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Analysis of the vegetation on the glacial moraines in the upper Blackfoot Valley Montana

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ANALYSIS OF THE VEGETATION ON THE GLACIAL MORAINES
IN THE UPPER BLACKFOOT VALLEY, MONTANA

By

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INTRODUCTION

Man has long been aware of the influential role of climate in the distribution of living organisms. However, not only are regional differences in temperature, moisture and other macroclimatic factors important, but also local microclimatic and topographic differences. Therefore, entirely different conditions may exist for organisms occupying the same general habitat.

A microclimate is, as the name implies, the climate of a small area as opposed to the general climate or macroclimate. It has been defined variously by different authors as: (1) the climate within the layer of air near the ground (Geiger, 1957), (2) a complex of above ground conditions distinct with respect to location or meteorological phenomena (Wolfe, *et al*. 1949) and (3) strictly local combinations of atmospheric factors which, owing to uneven topography, plant cover, etc. differs from the macroclimate as measured in locations where these modifying factors have negligible influence (Daubenmire, 1946). The point to be stressed, however, is that a microclimate is created by a particular set of environmental conditions (usually topographic or vegetational) which modify the regional climate so as to create a new and distinctive local climate.

Since the distribution and response of living organisms have been shown to reflect microclimatic factors or variation, the relationship should permit orgamisms to be used as indicators of microclimates. Plants are more useful than animals in this respect because of their stationary mode of life.

Striking compositional changes of vegetation may be observed on adjoining exposures. The direction of slope exposure produces a difference in the microclimate of different adjoining slopes of sufficient magnitude to influence plant life (Cantlon, 1953). In general, it has been found that various adjoining exposures of a mound may differ in soil and air temperature, soil and atmospheric moisture, light intensity and wind velocity.

The procedural and financial difficulties involved in an intensive field program of microclimatic sampling are great. Such a project requires costly meteorological instruments and involves a considerable amount of time. However, certain basic ideas involving microenvironmental interrelationships may be presented without the aid of elaborate equipment.

The present study was conducted to illustrate the interrelationships between microenvironmental and vegetational patterns in grasslands occupying various exposures on morainal mounds. These morainal knobs were located in the upper Blackfoot Valley, and offer an excellent opportunity for studying exposure and position-induced vegetative variations within a local scale.

The primary objectives of this investigation were two-fold: (1) an analysis of the morainal communities---their composition and distributional patterns as correlated with slope exposure, surface and soil temperatures, and soil moisture regimes, and (2) a vegetational-microenvironmental comparison of sites under intensive grazing and those under limited grazing conditions. Secondarily, a list was compiled of the flora occurring in the Upper Blackfoot Valley.

REVIEW OF LITERATURE

Through the years, vegetational patterns with respect to slope and exposure have had considerable investigation. Many of the early investigations on slope exposure were carried on in Europe. Braun-Blanquet (1932) mentioned the work of Sendtner (1854) and de Candolle (1856) on the relationship of slope exposure to altitudinal limits of species. Turesson (1914) reviewed the work of Gittay (1886) who indicated a great difference between the temperature and atmospheric humidity on the northern and southern slopes of sand dunes in Holland. Warming (1909) suggested that a slope exposed to sun and wind bears vegetation entirely different from that on one less exposed to these conditions.

Recent work in Europe includes Braun-Blanquet's (1932) study of north and south slopes in the Swiss Alps. He indicated that the southern exposures unlike the north, are occupied predominately be communities requiring considerable amounts of light. Similarly, Geiger (1965) indicated the north and south slopes in the Alps are two fundamentally different habitats for all life dependent on the sun. He noticed that at a certain time in the spring when everything is dormant on the snow covered north slopes, the first flowers are in bloom on the south slopes between the banks of melting snow.

Early investigations in the United States concerned with the influence of slope exposure on vegetation were primarily conducted in west. In the southern Rocky Mountains, Blumer (1911) reported that the distribution of many plants shifts from northern to southern slopes with an increase in altitude.

Turesson (1914) in studying slope exposure in the arid parts of Washington found a flora of mainly xerophytic character inhabiting the south-facing slopes, while the northern slopes, less exposed to insolation, were covered with a more or less mesophytic vegetation. He concluded that these xerophytic conditions prevent the occurrence of Douglas fir on southern exposures. Similarly, Gail (1921) indicated the greater wind velocities and high temperatures on the southwest slopes seem to prevent the growth of Douglas fir only in as much as they promote evaporation and transpiration.

Shreve (1922-1927) in his investigations of the vegetation in the mountains of western United States found that the relative importance of soil temperatures in connection with slope differences of vegetation increases greatly at high altitudes and latitudes. In addition he concluded that differences between the vegetation of the north and south slopes are due to a group of conditions initiated by the differences in insolation and soil temperatures existing on them.

In southwestern Texas, Cottle (1932) attributed the marked differences in the vegetation on north and south slopes of mountains to the less favorable environmental conditions existing on the south. He reported the evaporation rate to be 24-44% higher, soil temperature 10-20°F higher at the two-inch level, and much higher at a depth of 12 inches. Humidity was 5-11% lower and wind velocity much greater. Vegetative cover was less than ½ as great and production of dry matter about 1/20 of that on the north. He pointed out that several factors interact to produce these conditions, with the water relation being the controlling factors.

In central Indiana Potzger (1935), found topography to be a controlling factor of forest types. He reported a mixed hardwood forest with beech-maple tendencies constituting the climax on north-facing slopes whereas oak-hickory predominated the subclimax forest on south-facing slopes. In northern Idaho, Parker (1952) also found topography to be a controlling factor of forest types. He reported *Abies grandis* and *Thuja plicata* to be common on northern exposures with *Pinus ponderosa* and *Pseudotsuga menziesii* common on south-facing slopes.

Aikman and Smelser (1938) investigated the influence of slope exposure on natural vegetation and cultivated fields in Iowa. In this study, soil temperatures showed slightly less variation between the communities than did air temperatures and also showed less daily fluctuations.

In North Dakota, Dix (1958) suggested that the most important single factor in determining the kinds and numbers of plants which occupy a site is soil moisture, with other variables, such as exposure, slope and topography important only in so far as they influence it.

Investigations in central Indiana by Potzger (1939) suggested differences in wind, insolation, temperature and humus content of the soil are cases for differences in available soil moisture on north and south slopes. He reported that surface soils on northern slopes had 30% more moisture than southern exposures. In northern Idaho, Daubenmire and Slipp (1943) pointed out that the relative dryness which is evident on the south slopes is due primarily to the scanty snow accumulation operating together with high surface temperatures.

Platt (1951) in an ecological study of the Appalachian shale barrens, reported that general bareness becomes more pronounced with increase in slope. He described barren slopes with pH ranges of 4.5-5.5 whereas vegetated exposures had ranges of 4.0-5.0.

Oosting (1942) found a great diversity of species on north and south exposures along stream bluffs in North Carolina. He found north-facing bluffs to be quite mesic and usually supporting a variety of vegetation among which were typical of cooler latitudes and altitudes. Shanks and Norris (1950) in studying north and south-facing slopes in Tennessee reported certain species to be entirely restricted to one slope or the other. This was attributed to differences in environmental conditions on the two slopes. In addition they found no one species dominant on both slopes. A study of the vegetation and microclimates on the north and south-facing slopes of a ridge in central New Jersey was made by Cantlon (1953). He found the structure composition of the vegetation on the two slopes quite different. Furthermore, few species were found to be absolutely exclusive to either slope, rather, the differences between the slopes were due to the shifting in the relative density, frequency and cover of the species.

Miller and Buell (1956) described pronounced differences between vegetation on contrasting northeast and northwest-facing slopes in Itasca Park, Minnesota. They found the greater proportion of the more protected life forms occurring on the southwest-facing slopes as compared to northeast-facing slopes. They concluded that the greater number of freeze-thaw cycles, especially during the spring, shorter duration of snow cover, hot afternoon summer sun and drying winds from the west all make the southwest a more difficult environment to live on. Cooper (1961) described the relationships between microclimates and plant life forms in southeastern Michigan. He reported that the microclimates of the slopes varied from a cool moist (mesic) extreme at the bottom of the north slopes to a warm dry (xeric) extreme at the top of the south slopes. In summarizing his data, he found a greater phanerophyte cover on the north slopes in contrast to the hemicryptophyte cover on the southern exposure.

Klemmedson (1964) studied the effects of exposure and slope position on soils in south-central Idaho. He found the average nitrogen content of the 0-to-10cm. layer for all north slope sites to be 56% higher than southern exposure sites. Organic carbon was 61% higher on north exposures. In addition he reported the gravel content of the soil increases with distance downslope on south exposures, whereas the reverse is true of north exposures.

Coupland (1950), in studying the ecology of the mixed grass prairie of Canada found the Stipa-Bouteloua faciation to be the most extensive. He described this faciation, where the land was hilly, to be typically limited to the lower slopes in the dry part of the brown soil zone, to intermediate slopes in the more moist part of the brown soil zone and to upper slopes and knolls in parts of the dark-brown soil zone.

More recently, Ayyad and Dix (1964) measured several microenvironmental factors thought to be particularly important in determining vegetational distribution on the glacial knolls near Saskatoon, Saskatchewan. They reported a significant variation in soil temperature and soil moisture content with regard to aspect and position. They described the moisture regime as being a function of both aspect and position, while the heat regime is largely a product of aspect. They suggested that the distribution of species on slopes is controlled by moisture and heat regimes of the soil layers in contact with the vegetation. Species such as Phlox hoodii, Carex filifolia, Stipa comata and Artemisia frigida reached their highest densities on the warm dry upper south slopes; whereas Festuca scabrella, Carex obtusata and Galium boreale are among the species which obtained their optimum densities at the moist and cool lower positions of north slopes. Intermediate positions were occupied by Koleria cristata, Carex eleocharis, Stipa spartea var. curtisita and Agropyron dasystachyum.

DESCRIPTION OF STUDY AREA

Location:

The study area is located in the Upper Blackfoot Valley of northwestern Montana approximately 55 miles northeast of Missoula, Montana. Geographically the valley lies along the 47° N latitudinal meridian with an approximate 113° W longitudinal reading. The valley is orientated in an east-west direction and is bordered on the north by the southern boot of the Swan Mountain Range and on the south by the Garnet Mountain Range. It has an average elevational reading of 4100 ft. and is located within the political boundaries of Powell County.

Sites were concentrated primarily on the southeastern section of the Blackfoot-Clearwater Fish and Game Range which is located approximately six miles west of Ovando, Montana. These sites encompass an area of about 2½ square miles. Two other locations were selected in the valley. One was adjoining the eastern boundary of the Fish and Game Range and the other was located one mile southwest of Ovando.

Geology:

The glacial history of the Upper Blackfoot Valley is illustrated by the presence of numerous glacial moraines. These moraines were formed during the Wisconsin Age of the Pleistocene when several ice sheets from Glacier National Park extended southward into the Blackfoot Valley. The glacier of interest to this study occupied the mountain gorges of Monture Creek and its tributaries north of Ovando (Alden, 1953). A strongly defined knob and kettle topography resulted from this glacier, especially one to three miles northwest of Ovando. These morainal mounds, bordered on the west by an outwash plain, are also evident five to six miles west of Ovando (Fig. 1). Captain Lewis in 1806, described this valley of irregularly scattered mounds as "The Prairie of the Knobs" (Coues, 1965).

Description of Mounds:

The morainal mounds in the Upper Blackfoot Valley demonstrate a strong rolling topography with the knobs composed of erratic boulders and stones of various sizes. Many of the mounds are unsymmetrical with the varied cardinal exposures (eg. North, South etc.) achieving the following average degrees of slope: north 25.4°, east 18.8°, west 20.2° and south 17.8°. Excessive snow accumulation on the north slopes, therefore initiation conditions for greater erosive action due to melting snow, may be a possible explanation for the sharper incline on the northern exposures (Beaty, 1962). All of the mounds within the study area appeared to reach approximately the same height.

Soils may be classified, according to the soil survey staff's classification scheme (1960), as mollic epipedons or within the chestnut and chernozem groups. The boulders and stones present throughout the mound consisted of mainly quartzite, red and green argillite, diorite, and limestone (Alden, 1953). These boulders decreased in size and number from the crest to the base of the mound, where they were almost absent near the surface at least.

Climate:

Climatological records are maintained in the Blackfoot Valley at two locations. One station is located on the Blackfoot-Clearwater Fish and Game Range, whereas recordings for the second station date back almost

Figure 1. Strongly defined knob and kettle topography of the Upper Blackfoot Valley six miles west of Ovando, Montana.

50 years. In comparing the data for these two stations, there appears to be an avarage difference of three inches in annual average precipitation, with no appreciable difference in the temperature (U.S. Weather Bureau).

Explanation for this difference may be found in the location of these two stations. Boyd Mountain is situated within a ½ mile from the station on the Fish and Game Range whereas the second station is located approximately seven miles southeast of this point. Assuming the absence of mechanical errors, the difference may be due to a rain shadow caused by Boyd Mountain, therefore influencing the precipitation recordings on the Fish and Game Range. Taking this into account, climatological data have been compiled from the station located one mile southwest of Ovando. Average annual precipitation for the valley is approximately 16 inches with the highest peak coming in May and June. Precipitation averages indicate that these two months account for almost one-third of the total annual rainfall (U.S. Weather Bureau). Precipitation tapers off drastically through July and August reaching average minimums of below .25 inches. Average snowfall for the valley is approximately 85 inches per year, with highest recordings occurring in December through February. Although these data represent the overall climate of the Upper Blackfoot Valley, it should be strongly emphasized, however, that the microclimates of each slope exposure and slope position are unique among themselves.

Microclimatological data recorded by the author for the summer of 1965 are indicated in Tables II-VI.

METHODS AND PROCEDURES

Field Methods:

During the months of June, July and August of 1965 a vegetative-microenvironmental study was conducted on a series of eight different exposures as well as crests occupying the morainal mounds of the Blackfoot Valley. The eight exposures consisted of four representing the cardinal directions and the remaining four the intermediate positions. In addition to the vegetation on these morainal mounds a partial vegetative species presence list was compiled for the Blackfoot Valley (Table I).

As in all studies of this nature, the location of suitable stands presented a problem. Undisturbed sites were not available, however an area which had been relatively free from grazing for a period exceeding 12 years was located on the Fish and Game Range. Therefore throughout the remainder of this paper it is extremely important to keep in mind the terminology used in reference to "grazed" and "ungrazed" sites.

Since the morainal mounds on the "ungrazed" Fish and Game Range were unsymetrical, therefore not lending to eight suitable expósures, numerous mounds were sampled using only those exposures which met pre-determined criteria. These criteria consisted of each slope having only one true exposure with approximately the same distance from base to crest. Slope exposure was determined by a hand compass and the degree of slope was measured with an Abney level. A total of 45 exposures including five crests were selected and sampled; i.e. five north, five northeast etc., making up five imaginary mounds each displaying a crest and the eight prescribed exposures.

In contrast to the "ungrazed" stands, three other mounds under heavy grazing conditions were selected. On each of these three mounds all eight exposures as well as crests were suitable for sampling. Similar sampling techniques were used in sampling the grazed and "ungrazed" sites.

A heavy wire frame (20X50 cm.) quadrat was employed in obtaining both frequency and canopy-coverage of the species occurring in the selected stands. Employment of Daubenmire's canopy-coverage method was generally made (1959).

Each of the 64 slopes, making up eight morainal mounds, was divided into an upper and lower position, therefore making a total of 136 stands including the crests. Two diagonal transects forming an 'X' were employed on each slope with the point of intersection used as the boundary for the upper and lower stands. The upper two segments of the diagonals were used in sampling the upper stands and the lower two used in sampling the lower stands. Each of the four segments consisted of 10 quadrats placed 250 cm. apart or five times the length of one quadrat. Therefore each upper and lower stand was sampled with 20 quadrats.

Difficulty was encountered in selecting suitable crest sites for sampling, because in many cases the actual crest itself was represented, if at all, by a very narrow ridge. Therefore with such a limited area, it would be possible to sample crests which include many exposures. Careful selection of crests may have eliminated this problem somewhat, however, complete elimination was impossible.

Techniques similar to those used on the slopes were employed in sampling the crests. Two diagonal transects were again utilized forming an 'X' across the crest. Each diagonal consisted of 10 quadrats placed 50 cm. apart.

Species occurring in each quadrat were recorded on field data sheets. Canopy-coverage of each species occurring in the area of the quadrat at each station was estimated on the basis of six classes (Daubenmire, 1959) as indicated below:

Class 1 -- up to 5% coverage

Class 2 -- between 5% and 25% coverage

Class 3 -- between 25% and 50% coverage

Class 4 -- between 50% and 75% coverage

Class 5 -- between 75% and 95% coverage

Class 6 -- between 95% and 100% coverage

In summarizing the canopy-coverage classes the mid-point of each class was used. Class summaries were totaled and divided by 20 to obtain the average per cent canopy-coverage in a stand for each species.

Soil moisture readings were recorded at approximately two-week intervals between June and August; these values were calculated on a dry weight basis (Table V and VI). One day in each month was selected to measure soil temperature. This was done at two hour intervals, above and below the surface on the crest and eight exposures. Measurements were taken at the mid-point on each slope at a depth of four inches for soil temperatures and 1 mm. for surface temperatures. Hourly temperature fluctuations on a given day are illustrated in Tables II-IV.

