit of Uncompahgre Peak. They are composed largely of Tertiary volcanic tuffs and lavas that lie unconformably over metamorphic sedimentary and volcanic intrusive rocks of Precambrian age as well as sediments of Paleozoic, Mesozoic, and early Cenozoic age (Casadwall and Ohmoto 1977). Broad regional ice fields and transection glaciers occurred during the Pleistocene, producing cirques, basins, tarns, hanging valleys, and broad U-shaped valleys. Today periglacial features such as active patterned ground, active rock glaciers, and persistent ponds indicate the occurrence of sporadic or discontinuous permafrost (Ives and Fahey 1971, Barsch 1978).

Three alpine cirque basins, representative of the northern San Juan Mountain tundra, were studied. American Basin, Hinsdale County, is characterized by a well-developed moist turf mantle interrupted by areas of bedrock outcrops, talus deposits, and patterned ground features. The vegetation in this basin reflects a more moist climatic regime than in the other two basins, as evidenced by the predominance of moist meadows, absence of dry meadows, and minimal occurrence of fell-fields. The elevational range of this basin is 3536–3962 m.

¹Department of Biology, University of Colorado, Denver, Colorado 80202.

Burns Basin, San Juan County, has a north-west-southeast orientation. The convex slopes forming the perimeter of the main basin present an interesting contrast of moisture regimes. The southwest-facing slope is characterized by a dry turf alternating with fell-fields and unvegetated talus. The northwest-facing slope consists of a series of tiers of massive moist and wet ledges with adjacent moist meadows. Midsection of the basin consists of moist and wet meadows. The elevational range of this basin is 3634-3932 m. Both Burns and American basins have rock glacier complexes composed of tongue and lobate units.

Stony Basin, San Juan County, is formed of three broad turf-mantled steps, each separated by a bedrock escarpment. Because of its topographic position, the basin is continually buffeted by strong wind resulting in a more severe climatic regime than is found in the other two basins. Islands of dry meadows and fell-fields interrupt the moist meadow of the upper two steps of the basin. The latter have an abundance of frost-associated features including frost boils, patterned ground, ephemeral ponds, and rock debris islands. The lower step is characterized by a shallow lake and hummocky wet meadow. The elevational range of Stony Basin is 3764-3926 m.

METHODS

Three field seasons, 1981-1983, were involved in the study. One hundred ninety-nine habitats and their associated vascular plant communities were sampled. The abundance of each species was estimated using the standard abundance classes of Daubenmire (1968). As data from multiple samples of a particular habitat type accumulated, the inventoried species and their abundance ratings were analyzed on the basis of constancy of occurrence between samples (Mueller-Dombois and Ellenberg 1974). The terms used in describing the species within a community, dominant, secondary, frequent, occasional, and rare, are defined as follows. A dominant species is very abundant (abundance class) and occurs with a high constancy (80.1%-100%). A frequent species is frequent in abundance and has an intermediate constancy (40.1%-60%). An occasional species

occurs in scattered instances, and its presence or absence is inconsequential to the character of the community in which it may occur. It is occasional in abundance and has a low constancy (20.1%-40%). A rare species is both rare in abundance and rare in constancy (1.0%-20%).

The term *habitat type* in this study refers to all of the area (sum of discrete units) that support one plant community. A habitat type may be considered as the abiotic equivalent of the stand-type in that the habitat type is a synthetic unit whose characteristics are obtained by combining all the samples of a particular habitat. The habitat types defined are: dry ledge, moist-wet ledge, rock crevice, talus slope, patterned ground, fell-field, dry meadow, moist meadow, wet meadow, shrub tundra, and krummholz. Nomenclature follows Kartesz and Kartesz (1980).

RESULTS

In the following description of habitat types and associated communities, only the dominant and secondary or more important species are listed.

Ledge Habitat Type

The rock ledge habitat consists of the bedrock outcrops which, as a result of jointing and weathering, form benches and channels where windborne fines are deposited and organic debris is accumulated to form a substrate for vegetation. The orientation of the bedrock and amount of protection provided by rock overhang are controlling factors in the microenvironment of this habitat type (Younkin 1970). For purposes of vegetation analysis, the ledge habitat is divided along a moisture gradient and includes dry ledges and moist-wet ledges. Two communities are found in the dry ledge habitat and three in the moist-wet ledge habitat.

Geum rossii var. *turbinatum* and *Selaginella densa* are frequent species in one of the dry ledge communities. Other important species include *Aquilegia coerulea*, *Cystopteris fragilis*, *Draba crassa*, *Potentilla subjuga* var. *subjuga*, *Silene acaulis* var. *subacaulis*, and *Smelowskia calycina*. The other dry ledge

community is characterized by *Carex haydeniana*, *Cerastium earlei*, *Draba crassa*, *Festuca brachyphylla*, *Potentilla nivea*, *P. rubricaulis*, *Saxifraga flagellaris* ssp. *platysepala*, and *Trifolium nanum*.

