

For DeVelice

Rob, Thanks for taking the time to
go over my manuscript. The
ECODATA has been entered

P.

**ALPINE PLANT COMMUNITIES OF THE BEAVERHEAD, GRAVELLY AND
SNOWCREST RANGES OF SOUTHWEST MONTANA**

Stephen V. Cooper
9604 Goneway Drive
Richmond, Virginia 23233

and

Peter Lesica
P.O. Box 8944
Missoula, Montana 59807

Prepared for:
USDA Forest Service, Region One
Range, Air, Watershed and Ecology
P.O. Box 7669
Missoula, Montana 59807

October, 1990

INTRODUCTION

Scattered studies of alpine vegetation and the flora of the North American Cordillera had been reported prior to the early-1960's; however, since that time information has accumulated at a quickened pace. Initial studies on the alpine of Montana and adjacent regions concerned those areas with greatest accessibility and fewest logistic concerns, Logan Pass at Glacier National Park (Choate and Habeck 1967) Siyeh Pass, Glacier National Park, Big Snowy Mtns. and Flint Creek Range (Bamberg and Major 1968) and the extensive alpine of the Beartooth Plateau (Johnson and Billings 1962). More recent alpine studies have been completed in northwestern Wyoming (Spence and Shaw 1981, Scott 1966) and adjacent east-central Idaho (Moseley and Henderson 1988, Brunfeldt 1981) and south-central Idaho (Caicco 1983). Knowledge of alpine communities in southwest Montana will allow a more comprehensive portrayal of Northern Rocky Mountain alpine ecosystems.

OBJECTIVES

We collected quantitative data on physical site descriptors and on the composition, structure and productivity of the alpine vegetation from the southern portion of the Beaverhead National Forest. We used this data to: 1) compile a brief description of physical habitat and community types, 2) compare and contrast the flora/vegetation of our study area with that of adjacent areas, 3) perform preliminary ordinations and objective classifications for insight into environment-plant community relations. This project also constituted a test case for the application of the USFS Northern Region's ECODATA procedures to a vegetation type not previously sampled.

STUDY AREA; REGIONAL VEGETATION, CLIMATE, and GEOLOGY

Our study area encompassed the Gravelly, Snowcrest, Lima Peaks and Beaverhead Ranges of southern Beaverhead and Madison Counties, Montana. These ranges are east of the Continental Divide and in the lee of high mountain ranges of central Idaho. This area is semi-arid, with both a lower and upper treeline. In addition, the valleys are rather high and usually rimmed by relatively high ranges. This accounts for their being generally cold, frosty and unsuitable for establishment of tree species that are not cold-adapted. Thus Pseudotsuga menziesii and Pinus flexilis, not Pinus ponderosa, are climax dominants of lower treeline and extend through the montane to the middle of the subalpine. Pinus flexilis extends onto sites drier/warmer than can be tolerated by Pseudotsuga; it also shows a preference for the calcareous substrates of this area.

The upper subalpine is composed of Abies lasiocarpa, Picea, Pinus contorta and Pinus albicaulis (very occasionally P. flexilis)