Soil samples were collected at each of the 136 stands and placed in paper bags. Upon allowing the soils to air dry they were then sieved through a 2 mm. screen. A portion of each sample was sent to the

University of Wisconsin Soils Testing Laboratory where the following procedures were used to analyze the samples (R.A. Wiese, Personal Communication):

1. Calcium and magnesium were extracted with 1N NH_4OAc and determined flame photometrically using the Coleman Model 21.

2. Phosphorus and potassium were both extracted with Bray P_1 solution. Phosphorus was determined colorimetrically using ammonium molybdate to develop color. Potassium was determined by flame photometric procedures.

3. Organic matter was determined by modified wet digestion using a NaCr O - H_2SO_4 mixture. Final analysis was made colorimetrically for the chromate color.

4. Nitrate was extracted with water and determined semi-quantitatively with the visual brucine-yellow color.

5. Ammonium was extracted with 0.3N HCl and determined semi-quantitatively using visual color developed with Nessler's reagent.

The remaining portion of each soil sample was retained in the plant ecology laboratory where further tests were completed.

Water holding capacity and permanent wilting percentage were measured in the soils laboratory of the University of Montana School of Forestry. Available soil moisture was determined by subtracting the permanent wilting percentage from the water holding capacity.

Metal cylinders, 2.5 inches in diameter, were used in the field to test the difference in the ability of the soil to absorb water on the crests and four cardinal exposures on disturbed and "undisturbed" sites. After careful selection of a position on an exposure, three successive 125 ml. increments of water were added. The time for each increment to be absorbed was recorded. Average measurements for each slope are indicated in the results.

Laboratory Treatment of Data:

The field data sheets were transcribed onto laboratory analysis forms adapted for this study. Frequency percentages for each species occurring in the quadrats were tabulated from the field data sheets. Files containing summarized data for each exposure along with the crests were developed. Separate files with summarized microenvironmental data were also used.

Target diagrams, adapted from those used by Ayyad and Dix (1964), were utilized to show species frequency values for the upper and lower stands on each exposure as well as the crests. These target diagrams were constructed with the inner circle representing the crest and the intermediate and outer circles representing respectively the upper and lower position on each exposure. Eight lines were drawn through the outer two circles, thus delimiting the four cardinal exposures (N,S,E,W) and the remaining four representing the intermediate exposures (NE, SE, NW, SW). Thus a target diagram graphically represents a mound with 17 stands; the crest, eight upper slope stands and eight lower slope stands.

Frequency values for individual species on the five theoretical mounds were synthesized into one target diagram (Figs. 2-7). In addition, eight paired target diagrams were constructed to compare certain disturbance indicator species for grazed and "ungrazed" conditions (Fig. 8-9).

The plants encountered in each stand and in general collections were pressed for later identification. The nomenclature follows that of Hitchcock and Chase (1950) for the Gramineae, and Hitchcock et. al. (1955, 1959, 1961, 1964) for the Dicotyledoneae. The rest of the Monocotyledoneae, Equisetaceae, and Polypodiaceae were determined according to the concepts of either Davis (1952) or Moss (1959).

RESULTS

Because of the diversity of microenvironmental data recorded during the study, variations in each factor will be discussed separately, first under "undisturbed" conditions and finally under disturbed conditions. The results will also include a summary of distributional patterns of representative species on the mounds.

Soil Moisture:

Soil moisture data were taken throughout the summer months at approximately two week intervals on each of the 17 designated mound positions (Tables V and VI). Measurements of soil moisture on the crest and the four cardinal exposures began three weeks earlier (May 22) than recordings on the intermediate exposures (June 11).

The overall abundance of soil moisture during spring gradually diminishes through the summer months with the exception of samples taken on June 20, which indicated a noticeable overall increase in soil moisture content. Assuming there were no sampling errors involved, this increase in soil moisture may be correlated with the relatively high amount of precipitation (1.29 inches) which fell between the two sampling dates.

Lower slope positions consistantly maintained a higher soil moisture content than adjoining upper positions throughout the entire study period. Lower positions on the four cardinal exposures maintained an overall average soil moisture content of 15.5% in contrast to 11.0% for the adjoining upper positions. These figures correspond with the available soil moisture[1.] averages, with relative values reaching 17.4% and 15.2% on the lower and upper positions respectively (Table IX). Varying amounts of runoff water lost or received may account for soil moisture differences on adjoining upper and lower positions. Greater drainage and wind velocities encountered by upper positions cause lower soil moisture values when compared to adjacent lower positions. Differences in density of vegetation cover at various slope positions may also influence the moisture content of the soil (Ayyad and Dix, 1964).

In considering all 17 positions on a mound throughout the summer, the lower northeast site was found to be the most mesic with an overall average soil moisture content of 20.3%, while the crest was the driest site with an average soil moisture content of only 7.2%. Based on summer overall averages of 1965, a soil moisture gradient from moist to dry may be constructed involving the nine following positions:

Position	Average Absolute Soil Moisture %
North Lower	18.8%
East Lower	15.8%
West Lower	14.4%
North Upper	13.6%
South Lower	13.2%
East Upper	11.4%
West Upper	9.7%
South Upper	9.4%
Crest	7.2%

1. Available soil moisture is expressed as the difference between the moisture contents at field capacity and wilting point (Platt and Griffiths, 1965).

Overall averages indicate the lower north position has the highest available soil moisture value (2.69) in contrast to the crest, which has the smallest amount of available soil moisture (1.22) (Table IX).

Soil and Surface Temperatures:

Due to the type of equipment employed, soil and surface temperatures on various exposures were recorded only once a month during the period of study (Tables II-IV). In addition, only immediate surface temperatures were recorded since the difference in air temperature between the exposures is more marked near the surface than at higher levels (Cantlon, 1953). With these limitations in mind, it must be emphasized that the present values are useful only on a comparative basis.

Both soil and surface values increased on all exposures from June through August. The greatest monthly temperature increase for the three separate dates was between June and July, with temperatures in August increasing only slightly over July (Tables III and IV).

Soil, being a poor conductor of heat (Billings 1956), demonstrated lower temperatures and less hourly fluctuations than temperatures taken at the immediate surface. Average fluctuations for soil and surface temperatures on north exposures were 6.4°C and 12.3°C respectively, in contrast to 13.1°C and 21.0°C for soil and surface temperatures on south exposures. These values indicate the greater fluctuations and higher temperatures existing on the southern exposures.

Temperature patterns throughout a typical day may be illustrated for various mound positions. High morning temperatures were obtained on the east and southeast positions, whereas afternoon highs were recorded on the south and southwest exposures. Higher average temperatures were found to exist on the southeast position rather than on the expected southwest. Similar occurrences were reported by Geiger (1965) in the Alps. He found that due to a general accumulation of cumulus clouds in the afternoon, more radiation was received by the east and southeast exposures in the forenoon when cloud-cover was at a minimum. Similar phenomena may have occurred in this study. Crest temperatures remained high throughout the entire day on 6/21, 7/14 and 8/9 with surface temperatures averaging 29.8°C, 34.2°C and 42.5° for the respective three dates. As expected, coolest temperatures were found on the northern exposures, particularly the northwest.

Based on the average recordings for the three summer dates, a surface and soil temperature gradient may be demonstrated for the cardinal exposures.

Slope	Average Soil Temperature	Average Surface Temperature
North	17.8°C	24.0°C
West	22.5°C	29.9°C
East	23.8°C	33.1°C
South	24.4°C	31.7°C
Crest	26.8°C	35.5°C

As the results indicate, average surface temperatures on the east slopes were higher than southern exposures, whereas the reverse was true for soil temperatures.

Soil Analyses:

The results of the soil analyses represent guide lines or indications of respective fertility levels. It is realized that the methods employed are not sufficiently precise for a characterization study of these soils. The methods used are of the type which lend themselves to rapid analysis and give information which is accurate enough for interpretative purposes.

In the results, organic matter is expressed in tons per acre, whereas the other nutrients (NH_4, NO_3, P, K, Ca, Mg) are measured in pounds per acre (Tables VII and VIII). The average organic level obtained on the upper positions was 39.7 tons per acre in contrast to 56.2 tons per acre on adjacent lower positions. Organic matter was characteristically higher on northern (N, NW, NE) exposures than on southern (S, SE, SW) slopes. Organic levels averaged 39.7 tons per acre and 56.2 tons per acre on upper and lower northern positions respectively in contrast to 30.0 tons per acre and 48.7 tons per acre on the upper and lower southern exposures. Differences in organic matter levels can be attributed to several factors, (1) erosive loss of the A horizon on upper slopes, therefore contributing to the thickened epipedons at the lower levels, (2) the lower positions develop a more mesic microclimate, which in turn produces more biomass and therefore more raw material for conversion into humus. The conversion to humus from raw plant material is stimulated by the more mesic conditions (Eyre, 1963).

Lower positions of each exposure were found to have higher levels of exchangeable cations in contrast to adjacent upper sites (Tables VII and VIII). High levels of exchangeable cations on the lower positions may be attributed to several factors, (1) continued deposition of cations through runoff from upper to lower regions, (2) greater amounts of organic matter (25% increase) on lower positions, therefore increasing the total exchangeable cation capacity.

Unlike the other cations, calcium and magnesium were maintained at higher levels on the upper positions (Tables VII and VIII). According to Russell (1956), calcium and magnesium are held much tighter to clay than most other cations. In addition, less infiltration of water due to excessive loss of moisture through runoff occurs on the upper positions. Therefore the tighter bond between clay and cation along with limited leaching and weathering on upper positions accounts for the higher levels of the calcium and magnesium on the upper positions.

Noticeably high levels of NH_4 were recorded for the northwest positions in comparison to other exposures (Tables VII and VIII). An adequate explanation for this is not available unless it may be due to a mechanical error in the analysis.

Upper positions characteristically maintained higher average pH values (6.2) in contrast to values (6.0) of lower adjoining positions. The pH levels were generally higher (6.4) on the drier sites (upper S, SW, SE) than on the more mesic (5.9) sites (lower N, NW, NE). More intensive soil development along with greater leaching and weathering may account for lower pH values on these more mesic sites.

Vegetational Analysis:

Nearly 100 species were encountered on the morainal mounds, however frequency values for only 48 representative species are plotted and discussed on the target diagrams. Frequency values are grouped into five classes (1-20%, 21-40%, etc.), represented on the target diagrams by five different sized circles ranging from an enclosed circle, indicating the smallest class to the largest circle representing the largest frequency class. Examples of ubiquitous species and species displaying limitations to one or several exposures are illustrated.

Ubiquitous species have wide ranges of distribution in relation to exposure, however generally showing a gradual increase in frequency values towards a maximum on one or two exposures. Such species are evidently able to tolerate the wide extremes of conditions present on these mounds, ranging from the extremely hot, dry sites (crests) to the cooler mesic positions (lower NE). Achillea millefolium, Agropyron spicatum, Antennaria umbrinella, Arenaria capillaris (Fig. 2), Carex filifolia, Chrysopsis villosa (Fig. 3), Eriogonum heracleoides, Festuca idahoensis (Fig. 4), Koleria cristata, Lomatium macrocarpum (Fig. 5), Lupinus spp. (Fig. 6), and Tragopogon dubius (Fig. 7) demonstrate this type of ubiquitous distribution pattern.

Frequency values for Agropyron spicatum (Fig.2) and Chrysopsis villosa (Fig. 3) increase and reach a maximum on south exposures, whereas Antennaria umbrinella and Arenaria capillaris (Fig. 2) increase towards a maximum on western (NW, SW, W) slopes. Achillea millefolium shows a general increase toward the northern, more mesic exposures. Carex filifolia (Fig. 3), Eriogonum heracleoides (Fig. 4), Lomatium macrocarpum (Fig. 5) and Tragopogon dubius (Fig. 7) demonstrate ubiquitous species which maintain very low frequency values throughout the mound. In contrast, Lupinus spp. (Fig. 6) generally maintains very high frequency values on all positions, which may have resulted from combining all individuals under one taxon.

Distributional patterns of ubiquitous species also demonstrate gradients with respect to position. Achillea millefolium (Fig. 2) and Lupinus spp. (Fig. 6) maintain higher average frequencies on the lower, more mesic positions of each exposure in contrast to the upper adjoining positions. Values for Achillea form a gradient, gradually decreasing from base to crest becoming almost absent on the crests. Antennaria umbrinella, Arenaria capillaris (Fig. 2), Chrysopsis villosa (Fig. 3) and Koleria cristata (Fig. 5) demonstrate the opposite effect with frequency values increasing from base to crest. Values for Chrysopsis form a gradient, gradually increasing from base to crest reaching maximum values on the crests. Agropyron spicatum (Fig. 2) reveals little preference for position on any given exposure.

Collinsia parviflora (Fig. 3), Phacelia hastata (Fig. 6) and Sedum stenopetalum (Fig. 7) illustrate species which reveal an ubiquitous nature, but are completely absent on one exposure. Collinsia is most abundant on the north and northeast exposures, but is completely absent on the crests and east exposures; whereas Phacelia reaches its highest frequency values on the east and southeast slopes, but does not occur on the crest and west exposures. Sedum reaches its highest frequency values on the crest and west slopes, and is completely absent on the northeast exposures. Assuming the absence of sampling error, these three species are absent from these exposures due to biological or environmental interrelations. Species reaching highest frequency values on exposures where Collinsia, Phacelia and Sedum are absent may have restricted their presence on these slopes.

Festuca idahoensis (Fig. 4) illustrates a shifting of frequency values on upper and lower positions with respect to different moisture conditions. On the more mesic northern exposures, higher frequency values are obtained on the upper positions, whereas on the more xeric south exposures, higher frequency values are revealed on the lower positions.

Species limited to several exposures on a mound represent individuals with narrow ranges of environmental tolerance. Restriction of a species to a particular exposure orientation may be due to one or several limiting factors. One must keep in mind that all environmental requirements for a given species may be satisfied and the individual may still fail as a result of biological interrelations (Odum, 1962). Mid-summer available soil moisture and soil temperatures appear to play a primary role in limiting plant distributions in the present study.

Amelanchier alnifolia, Anaphalis margaritacea (Fig. 2), Dodecatheon conjugens, Festuca scabrella, Fritillaria pudica, Galium boreale (Fig. 4), Geranium viscosissimum, Geum triflorum, Heuchera cylindrica, Hieracium albertinum, Lithospermum ruderale (Fig. 5), Penstemon procerus, Poa palustris, Potentilla arguta (Fig. 6), Potentilla gracilis, Rosa woodsii, Solidago missouriensis, Taraxacum spp. and Viola (Fig. 7) illustrate species which are limited to the more mesic northern positions. Anaphalis margaritacea (Fig. 2) and Dodecatheon conjugens (Fig. 3) illustrate species which are narrowly restricted to only the most northern exposures (N, NE, NW), with Anaphalis reaching highest frequency values on the north exposure and Dodecatheon maintaining highest values on the northwest exposure.

Species which reach highest frequency values on the northern (N, NE, NW) positions, but are present to a limited extent on the east and west positions include: Amelanchier alnifolia (Fig. 2), Geum triflorum, Heuchera cylindrica (Fig. 5), Penstemon procerus, Poa palustris, Potentilla arguta (Fig. 6) and Viola spp. (Fig. 7). Geum and Heuchera illustrate species which maintain higher frequency values on the north and northwest exposures than elsewhere. Frequency values for these two species decrease on the northeast and west positions and finally the species become absent on the drier southern slopes. Festuca scabrella, Fritillaria pudica, Galium boreale (Fig. 4), Geranium viscosissimum, Hieracium albertinum, Lithospermum ruderale (Fig. 5), Potentilla gracilis, Rosa woodsii, Solidago missouriensis, Taraxacum spp. (Fig. 7) are also somewhat restricted to the mesic positions reaching maximum frequency values on the northern (N, NW, NE) exposures. However, the diagrams reveal that these species can withstand drier environments than can the preceding species discussed, since they occur, to a very limited extent, primarily on the lower southern (S, SW, SE) positions. Species reaching highest frequency values on northern exposures and occurring to a limited degree on other exposures, generally obtain higher values on the lower positions of these exposures rather than on adjoining upper drier sites.

Lewisia rediviva (Fig. 5) and Opuntia fragilis (Fig. 6) are narrowly limited to the drier southern exposures. Lewisia occupies the crests and the upper southwest positions, whereas Opuntia occurs on the south and southeast exposures. Artemisia frigida (Fig. 2), Bromus tectorum (Fig. 3), Festuca octoflora (Fig. 4), Phlox hoodii, Plantago patagonica (Fig. 6) and Stipa comata (Fig. 7) represent species which reach highest frequency values on the southern (S, SW, SE) slopes, but are present to a limited degree on the east and west positions. Bromus tectorum (Fig. 3) and Festuca octoflora (Fig. 4) reach higher frequency values on the lower southern positions, whereas Phlox hoodii and Plantago patagonica (Fig. 6) maintain higher frequency values on the upper positions. Arabis holboellii (Fig. 2), Astragalus purshii, Commandra umbellata (Fig. 3) and Eriogonum flavum (Fig. 4) represent species which reach their highest frequency values on the southern exposures (S, SW, SE), however are able to tolerate or compete to a certain extent for position on the northern (N, NW, NE) slopes.