One of the moist-wet ledge communities is dominated by *Geum rossii* var. *turbinatum*, with *Carex albonigra*, *C. heteroneura* var. *chalciolepis*, *Erigeron melanocephalus*, and *Saxifraga cespitosa* ssp. *delicatula* as important associates. Another moist-wet ledge community has *Salix reticulata* ssp. *nivalis* as dominant. Associated with this species are *Carex albonigra*, *Salix arctica*, *Saxifraga ascendens* ssp. *oregonensis*, and *S. debilis*. Ledges with snowmelt water running through fissures in the rock constitute the third possible moist-wet ledge habitat. These are dominated by *Cardamine cordifolia* at the base of the ledges and *Salix reticulata* ssp. *nivalis* on the benches. *Caltha leptosepala*, *Carex nova*, *Primula parryi*, *Sedum rhodanthum*, and *Sibbaldia procumbens* are present in this community.

Rock Crevice Habitat Type

This is a restrictive habitat type that only includes soil-filled crevices on solitary boulders or contained crevices on rock outcrops or headwalls in the basins. The community concept is loosely applied to the species in these habitats. The only relationship that the singly-occurring species have to one another is their presence on the same boulder or bed-rock substrate. Certain species are frequently found in rock crevices: *Androsace septentrionalis*, *Artemisia scopulorum*, *Claytonia megarhiza*, *Draba crassa*, *D. crassifolia*, *Festuca brachyphylla*, and *Oreoxis bakeri*.

Talus Slope Habitat Type

Extensive talus slopes occur throughout the basins. White (1981) defines talus as an accumulation of rock debris of various sizes transported from the source areas by gravity, rain-wash, snowmelt water, or snow avalanching to a site below. Fine material may be present in the interstices of the rock material; these fines provide a suitable substrate for vegetation. Although dominance within the talus slope community is poorly defined, certain

species show a high constancy for this habitat: *Angelica grayi*, *Aquilegia coerulea*, *Cerastium earlei*, *Claytonia megarhiza*, *Polemonium viscosum*, *Senecio amplexens* var. *amplexens*, *S. amplexens* var. *holmii*, *S. soldanella*, and *S. wernerifolius*.

Patterned Ground Habitat Type

Washburn (1956) defines patterned ground as, "a group term for the more or less symmetrical forms, such as circles, polygons, nets, steps and stripes, that are characteristic of, but not necessarily confined to, a mantle subject to intensive frost action." The forms of patterned ground found in the study basins are nonsorted circles (frost boils and frost hummocks), sorted polygons, and debris islands. The centers of the sorted forms have from little to no vegetation because of the associated frost action that keeps the soil sufficiently disturbed to prevent plant colonization (Johnson and Billings 1962). The communities found in patterned ground habitats vary with the specific type of patterned ground form. Frost boils are another example of a habitat for which the community concept must be loosely applied. Several species are repeatedly found associated with frost boils: *Cerastium earlei*, *Draba crassifolia*, *Geum rossii* var. *turbinatum*, *Oreoxis bakeri*, and *Stellaria umbellata*. Frost hummock areas are traversed by water-filled channels in the wet meadows. The dominant species on the elevated portion of the hummock is *Carex nigricans*. Secondary species are *Carex pseudoscirpoidea* and *Festuca brachyphylla*. Dominant species in the saturated areas at the base of the hummocks are *Carex aquatilis* and *C. vernacula*. *Caltha leptosepala* and *Carex nova* are secondary species in these areas. Sorted polygons are characterized by lichenized rocks in the borders. The central fines of the polygons support a *Carex nigricans*-*Sibbaldia procumbens* community. Frequent associates in this community are *Artemisia scopulorum*, *Erigeron melanocephalus*, and *Juncus drummondii*. Debris islands, a sorted form of patterned ground, occur as repetitive units on talus debris. The vegetation on these islands suggests a successional development from talus slope to meadow. Depending upon the seral stage of development,

dominant species may be either *Salix reticulata* ssp. *nivalis* and *Silene acaulis* var. *subacaulis*, or *Senecio amplexans* var. *holmii* and *S. soldanella*.