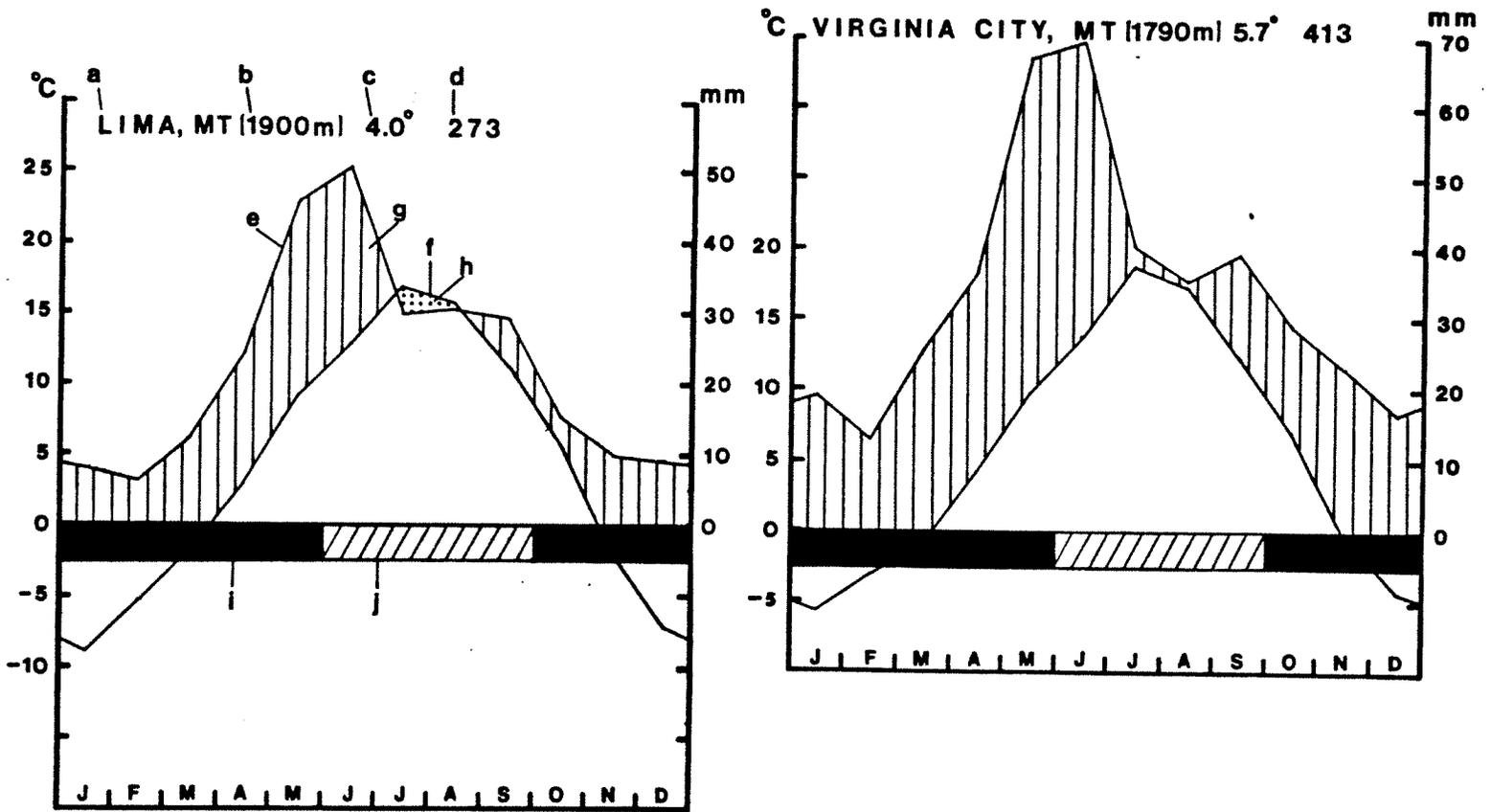
whose proportions depend primarily on successional status, aspect and to a lesser degree substrate. Above approximately 8,500 ft the forest canopy becomes progressively more open and dominated by Pinus albicaulis. Near timberline the belt of mostly continuous forest gives way to atolls of stunted and flagged trees interspersed among non-forest vegetation. The extent of true krummholz, trees not reaching much more than waist height due to ice particle abrasion of exposed surfaces, is very limited. Forest communities for this area are detailed in Pfister et al. (1977).

The non-forest communities at timberline can be described as Artemisia tridentata ssp. vaseyana dominated shrub-steppe as well as Festuca idahoensis dominated grassland and subalpine forb fields on the moister sites. Many of the plant associations comprising these high elevation steppes have been described by Mueggler and Stewart (1980).

Figure 1 presents Walter-type climate diagrams for Virginia City and Lima, MT. Though these stations are not alpine (probable climax vegetation characterized by, respectively, the Pseudotsuga menziesii series and Artemisia tridentata shrub-steppe), they do represent respectively, the north and south extremes of the study area and the patterns of precipitation distribution associated with each. Clearly the seasonal march of precipitation and temperature is very similar for the two stations. Despite being 110 m (360 ft) lower, Virginia City receives 140 mm more precipitation. We suspect that Lima lies in a rain shadow of the Beaverhead and Tendoy Ranges to the west and Lima Peaks to the southwest. A simplistic comparison of these stations would suggest that the Gravelly and Snowcrest Ranges receive greater amounts of precipitation than the Lima and Red Conglomerate Peaks and Beaverhead Range. In terms of gross appearance, especially in the larger extent of forested vegetation in the Gravelly and Snowcrest Ranges, these ranges seem wetter. Without climatic data from the respective ranges, or at least a storm track map, the above comparison is pure conjecture.