Table XIII reveals the general pattern for a selected group of species reaching their highest frequency values on the most mesic positions, in comparison to species most abundant on the more xeric slopes. Frequency values decreasing from these optimums are also indicated for the other exposures. Criteria employed in selecting species for the table included: (1) species must be present on at least three sites, and (2) these species must attain a frequency value of 15% on at least one of these sites. Species such as Hieracium albertinum (46%) and Geranium viscosissimum (45%) reach their highest average frequency values on the northeast exposures in contrast to Chrysopsis villosa (79%) which is most abundant on the dry crests (Table XIII). Eriogonum heracleoides and Commandra umbellata reach their highest frequencies of 18.5% and 17.5% respectively on the east exposures in contrast to Arenaria capillaris (74.5%), Antennaria umbrinella (59.5%), and Phlox hoodii (30.0%) reaching their highest values on west slopes.

Balsamorhiza sagittata and Castilleja spp. (Fig. 3) represent species which possibly may merit further taxonomic or ecological study due to their ecological orientations on the morainal mounds. Assuming the absence of sampling error, Balsamorhiza and Castilleja form two distinct groups due to their absence on two given exposures. Balsamorhiza may be isolated into a mesic variant or ecotype (N, NE, E) and a xeric variant (W, SW) by the absence of this species on the northwest and south exposures. Likewise the diagrams of Castilleja spp. reveal similar isolations with this genus being absent on the northeast and south exposures, possible supplying validity for recognition of two species of Castilleja.

Festuca scabrella and Festuca octoflora (Fig. 4) illustrate species within the same genus occupying exactly opposite exposure orientations. Festuca octoflora occurs primarily on the south and southeast exposures, whereas Festuca scabrella is generally absent on these two slopes, but achieving high frequencies on the other more mesic exposures. The negative association of these two species may be due to different environmental requirements or to some type of biological anatagonism for one another.

Canopy-coverage values were estimated for species encountered on each position, however, only twenty of those contributing a major portion of the cover were tabulated (Tables X and XI).

Table XII indicates that the most mesic mound positions (lower NE) display the greatest average canopy-coverage (65.6%), while the most xeric sites (crests) have the lowest average plant cover (27.5%). Dominant species encountered on the more mesic NE exposures include Geranium viscosissimum and Festuca idahoensis with average coverage values of 6.3% and 5.9% respectively. Chrysopsis villosa and Antennaria umbrinella were dominants on the drier crest with average coverage values of 6.7% and 4.2% respectively. Although the differences are admittedly small, lower positions of each exposure average greater coverage values (48.7%) than their adjoining upper more xeric sites (46.1%). Upper and lower northern slopes (N, NW, NE) displayed average coverages of 56.0% and 60.2% respectively, while upper and lower southern exposures (S, SW, SE) averaged 34.6% and 36.4% respectively (Tables XII).

COMPARISON OF GRAZED AND "UNGRAZED" MORAINES

The following section is a similar treatment of microenvironmental measurements and vegetational analyses on disturbed sites. This phase of the investigation was conducted primarily to study distributional changes in vegetation on similar morainal mounds when influenced by grazing disturbance. In the Upper Blackfoot Valley, the convenience of selecting exposures from mounds under intensive grazing provided an excellent opportunity to compare the two conditions. Due to lack of time and equipment, a thorough comparative study of grazed and "ungrazed" conditions was impossible, however changes were observed as will be discussed in the following section.

Infiltration Rates:

Soil infiltration rates were measured on grazed and "ungrazed" exposures. Grazed positions consistently indicated a slower infiltration of water, therefore indicating greater erosion and loss of water through runoff. This is in agreement with Murray (1954), who made similar measurements for soil compaction on grazed and "ungrazed" sites elsewhere in western Montana. Average infiltration rates were consistantly higher on south exposures and lowest on east exposures on both grazed and "ungrazed" conditions. Average infiltration rates for grazed and "ungrazed" soils may be compared as follows:

Position	"Ungrazed"	Grazed
North	4:01 min.	9:43 min.
East	1:57	5:42
South	4:02	11:39
West	2:07	7:28
Crest	3:00	6:49
Average	3:01	8:16

Soil Moisture:

Periodic measurements of soil moisture corresponding with samples obtained on "ungrazed" mounds were taken on the 17 grazed mound positions. A gradual decrease in soil moisture, similar to that on "undisturbed" positions, was observed throughout the summer (Table VI). Average soil moisture content on the more mesic position (lower NE) decreased 7.8% from the first reading (7/1) to the last (8/27) as compared to 3.5% decrease on the crest. Soil moisture levels were considerably lower on the grazed positions in contrast to the "ungrazed" sites (Table VI). Differences in available moisture between grazed and "ungrazed" conditions were not consistent in any way, however, values for the grazed sites appeared to be higher than "ungrazed" areas (Table IX). This may be correlated with high levels of organic matter on grazed sites as indicated in the following section.

Soil Analyses:

Loss of chemical constituents from the soil may be due to increased grazing pressures. These losses may be correlated with the degree of erosion accompanying vegetational deterioration. Chemical analyses of the grazed soils are summarized in Table VI. The results are highly variable possibly due to several factors and therefore indicate no general trend in the loss of chemicals with increased grazing. In fact, several constituents appear to increase. This was particularly true of organic matter, where a considerable increase over "undisturbed" areas was observed (Table VIII). Similar occurrences have been recorded by Reed and Peterson (1961), and Murray (1961). They attributed this increase primarily to the types of available plants returning to the soil.

Vegetational Analysis- Grazed:

After 13 years of research in western United States, Sampson (1919) arrived at two valid conclusions (1) "The most rational and reliable way to detect overgrazing is to recognize the replacement of one type of plant cover by another", and (2) "The grazing value of the vegetative covers is essentially determined by the stage of succession." Since Sampson's work, a quantitative system of range classification, based upon individual responses of species to grazing pressures, has been devised (Weaver and Hansen, 1941). From this classification three categories were constructed which included, "Decreasers", "Increasers" and "Invaders". Decreasers are those which decrease from the percentages found in the climax. Increasers are characterized by a period of increase, after which they too may decrease. Invaders are species that enter plant communities as the climax vegetation is destroyed.

Eight paired target diagrams with three possible stands to a position

(Figs. 8 and 9) were prepared to illustrate species which increase under intensive grazing as well as those which decrease. Artemisia frigida, Bromus tectorum, Plantago patagonica and Stipa comata represent species which increase in frequency with an increase in disturbance (Fig. 8). These four species occupied the drier exposures on mounds without intensive grazing pressure. However, when compared to mounds under intensive grazing, frequency values for these species not only increased on presently occupied positions, but also appeared on the more mesic northern positions (Fig. 8). Invasion onto another position by a species is undoubtedly due to the removal of one or more limiting factors. In this case the limiting factors involved biological interrelations (Odum, 1962). Increases in abundance on a given position may result from a species being unpalatable or forming a mat-like cushion close to the ground.

Dix (1959) in studying grazing effects on the thin-soil prairies of Wisconsin, found the leaves of Artemisia frigida unpalatable to livestock, because of its aromatic and pubescent leaves. Also Plantago was undisturbed, therefore an increaser, due to its low growth forms. Similar responses may have occurred in the present study.

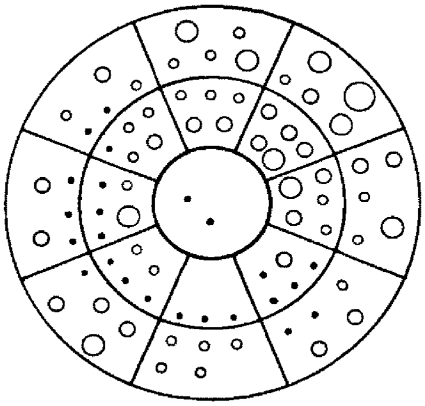
Festuca idahoensis and Geum triflorum (Fig. 9) represent species which decrease in frequency when subjected to grazing pressure. Festuca idahoensis occurred on all "undisturbed" mound positions, whereas on the grazed mounds, it disappeared on the south, southeast and east positions, being restricted primarily to the more mesic northern sites. This is in agreement with Mitchell's work (1957), where he did an ecological study of disturbed grasslands in the Missoula region. Geum triflorum shows similar decreases in frequency values on grazed areas.

Koleria cristata and Lupinus spp. represent species which occupy all mound positions on grazed and "ungrazed" areas, but illustrate a shifting of frequency values from one position to another on the two conditions (Fig. 9).

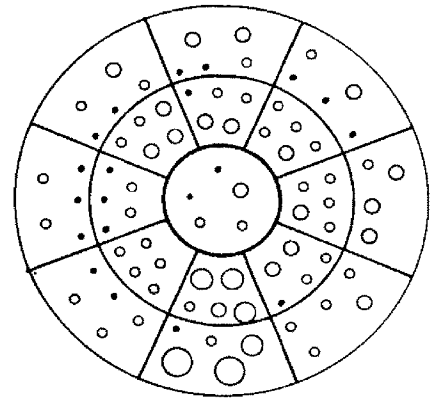
Canopy-coverage values are consistently higher on the "undisturbed" mounds in contrast to the grazed areas (Table XII). (Average canopy-coverage values for upper and lower positions on the "undisturbed" mounds are 46.1% and 48.7% respectively in contrast to 34.6% and 37.1% for the grazed mounds. Average values for the more mesic (N,NE,NW) upper and lower positions on the grazed sites are 39.1% and 43.7% in contrast to upper (46.1%) and lower (48.7%) mesic positions on "undisturbed" sites. Crest canopy-coverage values are nearly identical on the grazed sites (27.7%) and on the "undisturbed" crests (27.5%).

Dominant species encountered on the more mesic NE exposures include Antennaria umbrinella and Lupinus spp. with respective average coverage values of 3.0% and 4.5%. This indicates a shift of species dominance since Geranium viscosissimum and Festuca idahoensis occupy this mesic position on the "undisturbed" areas. Artemisia frigida, Koleria cristata and Chrysopsis villosa are dominants on the grazed crests with average coverage values of 4.1%.

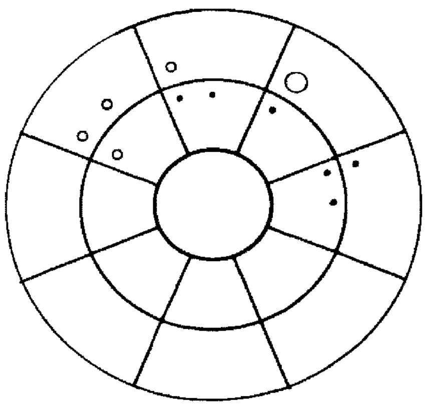
Antennaria umbrinella provides an interesting sequence or pattern in that it achieves dominance on the "undisturbed" crests as well as on grazed northeast positions, but was replaced on the disturbed crest by two new species, namely Koleria cristata and Artemisia frigida.



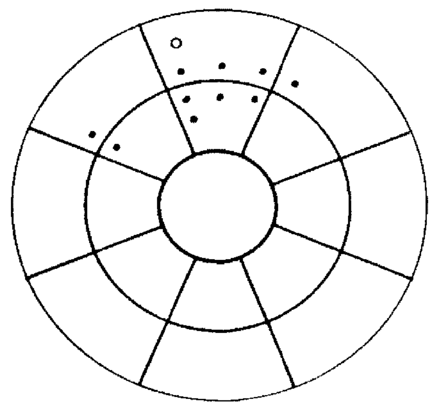
Achillea millefolium



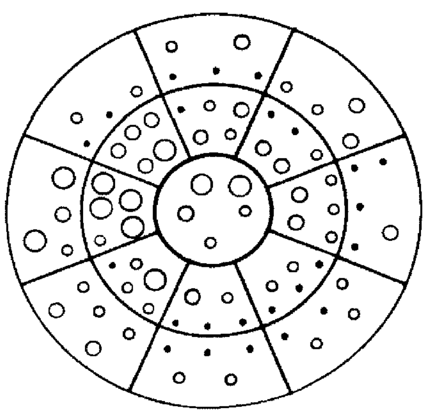
Agropyron spicatum



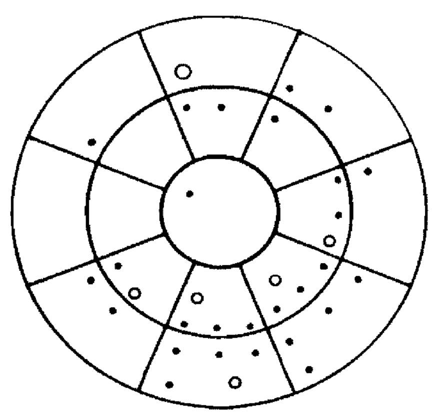
Amelanchier alnifolia



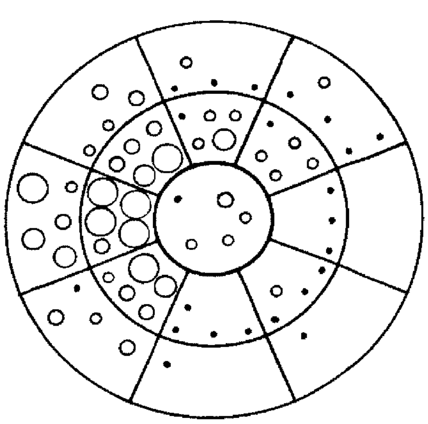
Anaphalis margaritacea



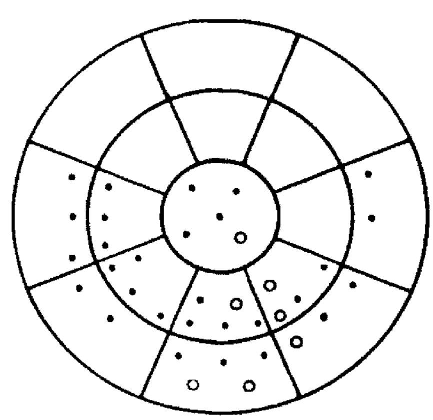
Antennaria umbrinella



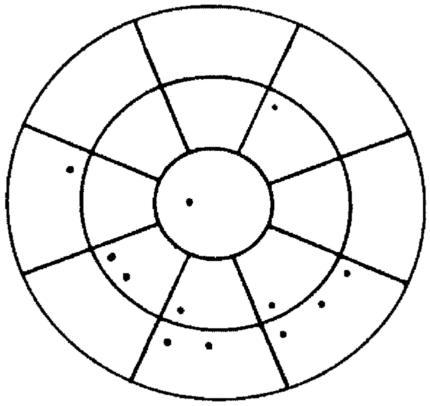
Arabis holboellii



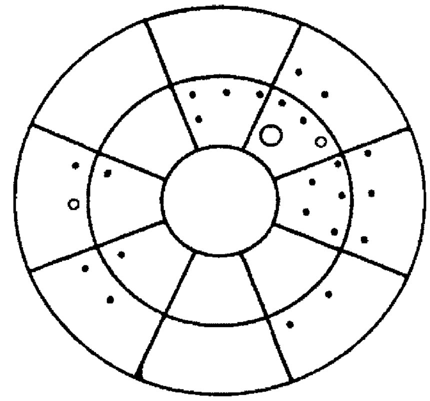
Arenaria capillaris



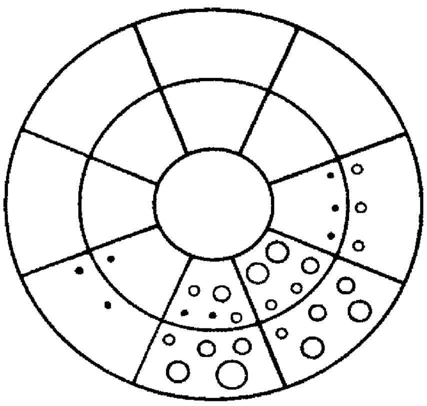
Artemisia frigida



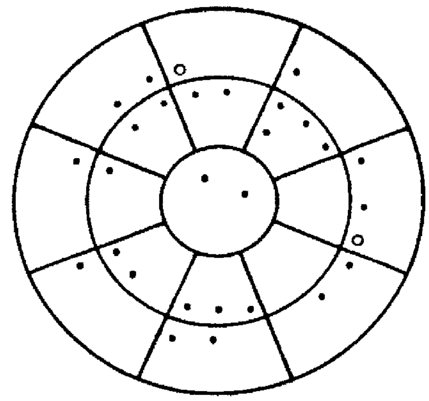
Astragalus purshii



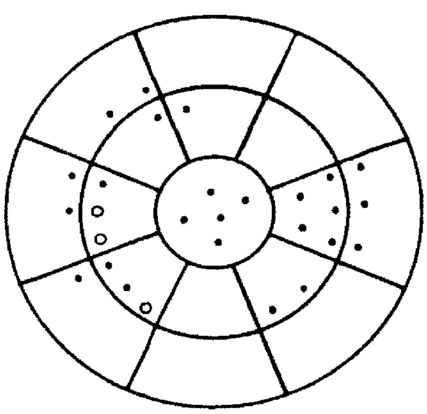
Balsamorhiza sagittata



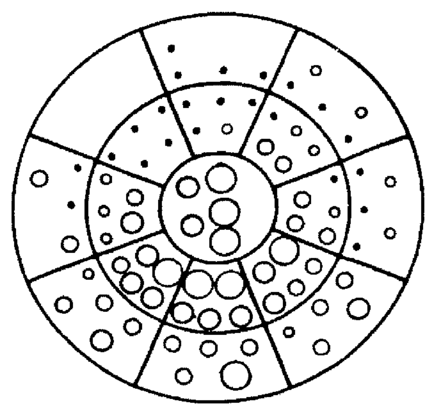
Bromus tectorum



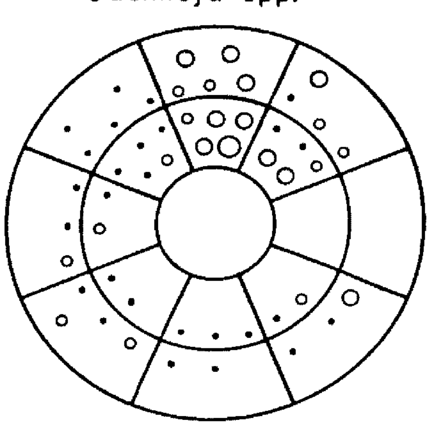
Carex filifolia



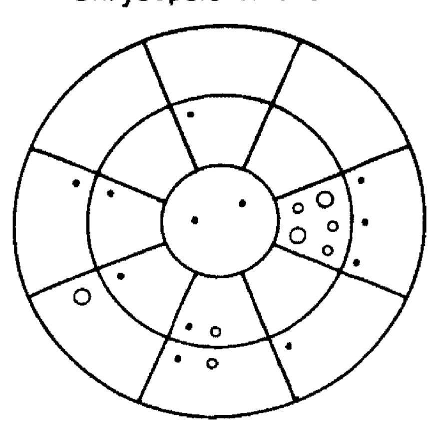
Castilleja spp.