Fell-field Habitat Type

The fell-field habitat type is characterized by a high proportion of weathered rock material. Soils are coarse textured, with little organic material and only rudimentary profiles. Fell-fields occur on windward sites, with little or no snow cover, thus exposing the plants and soil to severe desiccation. The longest growing season in the tundra occurs in this habitat type. The high diversity found in fell-field communities is contributed primarily by the frequent and occasional species. One of the fell-field communities is dominated by *Silene acaulis* var. *subacaulis* and *Geum rossii* var. *turbinatum*, with *Minuartia obtusiloba*, *Potentilla diversifolia*, *Selaginella densa*, and *Trifolium nanum* as secondary species. Another fell-field community has *Carex elynoides* and *Geum rossii* var. *turbinatum* as dominants. Secondary species include *Festuca brachyphylla*, *Minuartia obtusiloba*, *Selaginella densa*, and *Trifolium nanum*. *Carex elynoides* and *Trifolium nanum* are dominants in the fell-field community occurring on slopes and ridge tops. Associated with these species are *Festuca brachyphylla*, *Geum rossii* var. *turbinatum*, and *Silene acaulis* var. *subacaulis*.

Dry Meadow Habitat Type

The dry meadow habitat type occurs on exposed windy slopes high in the basins, where strong winds create snow-free conditions throughout much of the winter. The vegetation in these sites reaches anthesis early in the season, thus completing the growth cycle before vegetation in more protected areas reaches maturity. The most extensive dry meadow community is dominated by *Carex elynoides*. Secondary species include: *Festuca brachyphylla*, *Geum rossii* var. *turbinatum*, *Hymenoxys grandiflora*, *Poa rupicola*, and *Trisetum spicatum*. A minor and highly restricted dry meadow community is dominated by *Kobresia myosuroides*. *Carex ebenea*, *C. heteroneura* var. *chalciolepis*, *C. pseudoscirpoidea*, *Luzula spicata*, and

Trisetum spicatum are secondary species in this community.

Moist Meadow Habitat Type

This is perhaps the most widespread habitat type in the study basins and is most representative of the tundra in the northern San Juan Mountains. The moist meadows are situated on the lee slopes and in topographical concavities protected from the winter climate by snow accumulation that may remain until mid-July. The moist meadow may be regarded as a complex of several communities, each with a distinct spatial occurrence within the complex. A *Deschampsia caespitosa*-*Geum rossii* var. *turbinatum* community is found in lower sites on basin slopes and in concavities. Associated with these species are: *Artemisia scopulorum*, *Carex albonigra*, *C. nova*, *Oreoxis bakeri*, *Polygonum bistortoides*, and *Saxifraga rhomboidea*. In flat areas at midslope, a *Carex nigricans*-*Sibbaldia procumbens* community occurs with *Carex vernacula*, *Erigeron melanocephalus*, *Juncus drummondii*, *Oreoxis bakeri*, *Polygonum viviparum*, and *Ranunculus macaleyi* as secondary species. The third community in the complex, dominated by *Salix reticulata* ssp. *nivalis*, is present on the highest moist meadow sites in the basins. Secondary species include *Artemisia scopulorum*, *Erigeron simplex*, *Salix arctica*, *Sibbaldia procumbens*, and *Silene acaulis* var. *subacaulis*.

Wet Meadow Habitat Type

Wet meadows are situated on relatively flat surfaces below late-lying snowbanks, in catchment areas in the basins, and adjacent to ponds, lakes, and streams. Frequently dissected by rivulets, these areas are often associated with the presence of sporadic permafrost (Johnson and Billings 1962, Ives 1974). As a result of permafrost in the substrate and the runoff, the wet meadows are saturated throughout the growing season. Where shallow, standing water is present, a *Caltha leptosepala*-*Cardamine cordifolia*-dominated community occurs. The secondary species are *Carex nova*, *Juncus drummondii*, *Pedicularis groenlandica*, *Primula parryi*, *Sedum integrifolium*, and *Trifolium parryi*. A

second community, dominated by *Caltha leptosepala* and *Juncus drummondii*, is characteristic of better drained sites. Associated species include: *Carex aquatilis*, *Festuca brachyphylla*, *Geum rossii* var. *turbatum*, *Primula parryi*, *Sibbaldia procumbens*, and *Trifolium parryi*.

Shrub Tundra Habitat Type

The shrub tundra habitat type is made up of shrub thickets of *Salix brachycarpa* or *S. planifolia* and associated vegetation. A minor constituent of the basins in this study, this habitat type is limited to moist depressions and drainage areas. The moist areas are dominated by *Salix planifolia*. Secondary species in this community are: *Carex ebenea*, *C. heteroneura* var. *chalciolepis*, *C. nova*, *C. pseudoscirpoidea*, and *Geum rossii* var. *turbatum*. A *Salix brachycarpa*-dominated community occurs on well-drained slopes. A drier environment is reflected in the associated species: *Phacelia sericea*, *Polemonium viscosum*, *Potentilla diversifolia*, *Sedum lancoletatum*, and *Trifolium nanum*.