Compared to Billing's (1988) diagrams of three climatically typical U.S. alpine tundra areas, the study area pattern is closest to that of Niwot Ridge, Colorado, but with the notable exception of having a distinct precipitation bulge in May and June. This bulge also sets our study area apart from Sierra Nevada and Appalachian alpine. The relatively droughty conditions (where precipitation curve drops near to or below the temperature curve) portrayed by our valley stations would not obtain in the alpine where precipitation increases and the temperature curve would be depressed by about 3.2 to 3.8 degrees Celsius when extrapolated to the 9,500 feet contour (the lowest elevations of our alpine). Such a depression would result in a total of six months with below freezing average temperatures. Some authors characterize alpine tundra as having a climate for

Figure 1. Walter-type climatic diagrams for two stations in study area vicinity, Virginia City and Lima, Montana. Lower case letters on the Lima station indicate the following: a. station name; b. station elevation (meters); c. mean annual temperature (degrees Celsius); d. mean annual precipitation (millimeters); e. monthly march of precipitation; f. monthly march of temperature; g. relatively humid season (vertical hatching, note axes explicitly scaled so that 10 degrees = 20 mm precipitation); h. period of relative drought; i. period with mean daily minimum below 0 degrees Celsius (blackened); j. months with absolute minimum below 0 degrees Celsius.



which average temperature never exceeds 10 degrees Celsius. However, the Sierra Nevada alpine has at least three months exceeding this figure and our lowest elevation sites would exceed it in July and August.

Parent materials in our study area are composed of a melange of predominantly sedimentary rock types of various ages (Table 1). The Snowcrest and Beaverhead Ranges and Lima Peaks are dominated by Mississippian and Pennsylvanian sedimentary limestones and dolomites (calcareous formations). Quartzite is extensive at uppermost elevations of the Lima Peaks. Red Conglomerate Peaks are predominantly Tertiary sediments, mostly Beaverhead Conglomerate and a reddish sandstone. The Gravelly Range is composed Jurassic and Triassic sediments (mostly sandstone and limestone) but the highest point, Black Butte, is a remnant stock of Quaternary basalt.

METHODS

SELECTING SAMPLING SITES:

Following an examination of USGS topographic maps and interpolating from studies of adjacent regions, we chose 9,500 ft as the upper treeline and lower altitudinal limit for our study. The 9,500 ft elevation limit consistently proved to be above both the majority of the high elevation Artemisia tridentata var. vaseyana dominated shrub steppe, as well as the majority of the scattered treeline stands. Other workers have consistently failed to consider A. tridentata v. vaseyana- and A. arbuscula-dominated vegetation as alpine community types; even where this type occurred much above timberline. With one exception, we did not sample Artemisia dominated communities. Ease of access to an extensive alpine area was a major determinant for selecting sampling locations within them.

VEGETATION SAMPLING:

Sampling procedures abided by the criteria set by Gauch (1982) and the ECODATA handbook (1989): 1) sample stands that are homogeneous in structure and composition, 2) methods must be standardized and objective, 3) collected data should be appropriate to the community, research purposes and subsequent analysis techniques; 4) efficiency in time and effort guides choice of method.

Visual homogeneity of composition and structure was the first sampling criteria satisfied. Additional efforts were made to avoid areas where physical site variables were not constant, e.g. change in slope or amount of pavement exposed. Sampling community types in a landscape where microtopography is a major

Table 1. Distribution of sample plots by mountain range and parent material type.

Mountain Range	GR	LP	SC	BH	
Parent Material (PM)					Total by PM
Limestone/ Dolomite	10	1	4	16	31
Calcareous Sandstone/ Quartzite	3	0	12	0	15
Calcareous Conglomerate	0	0	2	0	2
Calcareous Subtotal	13	1	18	16	48
Sandstone	2	0	0	0	2
Conglomerate	0	4	0	0	4
Mixed sediment.	0	2	1	0	3
Quartzite	2	2	0	0	4
Extrusive Volcanics	8	0	0	0	8
Alluvium	2	0	1	1	4
Siliceous Subtotal	14	8	2	1	25
Total by Range	27	9	20	17	73

1 GR = Gravelly Range, LP = Lima Peaks, SC = Snowcrest Range
BH = Beaverhead Range

determinant of vegetation pattern frustrates many techniques with a set plot size or shape.