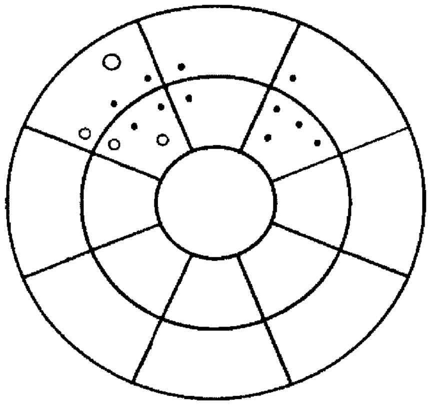
Chrysopsis villosa



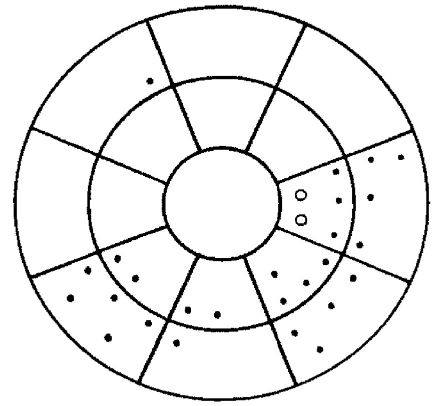
Collinsia parviflora



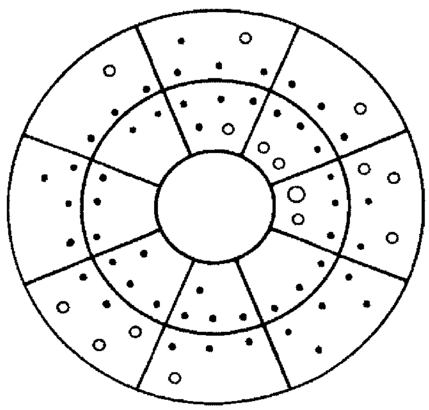
Commandra umbellata



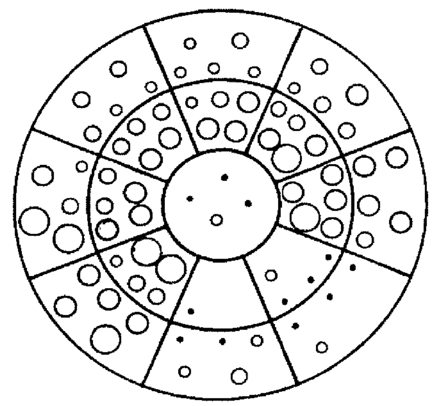
Dodecatheon conjugens



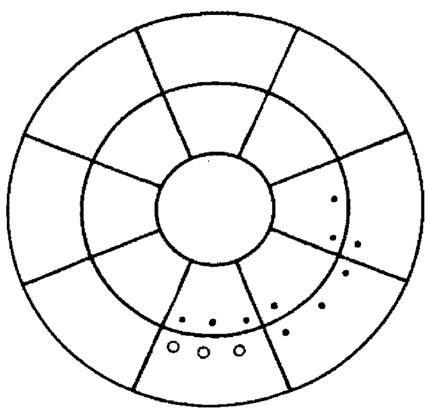
Eriogonum flavum



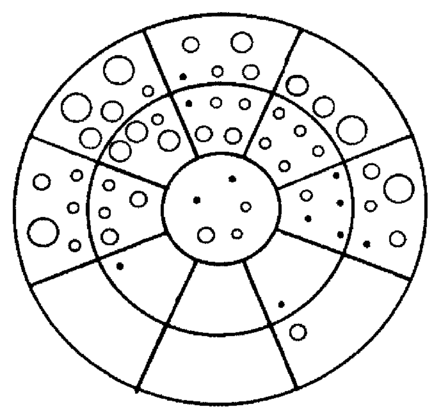
Eriogonum heracleoides



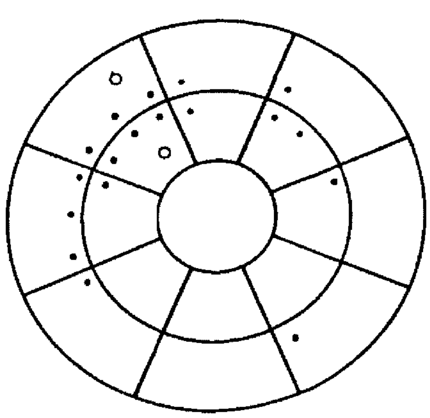
Festuca idahoensis



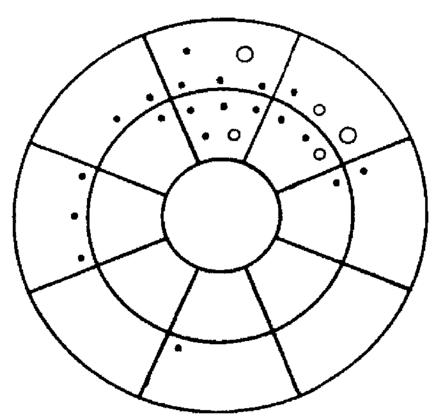
Festuca octoflora



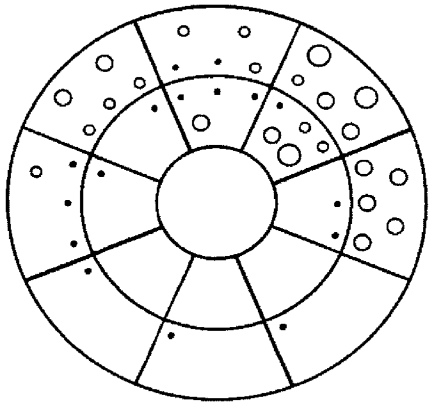
Festuca scabrella



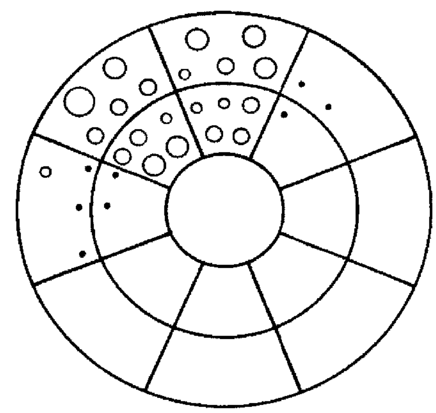
Fritillaria pudica



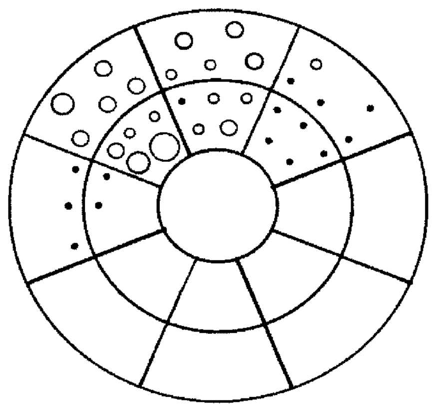
Galium boreale



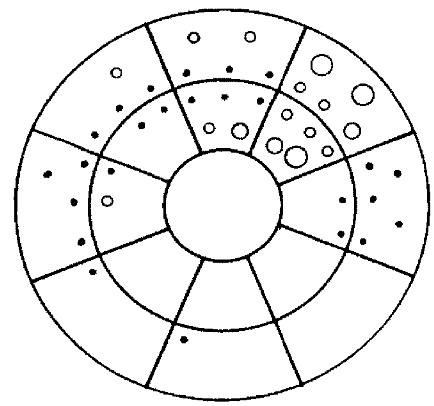
Geranium viscosissimum



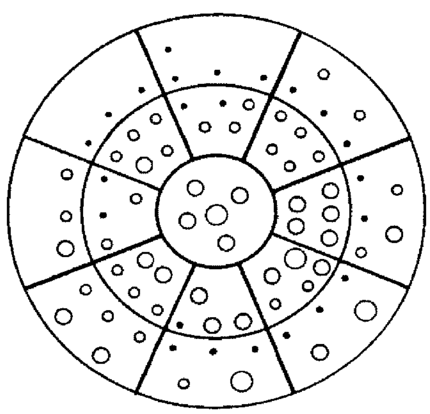
Geum triflorum



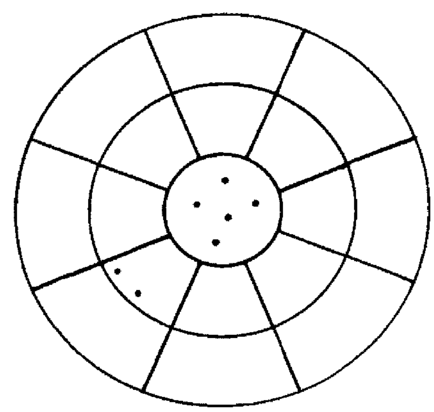
Heuchera cylindrica



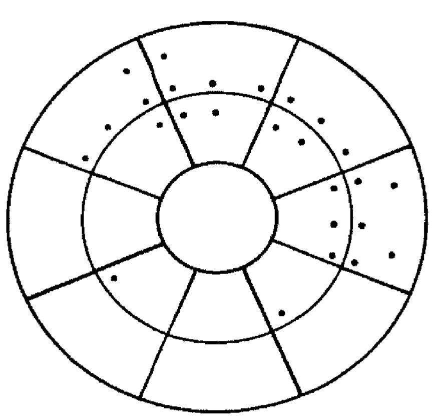
Hieracium albertinum



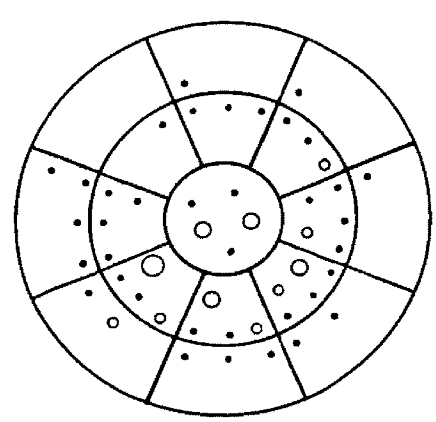
Koeleria cristata



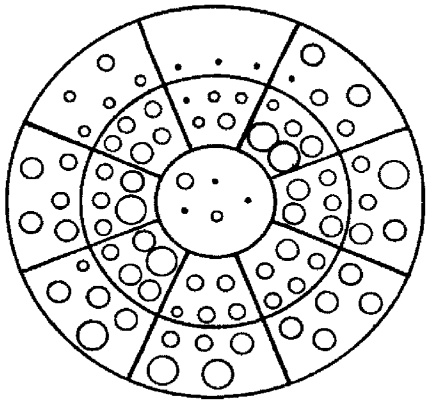
Lewisia rediviva



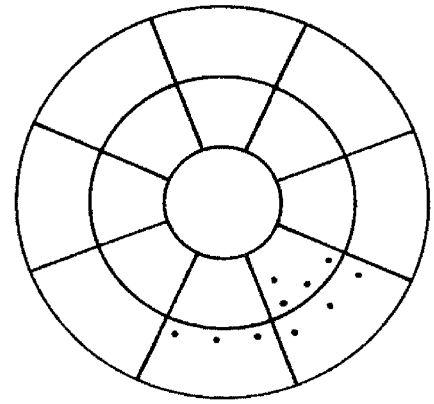
Lithospermum ruderale



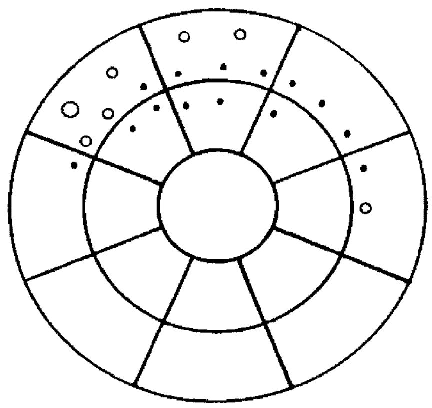
Lomatium macrocarpum



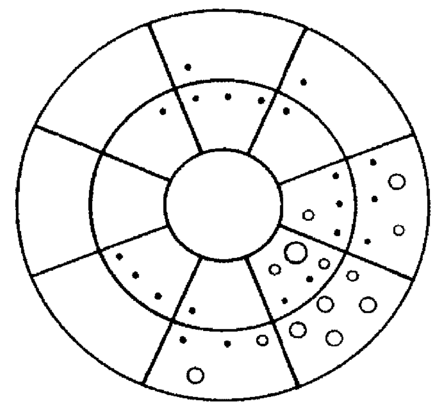
Lupinus spp.



Opuntia fragilis



Penstemon procerus



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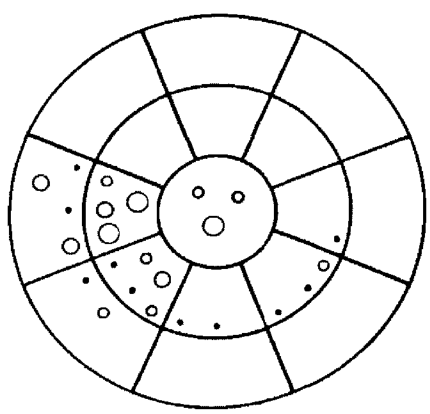

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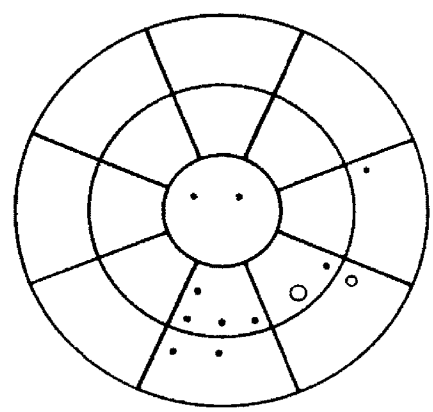
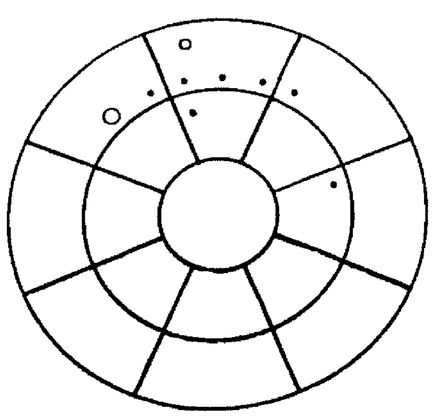
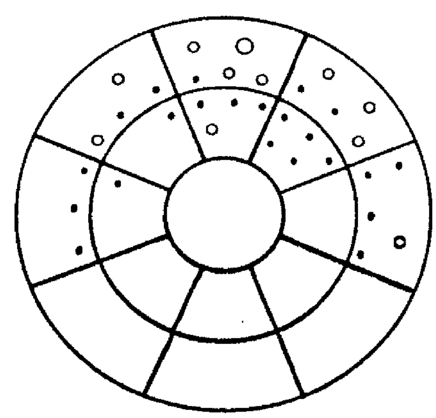