Krummholz Habitat Type

Timberline elevations range from approximately 3535 to 3720 m in the study basins. The ecotonal area characteristically has representative species from both the alpine and subalpine zones. Krummholz conifer species, *Abies lasiocarpa* and *Picea engelmannii*, are dominant and exert a primary influence on the surrounding environment and vegetation. The associated species are highly variable from one krummholz habitat to another; however, a list of the more frequent species serves to illustrate the ecotonal nature of the community: *Aquilegia coerulea*, *Arnica cordifolia*, *Dugaldia hoopesii*, *Minuartia obtusiloba*, *Polygonum bistortoides*, *Ribes montigenum*, *Silene acaulis* var. *subcaulis*, and *Thalictrum fendleri*.

DISCUSSION

A total of 197 vascular plant species representative of 31 families was inventoried in the study basins (Rottman 1984). Basin orientation, variability of moisture regimes, degree

of protection from wind, amount and nature of weathering, debris transport, and slope aspect determine the occurrence of specific habitat types and associated communities in terms of the dominant and secondary species. Minor variations are seen in the occurrence of occasional species. Rare species have a higher occurrence in the rock-predominating habitats, where competition appears to be less than in a closed turf meadow.

A consistent tendency toward dwarfing of species is noted in the *Carex nigricans*-*Sibbaldia procumbens* and *Salix reticulata* ssp. *nivalis*-dominated moist meadow communities. This appears to correlate with a pattern of late snow release. As noted by Owen (1976), plants of the same species under conditions of higher elevation and later snowmelt mature and flower at a smaller size than plants not under these conditions.

The *Kobresia myosuroides*-dominated dry meadow, which has long been recognized as the climatic climax of the Front Range (Cox 1933, Osburn 1958, Bamberg 1961, Marr 1961, Willard 1963), is highly restricted in its occurrence in the northern San Juan Mountains and is replaced in importance by a *Carex elynoides*-dominated dry meadow community.

Carex Indicators

Some members of the Cyperaceae, *Carex albonigra*, *C. arapahoensis*, *C. heteroneura* var. *chalciolepis*, and *C. pseudoscirpoidea*, have rather broad ecological tolerances that enable them to grow in both dry and moist habitats. *Carex nova* and *C. vernacula* occur in moist as well as wet habitats. Other *Carex* species are more specific in their moisture requirements or tolerances and are useful indicators of substrate moisture conditions. Indicators of dry substrates are: *Carex elynoides*, *C. perglobosa*, and *C. phaeocephala*. Indicators of moist substrates are: *C. nelsonii*, *C. nigricans*, *C. norvegica*, *C. pyrenaica*, and *C. nardina* var. *hepburnii*. *Carex aquatilis* is an indicator of wet substrates often characterized by standing water.

Species Growth Forms

Each species found in the study basins was assigned to a growth form category. The

growth forms of May and Webber (1982) were used. Based primarily on the nature of the shoot habit, these growth forms include: caespitose monocot, single-shooted monocot, erect dicot, rosette dicot, mat dicot, cushion dicot, erect shrub, and dwarf shrub.

The caespitose monocot is a tufted graminoid growth form. Graminoid sods are able to modify the microenvironment to a greater extent than any other growth form or pattern of spatial distribution (Billings 1974). When compared to other growth forms, the percentage of caespitose monocot species is relatively small (9%); however, this growth form contributes the greatest percentage of dominants in the communities analyzed.

The single-shooted monocot growth form is represented primarily by grasses and sedges (25 species, 12% of total). Although this category has more species than the caespitose monocot, it is never dominant within a community.

The highest percentage of species (38%) and the second highest percentage of dominants in the communities are erect dicots. Since both the root and shoot systems of erect dicot plants require less space for lateral spread, this growth form is compatible with extremely rocky habitats where only a minimal amount of soil is available.

The importance of the rosette dicot growth form (26%) is reflected in the fact that approximately 70% of the species with ubiquitous occurrences in the study basins are in this category. This growth form is found in all the habitat types studied and appears to be equally abundant in both meadow and rock habitats.

The mat (6%) and cushion dicot (2%) growth forms are minor in occurrence. Both of these growth forms are considerably more important in tundras to the north, where their greater occurrence is correlated with an increased wind factor. The erect and dwarf shrub growth forms are another minor segment of the growth form spectrum accounting for a combined 7% of the total species.

Community Specificity

The specificity of communities for particular habitat types was evaluated on the basis of community dominants. Although habitat

types are physically discrete and recognizable, a one-habitat type/one-community concept is not applicable. A similar finding is reported by Douglas (1972). It was found that virtually all habitat types have more than one potential community with different dominants and that some dominants are repetitive, by themselves or in combination, in different habitat types.

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