We speculated that ocular estimation would be most accurate and efficient if our initial class estimates were carefully calibrated. In the initial portion of the field season, vegetation sampling was directed at the largest, most homogeneous stands (Festuca idahoensis or Deschampsia cespitosa dominated alpine grassland or meadow). Initial sampling consisted of, 1) laying out a macroplot (30 by 30 m) and estimating canopy cover for all vascular species to one of the following 13 classes:

Code	Class Range	Midpoint
0	0-0	0.0%
T	>0 - < 1%	0.5%
P	= or > 1 - < 5%	3.0%
1	= or > 5 - < 15%	10.0%
2	= or > 15 - < 25%	20.0%
3	= or > 25 - < 35%	30.0%
4	= or > 35 - < 45%	40.0%
5	= or > 45 - < 55%	50.0%
6	= or > 55 - < 65%	60.0%
7	= or > 65 - < 75%	70.0%
8	= or > 75 - < 85%	80.0%
9	= or > 85 - < 95%	90.0%
F	= or > 95 - 100%	97.5%

2) estimating cover class on 25 to 50 microplots (10 x 20 in, Daubenmire 1955) spaced at 5 m intervals along 5 to 10 randomly spaced transects laid parallel to the slope contour, 3) measuring average height by species by 1 ft classes.

Data analysis conducted immediately following the initial sampling indicated canopy coverage estimates from the microplot transects never differed by more than one cover class from the ocular estimates. In fact, class estimates matched for more than 80% of the species. Thus we concluded that ocular estimation of species cover would be appropriate and considerably more efficient than microplots. In addition, the variable shape and usually small size of alpine communities could be accommodated more easily.

To establish some baseline estimates of primary productivity for these sites, current year's growth of 3 to 6 randomly located microplots (10 in x 20 in, 25.4 cm x 50.8 cm) was clipped, pooled by life form (shrub, forb, graminoid) and field weighed (nearest gram). Air-dried weight was recorded following drying to a static reading.

SITE INFORMATION:

We made entries for all fields regarding geographic location and physical site variables (elevation, aspect, slope etc.) according to ECODATA (1989) prescriptions. At the 5, 15 and 25 m marks of the 30 m baseline tape we excavated small pits to measure litter and duff depths. One liter of soil collected from the mineral horizons of these pits was used to determine percent coarse fragments greater than 2 mm by volumetric displacement with water. A portable, temperature-compensated Myron L DCH4 meter was used to measure pH (nearest 0.05 unit) on a 2:1 distilled water-soil slurry of the < 2 mm fraction. A portion of the < 2 mm fraction was saved for future analyses, possibly organic matter and particle size distribution.

DATA ENTRY and ANALYSIS

All plot data were entered into Northern Region files (drawer = REGION, folder = ECO DATA) and proofed for errors with the programs ERRCHK and REPORT.

Analysis has been cursory to this point. Gauch (1982) has advocated that community research include three complementary approaches, direct gradient analysis, classification and indirect ordination. Our data gathering procedures were not appropriate for direct gradient analysis. We made use of both the R-1 program STRATA (for constructing releve and constancy-coverage tables) and the programs TWINSpan and DECORANA of the Cornell Ecology Program package (imbedded within STRATA for convenience). STRATA offers a means to subjectively group plots based on field derived insight, producing a Braun-Blanquet type releve ordering and community type grouping. The goodness of fit of plots to groups may be tested objectively through a matrix of Sorensen's Coefficient of Community (plot to plot and plot to community type) and the data set reordered.

Our initial DECORANA and TWINSpan runs have been conducted with a data set unedited for rare species (contrary to the recommendations of Gauch and Singer (1982) to reduce sensitivity to multivariate manipulations). The data set was also unstandardized to a sample total of 100 as advocated by del Moral (1979) to reduce the potential distortion of dominant species and equalizing each stand's contribution.

RESULTS

Local parent material and mountain range for sample plots are presented in Table 2. The Gravelly Range was most intensively sampled because it has greater accessibility and more alpine terrain with a greater variety of parent materials. The volcanic substrates of this range, unique in our study, were possibly

Table 2. Soil variables and selected surface features by physiognomic types of the Beaverhead National Forest alpine study area (average followed or subtended by standard deviation in parentheses).