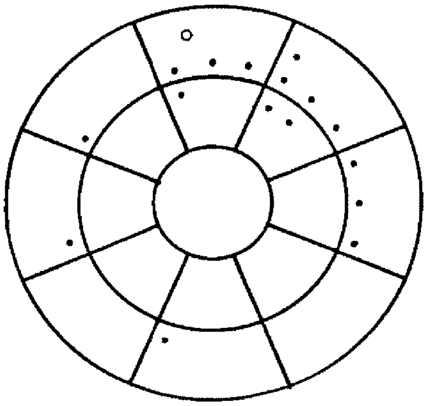
Plantago patagonica



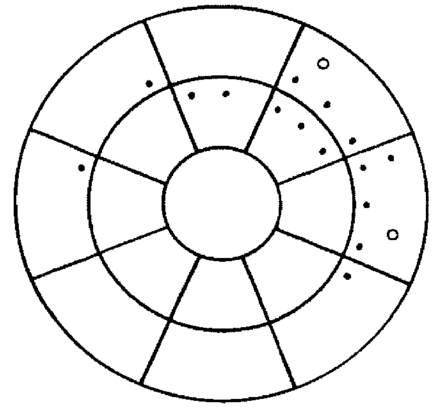
Poa palustris



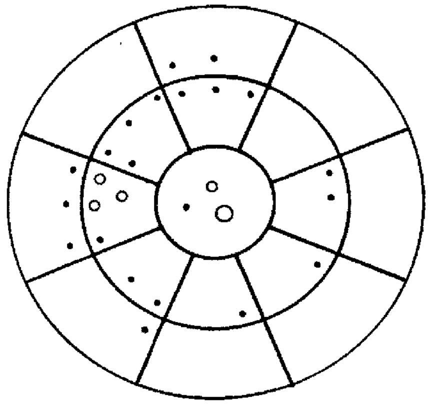
Potentilla arguta



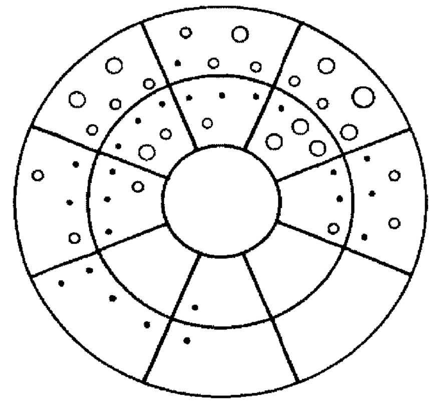
Potentilla gracilis



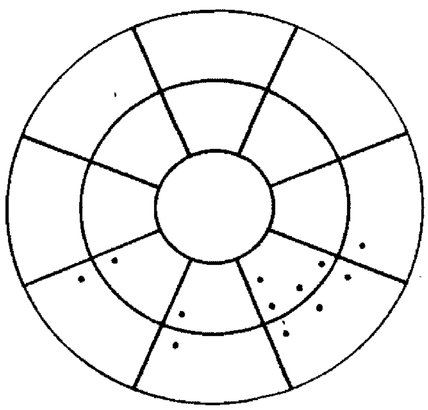
Rosa woodsii



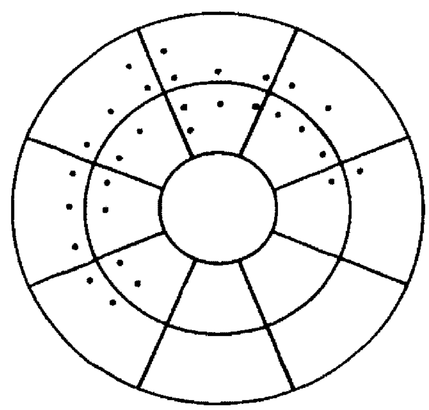
Sedum stenopetalum



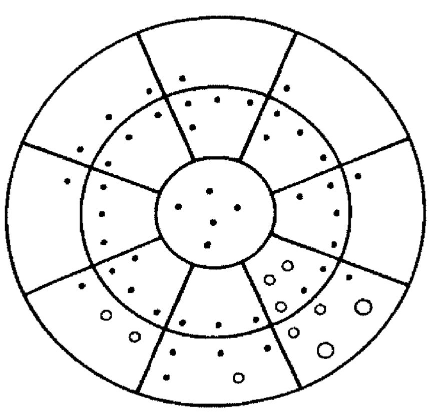
Solidago missouriensis



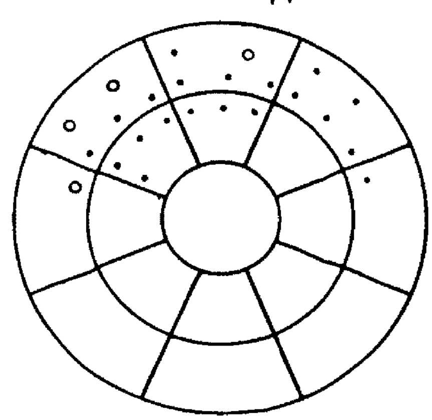
Stipa comata



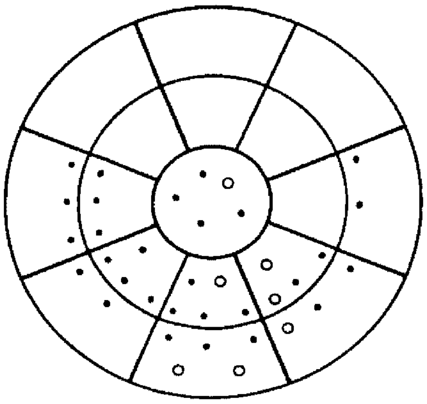
Taraxacum spp.



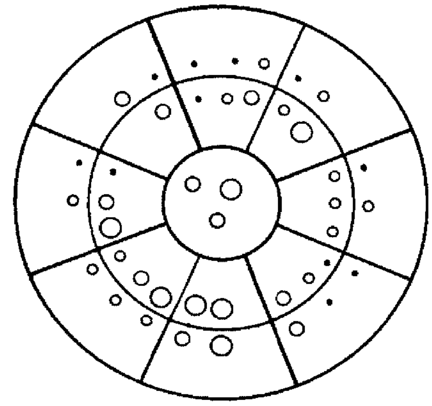
Tragopogon dubius



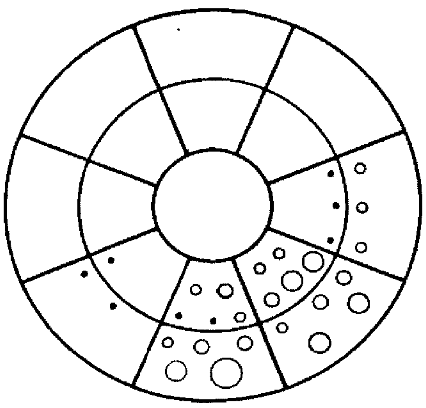
Viola spp.



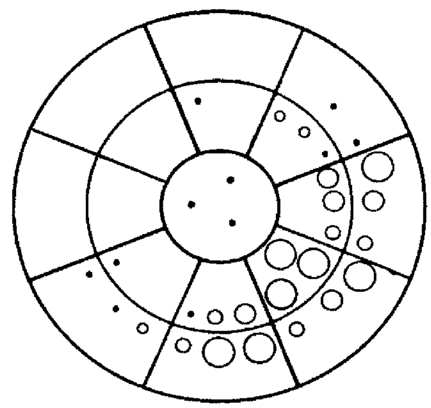
Artemisia frigida



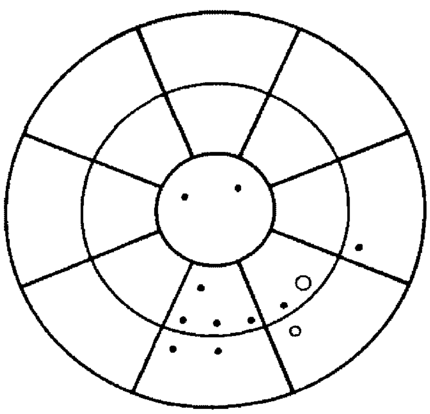
Artemisia frigida



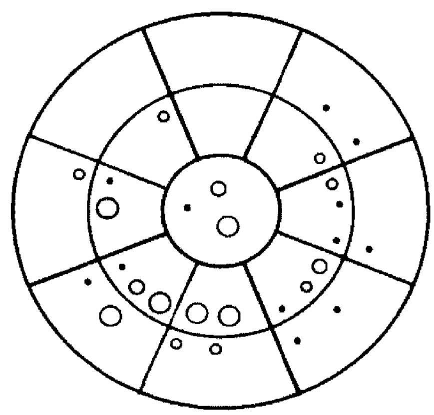
Bromus tectorum



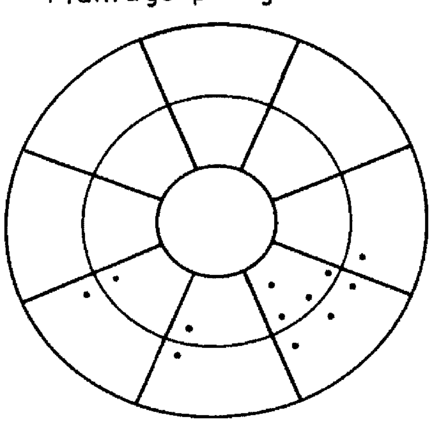
Bromus tectorum



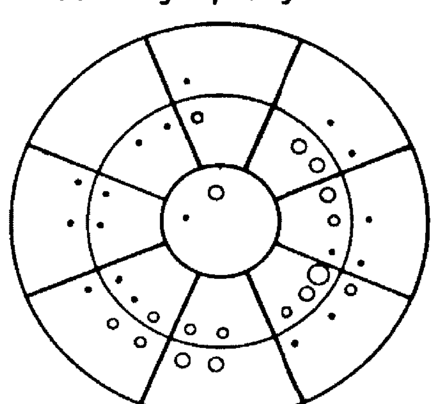
Plantago patagonica



Plantago patagonica



Stipa comata



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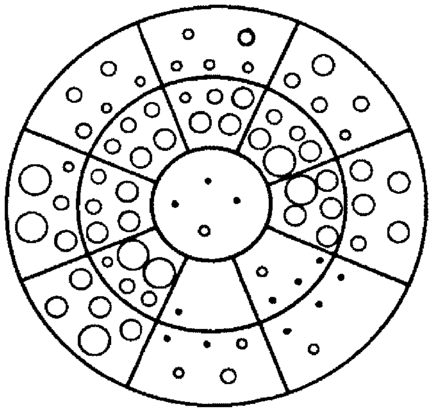
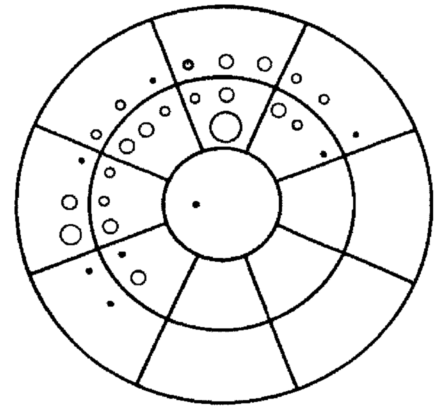
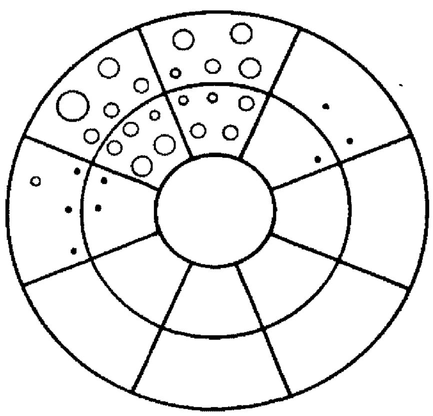


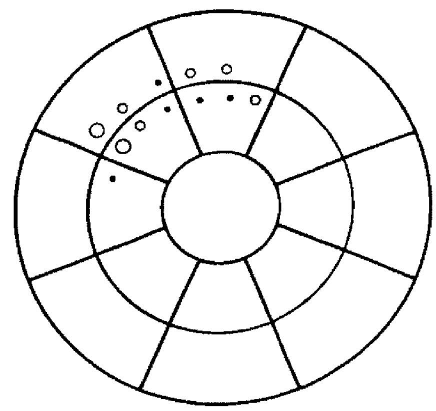
Festuca idahoensis



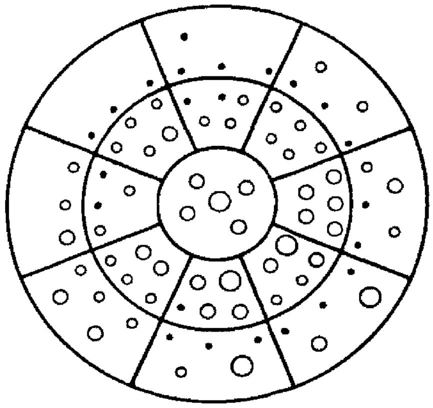
Festuca idahoensis



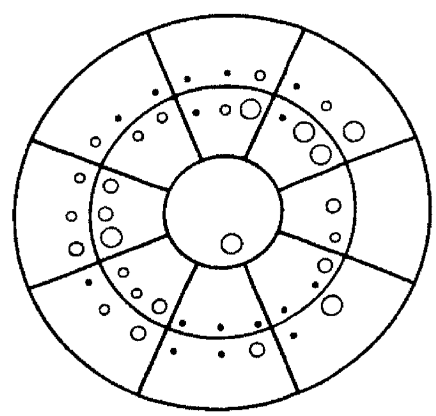
Geum triflorum



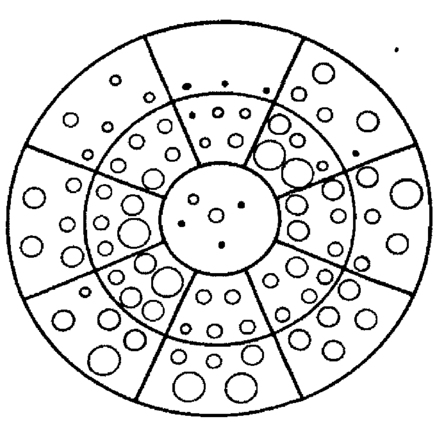
Geum triflorum



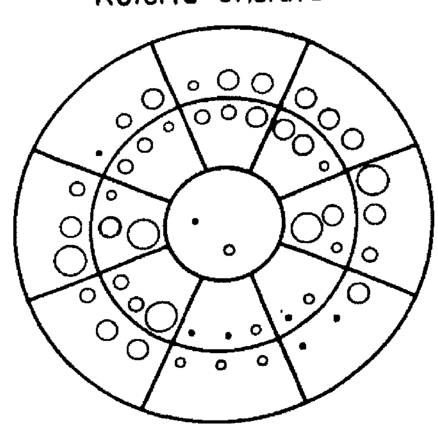
Koleria cristata



Koleria cristata



Lupinus spp.



Lupinus spp.

DISCUSSION

This study has shown that significant differences do exist in microenvironments and vegetational composition with respect to exposure and position on the morainal mounds in the Upper Blackfoot Valley. The greatest differences in microenvironmental factors are found to exist between the dry crests and the mesic lower northeast positions. In a similar study of grassland areas in Saskatchewan, Ayyad and Dix (1964) found the NNE and SSW exposures to be the two ooposite extremes. In their study, however, crest sites were either not present or not considered. Dissimilarities between the two extreme positions appear to be directly correlated with differences in temperature and moisture regimes. These differences in temperature and moisture may be partially explained by the fact that the morning sun falls on a moist soil and therefore much of the solar energy received is lost in evaporation. However, in the afternoon when the sun reaches the southern exposures, soils are somewhat drier and therefore radiant energy is applied towards an increase in air and soil temperature, creating a more xeric environment (Geiger, 1965). Additional factors influencing dissimilarities between the two extreme positions may include differences in wind velocity and runoff. Microclimatic gradients therefore exist between these two opposite extremes.

In addition to solar insolation, soil moisture is also controlled by the watar received and retained from both precipitation and surface movement. Therefore, position plays an important role on each exposure in that much of the water received by the upper position is lost through runoff, consequently producing a more mesic environment on the lower positions. Differences in available soil moisture on upper and lower positions may not only affect temperatures on these positions, but also produce striking variability in vegetational composition. For example, Geranium viscosissimum (Fig. 5) reaches its overall optimum frequency values (46%) on the northeast exposures, however, higher average frequency values are maintained on the lower east position (45%) than on the upper northeast (40%).

Greater amounts of organic matter (Table VII) on the northern exposures (N,NE,NW) may be correlated with higher moisture levels existing on these slopes. Naturally, the more mesic exposure will be able to support a greater vegetative coverage than the drier southern (S,SE,SW) exposures. Lower positions for each exposure reveal similar correlations (Table VII).

Since vegetational differences are directly influenced by environmental differences, they should be expected to be well correlated with them. These correlations may be best revealed in discussing vegetational patterns.

One example of this correlation may be found in species which are restricted to one or two positions on the morainal mounds and consequently serve as indicators of the microenvironment. For example, Lewisia rediviva (Fig. 5) is restricted entirely to the two driest positions on the morainal mounds, which includes the crest and upper southwest position. Similarly, Anaphalis margaritaceae (Fig. 2) is restricted to the more mesic northern positions. Goodall (1954) emphasized the importance of such species in his statement, "There is much to be said for the view that the complexes of environmental factors determining plant distribution can be indicated and measured better indirectly, through the plants themselves, than by direct physical measurements."

This study has emphasized that microenvironmental-vegetation continua exist on the morainal mounds with each species having its own distributional pattern. Driscoll (1964) states in reference to his treatment of rangeland communities in Oregon, that "Arranging the species into the resulting pattern of complex curves would illustrate the diversity of vegetation but would have little practical value from the land management point of view." Therefore, for practical convenience, community types or arbitrary units, based on species dominance or vegetative-moisture regimes may be recognized for the varied exposure orientations. Vegetative types or associations have been assigned by Daubenmire (1960, 1966), along with others, who feel that "If there is to be such a thing as vegetation science, there must be a framework for organizing, storing, and retrieving the information,----, one in which the mere indication of a position in the system automatically makes possible the maximum predictions about the unit."

Arbitrary community types for the morainal mounds can be assigned to the exposure orientations by selecting one or more species demonstrating some degree of restrictiveness to these positions. These associations or community types are as follows:

Exposure	Community Type
NE	Geranium - Hieracium type
N,NW	Heuchera - Geum type
W	Arenaria capillaris type
S,SE	Festuca octoflora - Opuntia fragilis type

Exposure	Community Type
SE	Plantago - Phacelia type
SW	Phlox hoodii type
Crest	Lewisia type

In addition to these individual slope associations, the morainal mounds of the Upper Blackfoot Valley could be arbitrarily placed into a single Festuca-Agropyron community type.

Contrary to the formation of typal communities, Whittaker (1956) expresses the point of view that "When population curves of species are drawn together along an environmental gradient...the resulting picture is not one of associations marked off from one another, but a pattern of curves flowing into one another, a continuum of population." Others (Cain, 1947; Curtis and McIntosh, 1951; Bray and Curtis, 1957) have also indicated similar existing vegetational-environmental gradients.

The target diagrams of the present study reveal that two separate species simply do not ordinarily have identical adaptations nor do they have identical distribution patterns. Consequently, a continual flow of increasing and decreasing frequency values for various species exist on the morainal mounds. This may be illustrated by choosing representative species such as Hieracium albertinum (Fig. 5) and Chrysopsis villosa (Fig. 3). Chrysopsis reaches its optimum distribution center on the drier exposures (S,SW,crests) and gradually declines in abundance as it approaches, in either direction, the margin of its ecological tolerance on the more mesic (N,NE,NW) exposures. The continual flow of decreasing values to a minimum may be attributed to the temperature and moisture gradients discussed earlier. Hieracium shows similar trends, gradually decreasing in abundance towards the more xeric positions.

It may be said that both of these controversial views just presented warrant attention, each being applicable to the individual concerned. Damman (1964) indicates in reference to his study area in Newfoundland, that it is evident a continuum of habitat conditions does exist, however despite this, vegetation types can occur due to competition, mutual intolerance and gregarious occurrence of certain species.

Disturbed morainal mounds, due to grazing, indicated similar correlations between vegetation and microenvironments. As expected, soil moisture values were somewhat lower on the grazed mounds in comparison to "ungrazed" areas (Table VI). This may be attributed to the soil being more compact on the grazed sites, consequently more water is lost through runoff. Species classified as "increasers" and "decreasers" were recognized on the grazed mounds. Artemisia frigida, Bromus tectorum, Plantago patagonica, and Stipa comata (Fig. 8) were all found to increase on grazed areas, whereas Festuca idahoensis and Geum triflorum indicated a decrease in frequency values. Similar kinds of responses were reported by Dix (1959) on the thin soil prairies of Wisconsin. Species may increase on a given area when other competitive plants are removed through grazing. Certain other species due to odor, taste, position, morphology, etc. are not selected by the livestock as palatable forage.

Due to the limited scope of time and equipment, this study may warrant further comprehensive investigations. Additional microclimatic measurements should be employed for a more comprehensive study. Soil and surface temperature recordings at various levels, would be beneficial in a study of this nature. Further studies should also be conducted during the fall, winter and spring since they play a very important part in determining the moisture supply for the coming year. Cantlon (1953), in reference to his study area in New Jersey, reported that maximum differences occurred on the various exposures during fall, whereas the smallest differences occurred during the summer months.

The present study provides quantitative information on the amplitudes of tolerance for individual species in relation to several major microenvironmental factors, namely soil moisture and temperature. This provides basic information for further autecological studies. Such studies could include the gregariousness and antagonistic responses of individual species on various exposures. Also certain ubiquitous species, which occupy wide ranges of microenvironmental habitats may need further study as to formation of possible local ecotypes.

SUMMARY

The main objective of this study was to analyze the vegetation on the morainal mounds in the Upper Blackfoot Valley with emphasis on the composition and distribution of communities as correlated with slope exposure and soil temperature and moisture regimes.

Five theoretical mounds, each displaying eight exposures along with the crest, were constructed from a study area which encompassed about 2½ square miles. The eight exposures on the morainal mounds were divided into upper and lower positions, each mound therefore consisted of 17 sites, including the crests. Frequency and canopy-coverage values were recorded for each site.

Diagramatic representations were constructed to aid in interpretating the interrelationships between the vegetation and microenvironments.

Soil moisture, surface and soil temperature and soil nutrients were thought to be of particular importance and therefore were recorded for each exposure. Soil moisture and soil nutrients were found to vary significantly with aspect and position. Temperature readings also correlated with changes in exposure.

Results obtained indicated that the distribution of individual species on various slopes and positions is controlled primarily by the soil moisture-temperature regimes. Species such as *Festuca scabrella*, *Galium boreale*, *Geranium visicosissimum*, *Geum triflorum* and *Potentilla arguta* reach their highest frequency values on the more mesic lower

north exposures, whereas others such as Chrysopsis villosa, Lewisia rediviva, Phlox hoodii and Plantago patagonica maintain higher frequency values on the upper drier exposures (S, SW, SE).

Each species was found to have a distribution pattern unlike any other species, and therefore a vegetational continuum exists on these morainal mounds. Recognition of vegetational units or community types is possible but is arbitrary.

The present study provides a basis for further comprehensive investigations with respect to autecological studies of individual species.

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APPENDIX

TABLE I. LIST OF PLANTS FOUND IN THE UPPER BLACKFOOT VALLEY

Alismaceae
- Alisma plantago-aquatica L.
- Sagittaria cunneata Sheld.

Apocynaceae
- Apocynum sibiricum Jacq.

Berberidaceae
- Berberis repens Lindl.

Betulaceae
- Alnus tenuifolia Nutt.
- Betula occidentalis Hook.

Boraginaceae
- Cryptantha ambigua (Gray) Greene.
- Hackelia floribunda (Lehm.) I.M. Johnston
- Lappula redowskii (Hornem.) Greene var. occidentalis (Wats.) Rydb.
- Lithospermum incisum Lehm.
- Lithospermum ruderale Lehm.

Cactaceae
- Opuntia fragilis (Nutt.) Haw.

Campanulaceae
- Campanula rotundifolia L.

Caprifoliaceae
- Linnaea borealis L. var. americana (Forbes) Rehd.
- Symphoricarpos albus (L.) Blake

Caryophyllaceae
- Arenaria lateriflora L.
- Dianthus armeria L.
- Lychnis alba Mill.
- Stellaria umbellata Turcz.

Compositae
- Achillea millefolium L.
- Agoseris glauca (Pursh) Raf.
- Anaphalis margaritacea (L.) Benth. & Hook.
- Antennaria rosea Greene.
- Antennaria umbrinella Rydb.
- Arnica chamissonis Less.
- Arnica cordifolia Hook.
- Arnica sororia Greene
- Artemisia frigida Willd.
- Artemisia ludoviciana Nutt.
- Artemisia tridentata Nutt.

TABLE I. (CONTINUED)

Aster eatonii (A. Gray) Howell
Aster falcatus Lindl.
Aster foliaceus Lindl.
Aster laevis L. var. geyeri A. Gray.
Carduus natans L.
Centaurea cyanus L.
Centaurea maculosa Lam.
Chrysanthemum leucanthemum L.
Chrysopsis villosa (Pursh) Nutt.
Chrysothamnus viscidiflorus (Hook.) Nutt.
Cirsium hookerianum Nutt.
Cirsium spp.
Cirsium undulatum (Nutt.) Spreng.
Cirsium vulgare (Savi) Airy-Shaw
Crepis acuminata Nutt.
Crepis atrabarba Heller
Crepis runcinata (James) T. & G.
Erigeron compositus Pursh
Erigeron corymbosus Nutt.
Erigeron glabellus Nutt.
Erigeron pumilus Nutt.
Erigeron speciosus (Lindl.) DC.
Erigeron subtrinervis Rydb. var. conspicuus (Rydb.) Cronq.
Gaillardia aristata Pursh
Grindelia squarrosa (Pursh) Dunal
Haplopappus acaulis (Nutt.) A. Gray
Haplopappus integrifolius Gray
Helenium autumale L.
Lactuca serriola L.
Matricaria matricarioides (Less.) Porter
Petasites sagittatus (Pursh) A. Gray
Senecio canus Hook.
Senecio interrimus Nutt. var. exaltatus (Nutt.) Cronq.
Senecio pseudaureus Rydb.
Senecio serra Hook.
Solidago canadensis L.
Solidago gigantea Ait.
Solidago missouriensis Nutt.
Taraxacum officinale Weber
Tetradymia canescens DC.
Tragopogon dubius Scop.

Cornaceae

Cornus canadensis L.
Cornus stolonifera Michx.

Crassulaceae

Sedum stenopetalum Pursh

TABLE I. (CONTINUED)

Cruciferae
- Arabis holboellii Hornem.
- Arabis nuttallii Robinson
- Descurainia pinnata (Walt.) Britt.
- Draba spp.
- Erysimum inconspicuum (S. Wats.) Mac M.
- Lepidium virginicum L.
- Thlaspi arvense L.

Cyperaceae
- Carex spp.
- Carex eleocharis Bailey
- Carex filifolia Nutt.
- Carex nebraskensis Dewey
- Carex rostrata Stokes
- Carex xerantica Bailey
- Scirpus validus Vahl.

Elaeagnaceae
- Eleagnus commutata Bernh.
- Shepherdia canadensis Nutt.

Equisetaceae
- Equisetum arvense L.
- Equisetum spp.

Ericaceae
- Arctostaphylos uva-ursi (L.) Spreng.
- Vaccinium caespitosum Michx.

Euphorbiaceae
- Euphorbia esula L.

Gentianaceae
- Gentiana affinis Griseb.

Geraniaceae
- Geranium viscosissimum Gisch. & Mey.

Gramineae
- Agropyron desertorum (Fisch.) Schutt.
- Agropyron spicatum (Pursh) Scribn. & Smith
- Agropyron subsecundum (Link) Hitchc.
- Agrostis alba L.
- Agrostis palustris Huds.
- Agrostis scabra Willd.
- Alopecurus alpinus J.E. Smith
- Bromus ciliatus L.
- Bromus inermis Leyss.

TABLE I. (CONTINUED)

Bromus marginatus Nees
Bromus tectorum L.
Calamagrostis canadensis (Michx.) Beauv.
Calamagrostis inexpanasa A. Gray
Calamagrostis montanensis Scribn.
Calamagrostis rubescens Buckl.
Dactylis glomerata L.
Danthonia intermedia Vasey
Danthonia unispicata (Thurb.) Munro.
Deschampsia caespitosa (L.) Beauv.
Elymus glaucus Buckl.
Festuca idahoensis Elmer
Festuca occidentalis Hook.
Festuca octoflora Walt.
Festuca scabrella Torr.
Hordeum jubatum L.
Koeleria cristata (L.) Pers.
Melica spectabilis Scribn.
Phleum pratense L.
Poa palustris L.
Poa pratensis L.
Poa scabrella (Thurb.) Benth.
Poa secunda Presl.
Stipa columbiana Macoun.
Stipa comata Trin. & Rupr.
Stipa richardsonii Link.
Stipa viridula Trin.

Haloragidaceae
Myriophyllum spicatum L.

Hippuridaceae
Hippuris vulgaris L.

Hydrophyllaceae
Hesperochiron californicus (Benth.) Wats.
Hydrophyllum capitatum Dougl.
Phacelia hastata var. leucophylla Torr.
Phacelia heterophylla Pursh.
Phacelia linearis (Pursh) Holz.

Hypericaceae
Hypericum perforatum L.

Iridaceae
Iris missouriensis Nutt.
Sisyrinchium sarmentosum Suksd.

Juncaceae
Juncus balticus Willd.

TABLE I. (CONTINUED)

Juncus longistylis Torr.
Juncus nodosus L.
Juncus tenuis Willd. var. dudleyi (Wieg.) Hermann
Juncus tracyi Rydb.

Juncaginaceae
Triglochin maritima L.

Labiatae
Agastache urticifolia (Benth.) Kuntze
Mentha arvensis L. var. villosa (Benth.) S.R. Stewart
Monarda fistulosa L. var. menthaefolia (Graham) Fern.
Prunella vulgaris L.
Salvia officinalis L.
Scutellaria galericulata L.
Stachys palustris L. var. pilosa (Nutt.) Fern.

Leguminosae
Astragalus bisulcatus (Hook.) A. Gray
Astragalus canadensis L.
Astragalus purshii Dougl.
Astragalus vexilliflexus Sheld.
Glycyrrhiza lepidota (Nutt.) Pursh
Lathyrus ochroleucus Hook.
Lupinus sericeus Pursh
Lupinus spp.
Medicago sativa L.
Trifolium hybridum L.
Trifolium pratense L.
Vicia americana Muhl.

Lemnaceae
Lemna trisculca L.

Lentibulariaceae
Utricularia vulgaris L. var. americana A. Gray

Liliaceae
Allium cernuum Roth
Camassia quamash (Pursh) Greene
Disporum trachycarpum (S. Wats.) B. & H.
Erythronium grandiflorum Pursh
Fritillaria pudica (Pursh) Spreng.
Smilacina racemosa (L.) Desf. var. amplexicaulis (Nutt.) S. Wats.
Zygadenus elegans Pursh
Zygadenus gramineus Rydb.

Malvaceae
Sphaeralcea coccinea (Pursh) Rydb.

TABLE I. (CONTINUED)

Onagraceae
- Epilobium angustifolium L.
- Epilobium glandulosum Lehm.
- Epilobium paniculatum Nutt.
- Oenothera biennis L.
- Oenothera heterantha Nutt.

Ophioglossaceae
- Botrychium virginianum (L.) Sw.

Orchidaceae
- Corallorhiza maculata Raf.
- Habenaria hyperborea (L.) R. Br.

Pinaceae
- Juniperus scopulorum Sarg.
- Larix occidentalis Nutt.
- Picea engelmannii Parry
- Pinus ponderosa Dougl.
- Pseudotsuga menziesii (Mirb.) Franco

Plantaginaceae
- Plantago patagonica Jacq.

Polemoniaceae
- Microsteris gracilis (Hook.) Greene
- Phlox hoodii Richards.
- Phlox longifolia Nutt.
- Polemonium pulcherrimum Hook.

Polygonaceae
- Eriogonum flavum Nutt.
- Eriogonum subalpinum Greene
- Polygonum amphibium L. var. stipulaceum (Coleman) Fern.
- Rumex acetosella L.
- Rumex occidentalis S. Wats. var. fenestratus (Greene) Le Page

Polypodiaceae
- Cystopteris fragilis (L.) Bernh.

Portulacaceae
- Lewisia rediviva Pursh.

Primulaceae
- Dodecatheon conjugens Greene
- Douglasia montana A. Gray
- Lysimachia ciliata L.

Pyrolaceae
- Chimaphila umbellata (L.) Bart. var. occidentalis (Rydb.) Blake

TABLE I. (CONTINUED)

Pyrola picta J.E. Smith

Ranunculaceae
- Anemone cylindrica A. Gray
- Anemone multifida Poir.
- Clematis columbiana (Nutt.) A. Gray var. verticellaris DC.
- Clematis hirsutissima Pursh
- Delphinium bicolor Nutt.
- Ranunculus acriformis A. Gray
- Ranunculus aquatilis L. var. capillaceus (Thuill.) DC.

Rosaceae
- Amelanchier alnifolia Nutt.
- Fragaria virginiana Duchesne
- Geum triflorum Pursh
- Potentilla anserina L.
- Potentilla arguta Pursh
- Potentilla fruticosa L.
- Potentilla gracilis Dougl. var. brunnescens (Rydb.) C.L. Hitchc.
- Potentilla gracilis Dougl. var. flabelliformis (Lehm.) Nutt.
- Prunus virginiana L.
- Rosa woodsii Lindl.
- Rubus idaeus L. var. peramoenus (Greene) Ferne.
- Sanguisorba occidentalis Nutt.

Rubiaceae
- Galium boreale L.
- Galium triflorum Michx.

Salicaceae
- Populus tremuloides Michx.
- Populus trichocarpa T. & G.
- Salix bebbiana Sarg. var. perrostrata (Rydb.) Schneid.
- Salix spp.

Santalaceae
- Commandra umbellata (L.) Nutt. var. pallida (A. DC) M.E. Jones

Saxifragaceae
- Heuchera cylindrica Dougl.
- Lithophragma parviflora (Hook.) Nutt.
- Ribes inerme Rydb.
- Ribes setosum Lindl.
- Saxifraga rhomboidea Greene

Scrophulariaceae
- Castilleja miniata Dougl.
- Castilleja pallescens (Gray) Greene
- Collinsia parviflora Dougl.
- Linaria vulgaris Hill

TABLE I. (CONTINUED)

Mimulus guttatus DC.
Orthocarpus luteus Nutt.
Orthocarpus tenuifolius (Pursh) Benth.
Pedicularis contorta Benth.
Pedicularis groenlandica Retz.
Penstemon albertinus Greene
Penstemon procerus Dougl.
Verbascum thapsus L.
Veronica americana (Raf.) Schw.

Selaginellaceae
Selaginella spp.

Solanaceae
Hyoscyamus niger L.

Typhaceae
Typha latifolia L.

Umbelliferae
Cicuta douglasii (DC.) Coult. & Rose
Heracleum lanatum Michx.
Lomatium cous (S. Wats.) C. & R.
Lomatium macrocarpum (Hook. & Arn.) Coult. & Rose
Lomatium triternatum (Pursh) Coult. & Rose
Osmorhiza chilensis Hook. & Arn.
Perideridia gairdneri (Hook. & Arn.) Mathias
Sanicula marilandica L.