Soil/Surface Variables	Physiognomic Types (Number of Plots)						
	AG (16)	AT (20)	FF (14)	SB (09)	DS (04)	WM (04)	AM (06)
Exposed Soil /gravel (%)	10 (08)	13 (22)	53 (28)	70 (27)	03 (02)	01 (01)	01 (01)
Exposed Rock (%)	03 (05)	03 (03)	23 (21)	09 (13)	06 (05)	00 (00)	01 (01)
Organic Cover (%)	86 (15)	78 (25)	12 (14)	18 (27)	90 (10)	95 (03)	92 (06)
Moss Cover (%)	13 (22)	04 (09)	01 (01)	03 (10)	43 (33)	40 (40)	82 (08)
Coarse Fragments (%)	25 (20)	28 (20)	54 (13)	30 (24)	15 (15)	08 (09)	02 (02)
pH (nearest 0.05 unit)							
Calcareous Substrates	7.30 (0.20)	7.40 (0.25)	7.90 (0.25)	7.35 (0.25)	7.45 (0.20)	7.00 (0.10)	7.60 (0.10)
Non-calc. Substrates	6.85 (0.15)	6.00 (0.40)	7.05 (0.25)	6.05 (0.65)	----	6.50 (0.20)	5.65 (0.25)

1 AG=alpine grassland, AT=alpine turf, FF=fellfield, SB=snowbed, DS=dwarf shrub, WM=alpine meadow, AM=alpine marsh

oversampled relative to their areal extent. The southern portion of the long and linear Beaverhead Range is a monotonous expanse of limestone and thus was somewhat less intensively sampled. The Red Conglomerate Peaks (considered as part of the Lima Peaks in reporting our results) may also have been undersampled. We observed significant expanses of limestone/dolomite and reddish-hued formations that were logistically inaccessible. Access to the Snowcrest Range was also difficult, and this range no doubt has some substrate types that we did not sample.

The predominance of calcareous substrates in the alpine of these is quite possibly greater than reflected by the 66% of our sample. After repetitively sampling calcareous sites we began actively seeking other substrate types knowing community composition is often substantially influenced by substrate type.

To report these preliminary results, stratifications could be based on habitats (site types) or floristically defined community types (plant associations). Various authors (Marr 1961, Johnson and Billings 1962, Brunsfeld 1982) have suggested site types and features characterizing them. Some habitats bearing a single appellation, e.g. the snowbed type, may encompass a diverse floristic gradient associated with a steep environmental gradient. These habitats are best described with intensive sampling along hypothesized gradients and are only crudely accommodated by our approach.

If one accepts similarity of species assemblages as indicative of similarity of environment (presuming similar successional status), then plots can be grouped and discussed as unique environments. This was essentially the approach of Eddleman and Ward (1984) in the Colorado Front Range, which corroborated the correspondence of specific plant assemblages and environmental factors. These studies were conducted over several years in a circumscribed area, allowing greater confidence in the correlation between environment and vegetation. Given the preliminary nature of our data, we considered it appropriate to organize the remainder of our report around physiognomic types. These types are recognized by their gross physical appearance which in turn is conditioned by both their physical setting and vegetational composition.

NOTE: In the following discussions of physiognomic types, physical site parameters and values related to cover and productivity by life form can be found in Appendix I and the vegetation descriptions (constancy/coverage tables) are documented in Appendix II.

Alpine Grassland (AG) physiognomic type (p.t.):

Physical Site Description: Some researchers would consider this physiognomic type to be an extension of montane grasslands rather

than alpine. Nonetheless, 16 plots ranged from upper treeline to several hundred feet above treeline (9,420-9,900 ft) in a complex alpine mosaic. In rolling terrain, such as the old erosion terraces of the Gravelly Range, the alpine grassland p.t. was often extensive. It frequently graded to alpine turf p.ts. on drier exposures and to wet meadow, usually Deschampsia cespitosa dominated, on moister sites of topographic lows. Alpine grassland was found on a broad range of parent materials from limestone to extrusive volcanics and siliceous sedimentary.

Alpine grasslands mostly occurred on mid- to upslope positions and terraces. They were notably scarce on windward (west- to southwest-facing) slope shoulders but were frequently found on lee slope (east-facing) shoulders. Slope inclination varied widely, from flat to 70%. Aspects include all but the warmest southerly exposures and were generally northwest- to east-facing.

Litter was shallow (0.6 in) and combined with moss (13%, Table 2) and basal vegetation presented a nearly continuous (mean=86%) cover. The high organic coverage accounts for the fact that amounts of exposed soil/gravel (10%) and rock (3%) were minor. Coarse fragment content (Table 2) averaged 25% and ranged from 2 to 65%. For calcareous substrates pH values were always greater than 7.00, averaging 7.30; those of siliceous substrates were in the 6.70 to 7.00 range.