Urticaceae
Urtica dioica L.

Valerianaceae
Valeriana dioica L.
Valeriana edulis Nutt.

Violaceae
Viola adunca J.E. Smith
Viola nephronphila Greene
Viola nuttallii Pursh

TEMPERATURE DATA (JUNE 21, 1965)

TABLE II

	7:00 A.M.		9:00 A.M.		11:00 A.M.		1:00 P.M.		3:00 P.M.		4:00 P.M.	
Slope	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.
N	10.0°C	15.5°C	12.8°C	18.0°C	15.0°C	21.0°C	15.7°C	21.5°C	15.7°C	20.5°C	15.7°C	19.0°C
NW	11.1	15.5	13.3	18.5	15.7	21.5	16.6	22.5	16.6	22.0	17.2	25.0
W	11.7	16.0	12.2	19.0	16.1	24.5	20.0	26.0	21.1	27.5	22.8	28.5
SW	11.7	15.5	14.4	19.5	17.7	22.0	20.0	24.0	23.9	33.0	24.4	34.0
S	12.2	16.5	14.4	20.5	17.7	25.5	20.0	28.0	22.2	29.5	22.2	29.0
SE	13.3	16.5	17.2	25.0	21.7	31.0	22.8	31.5	21.7	30.5	21.7	31.0
E	13.3	17.0	16.1	24.5	17.7	28.0	18.3	29.0	18.3	28.0	18.3	28.0
NE	12.2	16.0	15.0	21.0	17.7	28.5	20.0	29.0	19.5	28.0	17.7	26.5
CREST	13.9	17.0	17.2	26.0	22.2	32.0	23.3	35.0	24.4	36.0	23.9	33.0

TEMPERATURE DATA (JULY 14, 1965) TABLE III

	8:00 A.M.		10:00 A.M.		12:00 P.M.		2:00 P.M.		4:00 P.M.		5:00 P.M.	
Slope	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.
N	13.3°C	17.5°C	14.4°C	18.5°C	18.8°C	19.5°C	18.3°C	28.0°C	17.7°C	22.5°C	17.2°C	20.0°C
NW	12.8	18.0	16.1	25.0	18.8	24.5	20.6	22.0	18.8	22.0	19.5	22.5
W	14.4	18.0	15.0	23.0	22.2	33.0	28.9	36.0	29.4	36.5	30.6	37.0
SW	14.4	15.0	18.3	26.0	22.2	25.5	26.1	33.0	31.7	45.0	32.2	42.0
S	16.1	18.0	18.3	25.0	22.2	29.0	25.6	33.0	27.8	32.5	27.8	31.0
SE	16.6	22.0	22.2	27.0	31.1	34.0	32.2	35.5	31.7	35.0	30.0	34.0
E	22.2	22.0	26.1	33.0	30.0	35.0	28.3	35.0	27.8	31.5	28.4	31.0
NE	16.6	23.5	21.1	31.0	25.6	31.5	28.9	32.0	26.1	30.5	25.6	26.5
CREST	17.7	21.5	26.0	29.5	27.2	42.0	30.0	37.5	32.2	37.0	33.3	37.5

TEMPERATURE DATA (AUGUST 9,1965) TABLE IV

	7:00 A.M.		9:00 A.M.		11:00 A.M.		1:00 P.M.		3:00 P.M.		5:00 P.M.	
Slope	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.	Soil Temp.	Surface Temp.
N	17.7°C	19.0°C	20.6°C	33.0°C	22.2°C	39.0°C	23.3°C	39.5°C	25.6°C	31.5°C	25.6°C	28.0°C
NW	17.2	16.0	20.0	26.0	20.0	32.0	21.1	30.0	24.9	28.5	27.8	33.0
W	16.6	15.5	19.5	26.0	23.3	34.0	30.0	43.0	35.6	48.0	34.9	39.0
SW	18.3	18.0	22.2	29.0	26.7	47.5	31.7	57.0	37.2	48.0	37.8	46.0
S	20.6	20.0	23.3	34.0	28.9	48.0	35.6	55.0	38.3	52.0	37.8	44.5
SE	21.7	23.5	27.2	41.0	32.8	51.0	35.6	63.0	40.0	45.5	40.6	41.0
E	21.1	24.0	27.2	40.0	28.9	50.0	34.9	59.0	34.9	44.0	31.7	36.0
NE	18.8	20.0	26.7	43.0	26.1	45.0	28.9	43.0	35.0	42.5	32.2	35.5
CREST	2o.6	22.0	26.7	39.0	30.0	52.0	36.7	56.0	40.0	47.0	36.7	39.0

SOIL MOISTURE DATA ("UNGRAZED") TABLE V

Exposure	5/22/65	6/5/65	6/11/65	6/20/65	7/1/65	7/15/65	7/26/65	8/9/65	8/27/65
N Upper	19.7%	19.1%	14.5%	16.8%	15.9%	14.8%	10.9%	4.2%	6.6%
N Lower	25.8	23.5	18.9	23.1	23.4	20.2	16.4	8.0	9.8
NE Upper			18.1	18.2	17.2	15.7	13.2	7.5	9.8
NE Lower			25.7	28.3	26.6	24.6	18.0	8.1	11.0
E Upper	24.1	11.7	10.0	14.2	13.4	10.3	7.8	3.5	7.9
E Lower	27.3	16.8	15.3	19.3	18.9	17.6	12.1	6.1	8.6
SE Upper			8.6	11.3	8.4	7.7	6.2	4.3	5.8
SE Lower			12.2	13.0	12.2	11.6	8.4	5.6	7.3
S Upper	13.4	13.1	10.7	12.2	10.1	8.4	6.8	4.6	5.3
S Lower	17.2	16.5	15.6	18.6	15.4	12.1	8.4	6.7	8.7
SW Upper			8.9	11.1	8.3	7.4	5.7	3.1	5.5
SW Lower			13.1	17.1	14.0	11.1	8.6	5.6	7.9
W Upper	45.0	14.2	10.5	12.0	10.0	8.6	7.4	3.3	6.2
W Lower	21.5	21.4	15.1	18.1	16.5	13.5	9.8	4.7	8.8
NW Upper			14.9	16.4	16.0	14.2	10.7	4.3	7.8
NW Lower			22.2	24.9	22.7	21.2	17.0	7.9	9.2
Crest	11.0	10.2	7.6	9.0	8.2	7.0	4.7	3.6	5.7

SOIL MOISTURE DATA (GRAZED) TABLE VI

Exposure	7/1/65	7/15/65	7/26/65	8/9/65	8/27/65
N Upper	10.4%	9.6%	5.4%	3.7%	7.0%
N Lower	22.3	11.6	8.9	7.5	9.4
NE Upper	10.7	11.5	5.8	4.8	6.1
NE Lower	18.9	12.9	11.0	10.0	11.1
E Upper	12.7	9.8	7.0	3.1	6.0
E Lower	28.7	18.7	9.0	8.6	9.1
SE Upper	8.1	4.6	2.9	2.1	4.4
SE Lower	8.7	7.1	6.5	5.4	5.8
S Upper	7.5	6.5	4.6	2.8	5.5
S Lower	8.2	7.3	5.4	3.8	7.1
SW Upper	6.8	7.3	3.7	2.9	6.0
SW Lower	16.5	8.0	8.6	5.4	6.6
W Upper	7.9	8.7	3.6	3.1	5.9
W Lower	16.6	13.6	11.3	7.3	9.2
NW Upper	27.0	10.3	4.1	3.1	7.3
NW Lower	35.5	21.2	13.6	7.9	9.0
Crest	8.8	3.7	3.3	3.5	5.3

CHEMICAL DATA ("UNGRAZED") TABLE VII

Exposure	pH	Range	Organic Matter	Range
N Upper	6.0	5.8-6.3	52.0 Tons/A.	37-69 Tons/A.
N Lower	6.0	5.9-6.1	81.4	75-90
NE Upper	6.0	5.8-6.3	47.0	37-71
NE Lower	6.1	5.8-6.3	49.0	27-65
E Upper	6.2	5.9-6.4	33.0	30-39
E Lower	6.1	5.9-6.4	44.2	35-60
SE Upper	6.3	6.2-6.5	29.8	22-35
SE Lower	6.2	6.0-6.5	51.4	37-59
S Upper	6.6	6.5-7.1	27.2	23-32
S Lower	6.3	5.8-6.6	41.8	27-66
SW Upper	6.4	5.9-6.7	33.0	25-36
SW Lower	6.0	5.7-6.4	53.0	41-75
W Upper	6.0	5.6-6.3	46.0	34-60
W Lower	5.9	5.6-6.1	64.2	40-80
NW Upper	6.1	5.8-6.4	49.2	38-60
NW Lower	5.7	5.5-6.0	64.4	54-72
CREST	6.2	6.0-6.5	44.2	40-50

CHEMICAL DATA ("UNGRAZED") TABLE VII (CONTINUED)

Exposure	Calcium	Range	Magnesium	Range	NH_4	Range
N Upper	9,980 lbs./A.	6,400-11,000 lbs./A.	908 lbs./A.	800-1,030 lbs./A.	4.0 lbs./A.	3- 5 lbs./A.
N Lower	9,540	7,200-13,000	1,022	800-1,300	6.6	3-10
NE Upper	9,920	5,100-13,000	1,032	900-1,110	6.4	3-10
NE Lower	9,800	6,400-13,000	1,108	800-1,310	6.0	3-10
E Upper	7,180	5,000- 9,000	860	600-1,000	4.4	4- 5
E Lower	8,160	7,900- 9,000	840	600-1,000	4.8	4- 5
SE Upper	6,340	5,000- 7,600	980	700-1,400	5.6	4-10
SE Lower	8,740	6,700-10,000	820	600-1,000	6.8	4-15
S Upper	5,920	5,200- 7,600	860	800-1,000	3.8	3- 5
S Lower	7,240	6,100- 8,800	878	800-1,000	4.2	3- 7
SW Upper	7,460	5,600- 9,000	1,190	800-1,500	3.0	3
SW Lower	8,880	7,600-10,000	870	820-1,100	3.4	3- 5
W Upper	6,850	4,800- 8,000	998	700-1,400	3.4	3- 4
W Lower	8,020	7,100-10,000	880	800- 900	3.6	3- 4
NW Upper	9,000	7,000-11,000	1,140	1,100-1,200	16.0	5-20
NW Lower	8,760	4,800-10,000	1,010	900-1,100	19.0	10-30
CREST	6,940	5,200- 7,800	1,062	880-1,200	3.7	3- 5

Exposure	Phosphorus	Range	Potassium	Range	NO_3	Range
N Upper	48.6 lbs./A.	24- 85 lbs./A	371 lbs./A.	290-490 lbs./A.	Trace lbs./A.	Trace lbs./A
N Lower	96.6	57-200	500	500	1.0	Trace-5
NE Upper	70.8	35-130	382	300-450	Trace	Trace
NE Lower	92.8	50-180	471	370-500	2.0	Trace-5
E Upper	59.4	50- 69	416	395-450	Trace	Trace
E Lower	75.4	65- 89	500	500	Trace	Trace
SE Upper	33.8	14- 69	301	215-425	1.0	Trace-5
SE Lower	86.4	49-150	500	500	2.0	Trace-5
S Upper	25.8	14- 50	274	265-310	Trace	Trace
S Lower	70.4	50- 95	485	425-500	Trace	Trace
SW Upper	14.8	10- 20	235	185-325	1.6	Trace-5
SW Lower	86.4	49-150	500	500	1.6	Trace-5
W Upper	18.6	13- 24	220	200-230	2.8	Trace-4
W Lower	88.8	60-135	495	475-500	.6	Trace-3
NW Upper	17.0	14- 25	330	150-450	2.0	Trace-5
NW Lower	117.8	43-250	445	325-500	2.0	Trace-5
Crest	36.2	27- 52	370	300-495	Trace	Trace

CHEMICAL DATA (GRAZED) TABLE VIII

Exposure	pH	Range	Organic Matter	Range
N Upper	6.3	5.8-6.7	80.0 Tons/A.	55-125 Tons/A.
N Lower	6.1	6.0-6.2	88.0	67-125
NE Upper	6.4	6.3-6.6	57.0	47-70
NE Lower	6.2	6.0-6.5	68.7	59-80
E Upper	6.3	6.2-6.5	38.3	25-56
E Lower	6.4	6.2-6.5	61.3	51-73
SE Upper	6.8	6.7-6.9	39.3	31-55
SE Lower	6.3	6.0-6.6	48.7	36-60
S Upper	6.9	6.7-7.0	30.0	28-33
S Lower	6.7	6.6-6.9	47.3	35-62
SW Upper	7.0	6.6-7.7	27.7	18-35
SW Lower	6.9	6.4-7.6	56.3	30-79
W Upper	6.5	6.3-6.6	36.7	31-45
W Lower	6.7	5.6-7.9	72.0	65-76
NW Upper	6.6	6.1-7.4	43.7	32-57
NW Lower	6.1	5.6-6.7	69.0	61-76
CREST	6.7	6.2-7.1	32.7	29-37

CHEMICAL DATA (GRAZED)

TABLE VIII (CONTINUED)

Exposure	Calcium	Range	Magnesium	Range	NH_4	Range
N Upper	11,667 lbs./A.	9,000-15,000 lbs./A.	1,300 lbs./A.	1,100-1,600 lbs./A.	8.3 lbs./A.	5-15 lbs./A.
N Upper	12,000	11,000-13,000	1,233	1,200-1,300	6.0	3-10
NE Upper	12,167	10,000-14,000	1,100	1,000-1,200	10.0	5-15
NE Lower	9,667	9,000-11,000	1,050	1,000-1,100	11.7	5-20
E Upper	7,333	5,600-10,000	867	800-1,000	8.3	5-10
E Lower	10,000	10,000	1,180	1,090-1,350	8.3	5-10
SE Upper	8,000	5,200-13,000	1,170	1,010-1,400	5.0	5
SE Lower	9,833	8,000-13,000	1,203	1,000-1,600	8.3	5-10
S Upper	7,066	6,400- 7,800	1,293	1,000-1,478	6.0	3-10
S Lower	8,867	6,000-12,000	1,133	900-1,300	8.3	5-15
SW Upper	8,100	6,000-12,000	1,540	1,000-2,200	6.7	5-10
SW Lower	8,600	5,800-10,000	1,563	1,000-2,400	10.0	10
W Upper	7,467	5,600- 8,800	1,103	1,000-1,200	6.7	5-10
W Lower	16,333	9,000-28,000	1,703	900-3,000	1.0	3-15
NW Upper	11,000	6,400-20,000	1,405	1,100-2,000	8.3	5-10
NW Lower	1,020	7,600-14,000	1,263	1,090-1,500	6.7	5-10
CREST	9,500	6,100-16,000	1,403	1,110-1,900	7.3	5-10

CHEMICAL DATA (GRAZED) TABLE VIII (CONTINUED)

Exposure	Phosphorus	Range	Potassium	Range	NO_3	Range
N Upper	16.0 lbs./A.	14- 19 lbs./A.	275 lbs./A.	175-425 lbs./A.	1.3 lbs./A.	Trace-4 lbs./A
N Lower	37.0	17- 75	338	225-450	1.3	Trace-4
NE Upper	44.7	20- 55	403	350-500	Trace	Trace
NE Lower	76.3	25-125	458	375-500	1.3	Trace-4
E Upper	61.3	45- 75	410	230-500	3.3	Trace-5
E Lower	87.0	70-110	500	500	3.0	Trace-5
SE Upper	51.3	32- 82	442	325-500	1.3	Trace-4
SE Lower	84.7	39-110	400	350-500	1.3	Trace-4
S Upper	39.0	16- 79	433	375-500	Trace	Trace
S Lower	60.7	35- 76	429	285-500	1.6	Trace-5
SW Upper	23.7	13- 37	347	225-500	Trace	Trace
SW Lower	56.7	50- 66	447	340-500	1.6	Trace-5
W Upper	18.7	5- 34	330	175-450	1.6	Trace-5
W Lower	34.6	11- 49	405	215-500	2.7	Trace-4
NW Upper	17.0	7- 23	278	250-325	1.3	Trace-4
NW Lower	18.0	14- 25	395	385-400	1.3	Trace-4
CREST	74.3	53-103	417	325-500	1.6	Trace-5

TABLE IX. AVAILABLE SOIL MOISTURE* VALUES FOR GRAZED AND "UNGRAZED" POSITIONS

Exposure	Grazed A.S.M.	"Ungrazed A.S.M.
N Upper	2.10	2.20
N Lower	2.22	2.69
NE Upper	2.34	1.21
NE Lower	2.26	2.00
E Upper	2.53	1.50
E Lower	2.30	1.20
SE Upper	1.52	1.57
SE Lower	1.85	1.82
S Upper	2.01	1.10
S Lower	1.83	1.21
SW Upper	1.79	1.18
SW Lower	2.77	1.69
W Upper	1.23	1.28
W Lower	1.41	1.84
NW Upper	2.10	1.28
NW Lower	2.45	2.10
CREST	1.72	1.22

*Available soil moisture is the difference between the moisture contents at field capacity and wilting point.

CANOPY-COVERAGE DATA FOR TWENTY DOMINANT SPECIES ("UNGRAZED") TABLE X

Species		North	East	South	West	Crest
Achillea millefolium	Upper	2.2 %	2.5 %	.7 %	1.4 %	.06%
	Lower	2.0	2.0	.3	1.0	
Agropyron spicatum	Upper	3.8	2.7	5.7	.6	1.1
	Lower	2.7	4.9	4.2	.7	
Antennaria umbrinella	Upper	2.5	3.2	1.0	6.2	4.4
	Lower	.6	3.0	1.9	4.3	
Arabis holboellii	Upper	.1	.3	.5		.02
	Lower	.5	.02	.3		
Arenaria capillaris	Upper	3.1	.4	.2	4.9	1.3
	Lower	1.1		.2	4.3	
Artemisia frigida	Upper			.7	.06	2.2
	Lower		.04	1.3	.1	
Bromus tectorum	Upper		.6	2.5		
	Lower		1.5	3.7		
Chrysopsis villosa	Upper	.9	3.4	3.4	1.8	
	Lower	.3	1.5	3.9	1.4	
Collinsia parviflora	Upper	2.0		.2	.1	
	Lower	1.6		.02	.5	
Commandra umbellata	Upper	.02	2.8	.5	.02	.2
	Lower					

CANOPY-COVERAGE DATA FOR TWENTY DOMINANT SPECIES ("UNGRAZED") TABLE X (CONTINUED)

Species		North	East	South	West	Crest
Eriogonum heracleoides	Upper	1.3 %	3.1%	.8 %	.4 %	
	Lower	1.1	2.5	.9	.3	
Festuca idahoensis	Upper	9.3	11.9	1.3	8.8	.7%
	Lower	3.4	8.8	.5	8.8	
Festuca scabrella	Upper	3.0	1.7		7.0	3.0
	Lower	3.0	4.0		11.6	
Geranium viscosissimum	Upper	2.2	.3		.02	
	Lower	2.5	4.5	.02	.4	
Koleria cristata	Upper	1.1	2.4	1.4	.6	4.0
	Lower	.1	1.2	2.8	.3	
Lomatium macrocarpum	Upper	.3	.7	.2	.3	1.2
	Lower	.1	.3	.8	.2	
Lupinus spp.	Upper	2.0	4.8	4.9	6.0	1.6
	Lower	.3	6.6	4.7	5.7	
Phacelia hastata	Upper	.06	.7	.9		
	Lower	.06	1.5	.08	.8	
Solidago missouriensis	Upper	.4	.3	.02	.4	
	Lower	1.7	1.2	.02		
Tragopogon dubius	Upper	.1	.4	.4	.06	.1
	Lower	.02	.1	.4	.02	

CANOPY-COVERAGE DATA FOR TWENTY DOMINANT SPECIES ("UNGRAZED") TABLE X (CONTINUED)

Species		Northeast	Southeast	Southwest	Northwest
Achillea millefolium	Upper	3.0 %	.7 %	.5 %	1.0 %
	Lower	3.1	1.1	1.3	1.2
Agropyron spicatum	Upper	4.8	2.8	1.1	2.3
	Lower	1.8	2.6	1.5	2.2
Antennaria umbrinella	Upper	3.4	1.9	3.7	3.6
	Lower	1.5	1.1	2.4	.8
Arabis holboellii	Upper	.06	.1	.1	
	Lower	.2	.2	.08	.02
Arenaria capillaris	Upper	1.8	.6	3.4	4.2
	Lower	.8	.2	2.4	.02
Artemisia frigida	Upper		.4	.2	
	Lower		.2	.08	
Bromus tectorum	Upper		3.8	.02	
	Lower		3.0	.08	
Chrysopsis villosa	Upper	1.7	3.6	4.3	.6
	Lower	1.1	2.5	2.7	
Collinsia parviflora	Upper	1.0	.6	.1	.4
	Lower	.8	.3	.5	.4
Commandra umbellata	Upper			.02	
	Lower		.02	.4	

CANOPY-COVERAGE DATA FOR TWENTY DOMINANT SPECIES ("UNGRAZED") TABLE X (CONTINUED)

Species		Northeast	Southeast	Southwest	Northwest
Eriogonum heracleoides	Upper	1.7 %	.3 %	.8 %	.2 %
	Lower	1.6	1.3	2.1	1.2
Festuca idahoensis	Upper	9.2	1.4	5.1	9.0
	Lower	5.9	1.3	1.0	3.9
Festuca scabrella	Upper	4.7	.4	.02	9.5
	Lower	6.5	2.8		11.9
Geranium viscosissimum	Upper	3.7			.02
	Lower	7.7	.02	.02	2.5
Koleria cristata	Upper	1.6	4.3	2.3	1.7
	Lower	.9	2.4	1.7	.3
Lomatium macrocarpum	Upper	.5	1.0	.9	.02
	Lower	.02	.4	.08	
Lupinus spp.	Upper	6.5	4.3	5.5	5.1
	Lower	3.8	3.8	5.9	1.7
Phacelia hastata	Upper	.02	1.4	.1	.02
	Lower	.02	1.9	.3	
Solidago missouriensis	Upper	2.4			.7
	Lower	2.2		.7	1.0
Tragopogon dubius	Upper	.1	.9	.2	.1
	Lower	.02	.9	.5	.06

CANOPY-COVERAGE DATA FOR TWENTY DOMINANT SPECIES (GRAZED) TABLE XI

Species		North	East	South	West	Crest
Achillea millefolium	Upper	1.2 %	.4 %		.5 %	.2 %
	Lower	1.4	.5	.03%	1.2	
Agropyron spicatum	Upper	1.2	2.6		2.9	.2
	Lower	1.7	1.8	1.7	.3	
Antennaria umbrinella	Upper	3.2	.03	1.7	3.9	3.7
	Lower	3.7	.03		4.1	
Arabis holboellii	Upper	.03	.03	.1		.2
	Lower				.1	
Arenaria capillaris	Upper	1.9	.3		2.0	.1
	Lower	1.3	.5		2.7	
Artemisia frigida	Upper	1.4	2.6	2.9	1.6	4.1
	Lower	.8	1.9	2.6	1.0	
Bromus tectorum	Upper	.3	4.8	3.9		.3
	Lower	.03	2.9	6.0		
Chrysopsis villosa	Upper	.3	2.7	1.7	1.6	4.1
	Lower	.1	5.4	4.8	1.5	
Collinsia parviflora	Upper		.03			
	Lower		.1			
Commandra umbellata	Upper					
	Lower					

CANOPY-COVERAGE DATA FOR TWENTY DOMINANT SPECIES (GRAZED) TABLE XI (CONTINUED)

Species		North	East	South	West	Crest
Eriogonum heracleoides	Upper					
	Lower					
Festuca idahoensis	Upper	7.1 %			1.6 %	.1 %
	Lower	4.0			6.0	
Festuca scabrella	Upper	2.3				
	Lower	4.0				
Geranium viscosissimum	Upper					
	Lower	.03				
Koleria cristata	Upper	1.5	1.4 %	.2 %	3.5	4.1
	Lower	.6		1.4	1.5	
Lomatium macrocarpum	Upper	.5	1.2	1.4		1.9
	Lower	.3	.4	.6	.6	
Lupinus spp.	Upper	3.7	6.7	1.5	6.0	.8
	Lower	3.9	8.7	2.8	4.0	
Phacelia hastata	Upper					.03
	Lower					
Solidago missouriensis	Upper		.4		.4	
	Lower					
Tragopogon dubius	Upper	.6	1.3	.3	.2	.2
	Lower	.3	1.3	.9	.3	

CANOPY-COVERAGE DATA FOR TWENTY DOMINANT SPECIES (GRAZED) TABLE XI (CONTINUED)

Species		Northeast	Southeast	Southwest	Northwest
Achillea millefolium	Upper	.9 %		.1 %	1.1 %
	Lower	1.9	.2 %	.7	1.5
Agropyron spicatum	Upper	3.0	.5	1.1	2.5
	Lower	1.8	.1	.3	1.2
Antennaria umbrinella	Upper	2.3	.1	2.6	5.3
	Lower	.9		1.1	3.5
Arabis holboellii	Upper	.06	.03	.4	
	Lower		.2	.03	.07
Arenaria capillaris	Upper	.3	.07	1.8	3.0
	Lower			.9	3.1
Artemisia frigida	Upper	2.6	3.8	2.3	.9
	Lower	1.3	1.5	1.4	1.7
Bromus tectorum	Upper	1.3	10.1	.1	
	Lower	.5	4.9	1.1	
Chrysopsis villosa	Upper	3.6	1.4	3.0	.5
	Lower	3.7	2.4	2.9	.3
Collinsia parviflora	Upper	.03			
	Lower		.2		
Commandra umbellata	Upper			.3	
	Lower			.2	

CANOPY-COVERAGE DATA FOR TWENTY DOMINANT SPECIES (GRAZED) TABLE XI (CONTINUED)

Species		Northeast	Southeast	Southwest	Northwest
Eriogonum heracleoides	Upper				
	Lower				
Festuca idahoensis	Upper	1.7 %		1.6 %	4.8 %
	Lower	.4		.3	2.1
Festuca scabrella	Upper				
	Lower				
Geranium viscosissimum	Upper				
	Lower	.4		.3	
Koleria cristata	Upper	1.5	.6 %	2.7	3.2
	Lower	1.1	.2	2.4	.7
Lomatium macrocarpum	Upper	2.2	1.0	.6	.4
	Lower	.2	.5	.4	
Lupinus spp.	Upper	5.1	.6	6.9	2.7
	Lower	.4	2.4	5.3	3.6
Phacelia hastata	Upper		.03	.03	
	Lower		1.2		
Solidago missouriensis	Upper	.3			.7
	Lower				
Tragopogon dubius	Upper	17	.8	.6	.3
	Lower				

TABLE XII. AVERAGE CANOPY-COVERAGE VALUES FOR GRAZED AND "UNGRAZED" POSITIONS.

Position	Grazed	"Ungrazed"
N Upper	38.0%	55.8%
N Lower	39.9	58.0
NE Upper	35.1	61.2
NE Lower	43.8	65.6
E Upper	36.1	50.2
E Lower	41.0	51.0
SE Upper	28.9	33.3
SE Lower	29.2	33.8
S Upper	26.8	31.1
S Lower	29.1	34.4
SW Upper	33.4	39.6
SW Lower	32.4	40.9
W Upper	35.1	46.2
W Lower	33.7	48.1
NW Upper	44.1	51.0
NW Lower	47.5	57.0
Crest	27.7	27.5

TABLE XIII AVERAGE FREQUENCY VALUES FOR DOMINANT SPECIES OCCURRING ON AT LEAST THREE MORAINAL MOUND STANDS REACHING A FREQUENCY OF 15% ON ONE OF THESE STANDS.

Species	NE	N	NW	E	W	S	SE	SW	CREST
Achillea millefolium	60.5%	39.5%	29.5%	48.0%	32.5%	11.5%	23.0%	24.0%	
Hieracium albertinum	46.0	23.5	5.5	7.5	9.0	1.0		1.0	
Geranium viscosissimum	45.0	18.0	19.5	25.5	7.5	1.0	1.0	1.0	
Balsamorhiza sagittata	15.5	3.5		6.5	5.0	2.5	1.0	4.0	
Collinsia parviflora	32.5	50.0	14.5		8.5	4.5	5.0	5.5	
Potentilla arguta	18.0	26.0	9.0	12.0	2.5				
Galium boreale	10.5	19.0	3.5	1.0	1.5	1.5			
Carex filifolia	4.5	11.5	4.3	3.0	1.0		1.0	4.5	4.5%
Anaphalis margaritacea	.5	9.5	3.0						
Taraxacum spp.	4.5	8.5	5.5	2.5	3.5			2.0	
Arabis nuttallii	7.0	7.5	5.0	2.5	5.5	3.5	2.0	3.0	
Potentilla gracilis	4.0	7.0	.5	5.0	.5	.5			
Viola spp.	4.5	7.0	6.5	.5	4.0				
Rosa woodsii	6.4	6.5	.5	6.4	.5		1.0		
Geum triflorum	2.5	47.0	61.0		7.0				

TABLE XIII (CONTINUED)

Species	NE	N	NW	E	W	S	SE	SW	CREST
Heuchera cylindrica	10.5%	39.0%	58.0%		4.5%				
Festuca scabrella	40.0	43.0	47.5	31.0%	40.5		7.0%	2.5%	15.5%
Penstemon procerus	4.5	13.5	18.0	4.0	.5				
Erigeron pumilus	5.0	2.0	16.0	2.0					3.0
Dodecatheon conjugens	4.5	1.0	13.0						
Fritillaria pudica	2.0	1.5	12.0	.5	2.5		.5	.5	
Amelanchier alnifolia	7.5	5.0	10.0	3.5					
Delphinium bicolor		3.0	5.0						
Fragaria virginiana		2.5	4.5						
Carex xerantica	1.0		3.5						
Festuca idahoensis	58.5	49.5	56.5	74.5	64.0	14.5%	61.0	69.5	4.5
Eriogonum heracleoides	17.5	14.0	7.0	18.5	6.5	10.5	9.5	16.0	
Commandra umbellata		.5		17.5	1.0	9.5	.5	6.5	2.5
Eriogonum flavum			.5	15.5		1.0	5.5	5.0	
Lithospermum ruderale	3.5	4.0	2.5	7.5			1.0	.5	

TABLE XIII (CONTINUED)

Species	NE	N	NW	E	W	S	SE	SW	CREST
Arenaria capillaris	19.0%	29.0%	55.5%	4.0%	74.5%	3.0%	6.5%	29.5%	8.5%
Antennaria umbrinella	33.0	25.0	35.5	30.0	59.5	23.5	22.5	40.5	26.5
Phlox hoodii				.5	30.0	1.0	5.0	16.5	12.5
Sedum stenopetalum		3.5	4.5	1.0	12.0	.5	1.0	2.5	8.5
Castilleja spp.		1.0	.5	5.5	8.5		2.5	7.5	3.5
Agropyron spicatum	27.5	36.0	37.5	44.5	19.5	55.5	37.5	29.5	17.0
Artemisia frigida				1.0	3.0	18.5	13.5	3.5	8.5
Festuca octoflora				2.5		13.5	10.0		
Phacelia linearis	2.0			4.0		8.5	4.5	3.0	
Bromus tectorum				4.5		43.5	45.0	.6	
Phacelia hastata	1.0	2.5	.5	16.5		11.5	43.0	9.0	
Draba spp.	2.5	1.5		3.5	1.5	3.0	32.0	5.0	
Tragopogon dubius	2.0	3.0	2.5	3.5	.5	5.5	22.5	7.5	3.0
Microsteris gracilis	6.5	8.0		13.5		6.5	19.5	8.0	
Lactuca serriola					9.5	1.5	14.5	11.5	

TABLE XIII (CONTINUED)

Species	NE	N	NW	E	W	S	SE	SW	CREST
Crepis accuminata	.5%	.5%		.5%	7.0%		14.0%	11.5%	
Plantago patagonica				.5		5.0%	6.5		1.0%
Senecio canus	1.5	4.5		5.0	2.0	.5	6.5	4.5	1.5
Stipa comata				.5		1.0	5.5	1.0	
Opuntia fragilis						1.5	4.0		
Astragalus purshii	.5				.5	1.4	1.5		1.4
Lupinus spp.	60.5	11.5	43.0%	59.5	65.0	58.0	65.5	67.5	13.0
Arabis holboellii	4.0	5.0	.5	4.5		10.5	8.0	8.5	1.5
Erigeron compositus	.5				4.5	3.0	1.5	5.0	
Chrysopsis villosa	28.5	11.0	4.5	31.5	39.0	67.5	60.5	61.5	79.0
Koleria cristata	22.5	9.0	17.0	42.5	44.5	32.0	44.5	41.0	55.0
Lomatium macrocarpum	7.5	4.0	1.0	10.5	9.0	13.5	12.5	12.0	24.0
Lewisia rediviva								1.5	5.5

TABLE XIV. LIST OF OTHER SPECIES OCCURRING ON THE MORAINAL MOUNDS NOT MEETING CRITERIA SET UP FOR TABLE XIII

Berberidaceae
- Berberis repens Lindl.

Boraginaceae
- Cryptantha ambigua (Gray) Greene

Campanulaceae
- Campanula rotundifolia L.

Caprifoliaceae
- Symphoricarpos albus (L.) Blake

Compositae
- Artemisia tridentata Nutt.
- Cirsium spp.
- Chrysothamnus viscidiflorus (Hook.) Nutt.

Gramineae
- Calamagrostis montanensis Scribn.
- Danthonia unispicata (Thurb.) Munro
- Melica spectabilis Scribn.
- Poa secunda Presl.
- Stipa richardsonii Link.

Leguminosae
- Astragalus bisulcatus (Hook.) A. Gray.

Liliaceae
- Camassia quamash (Pursh) Greene

Onagraceae
- Epilobium paniculatum Nutt.

Polygonaceae
- Polygonum douglasii Greene.

Ranunculaceae
- Anemone cylindrica A. Gray
- Clematis hirsutissima Pursh.

Saxifragaceae
- Lithophragma parviflora (Hook.) Nutt.

TABLE XIV (CONTINUED)

Scrophulariaceae
- Orthocarpus luteus Nutt.
- Orthocarpus tenuifolius (Pursh.) Benth.
- Pedicularis contorta Benth.

Umbelliferae
- Lomatium cous (S. Wats.) C. & R.
- Lomatium triternatum (Pursh.) Coult. & Rose