Vegetation/Productivity: Graminoids clearly dominated this type with a canopy cover (c.c.) averaging 51% but c.c. varied widely (SD=17%). Forb cover was also high (35%) and variable (SD=14%). These c.c. figures are close to those of the alpine turf p.t. Across the landscape, alpine grassland and turf graded into one another; however, these types are generally distinct, with alpine grassland dominated by taller, bunch-forming grasses and alpine turf characterized by rhizomatous (turf-forming) graminoids. Community stature was reflected in the higher productivity of alpine relative to turf communities, 676 versus 449 and 679 versus 364 lbs/acre, respectively for graminoids and forbs. Shrub production is nearly absent in both community types.

Festuca idahoensis was the lower elevation dominant giving way to F. ovina, Carex obtusata and C. elynoides at higher elevations and more exposed sites. Leucopoa kingii was a minor to moderately important bunchgrass component on the more stressful and sparsely vegetated of the Lima Peaks and Beaverhead Ranges. Modest coverages, usually less than 10%, of Deschampsia cespitosa and Bromus pumpellianus indicated sites moister than average. Agropyron caninum regularly occurred here (50% constancy) and throughout the alpine. Other common (>25 % of plots) associates of this assemblage were Poa alpina, P. sandbergii, P. interior and Carex petasata. Artemisia frigida and A. tridentata var. vaseyana and Chrysothamnus viscidiflorus were found in minor

amounts only at the lower elevation fringes where AG graded to A. tridentata v. vaseyana dominated shrub-steppe.

Those relatively few forbs that had their highest coverage or constancy within AG were Arabis nuttallii, Besseya wyomingensis, Castilleja pallescens, Delphinium occidentale, Frasera speciosa, Geum triflorum, Heuchera parviflora, Hymenoxys grandiflora, Phlox hoodii, Polemonium viscosum, Saxifraga rhomboidea, Sedum lanceolatum, Senecio streptanthifolius and Valeriana edule. None of these species was unique to AG. Species indicative of moister sites include Antennaria anaphaloides, Lloydia serotina, Polygonum bistortoides, V. edule and Zigadenus elegans. Species not listed above but having at least 50% constancy are Achillea millefolium, Cerastium arvense, Phlox pulvinata, Potentilla diversifolia, Penstemon procerus, Lupinus argenteus and Oxytropis campestris. The high coverages of these species and P. viscosum may be due to past stock grazing practices.

Alpine Turf (AT) physiognomic type:

Physical Site Description: The alpine turf physiognomic type has perhaps the largest areal extent of all p.ts. in our study area and spans the full range of sampled parent materials. In Colorado's Front Range Marr (1961) considers a similar Kobresia-dominated turf to be the climatic climax of the alpine tundra zone. Our stands may also constitute climax communities. Sample site elevations ranged from 9,640 to 10,360 ft with an average of 9,925 ft (SD=248 ft). Of the broad spectrum of landscape positions only a few provide the microclimate requirements of this c.t. Alpine turf occupied mostly gentle upper slopes, saddles and gaps along ridges and slope shoulders. It was found only infrequently on ridges and topographic lows where snow accumulations are expected. In general the habitats of alpine turf qualify as less windswept than those of alpine grasslands. Average slope inclination was only 17% (SD=14%) and no slopes were steeper than 45%. Steeper slopes were often fellfields or mantled with talus-scrree.

The average amount of exposed gravel/soil was only 13% (SD=22%), but values ranged from greater than 90% on ridge sites where soil deflation was severe to trace amounts on ecotones with grassland sites. Amounts of exposed rock did not exceed 15% and mostly were less than 5%. The relative dryness of alpine turf was reflected in the low moss coverages (mean=04%), although moister sites had much higher moss coverage (40-80% cc). The coarse fragment content averaged 28%, ranging from 7% to 75%, only slightly rockier than grasslands. Calcareous soils tended to have higher pH values (mean=7.40) than those of alpine grasslands. Extrusive volcanics had notably low pH values (mean=6.00).

Vegetation/Productivity: Alpine turf varied from a sward of turf graminoids with diverse and abundant forbs and very little bare ground to an open canopy with cushion plants sharing dominance with turf-formers and litter or exposed gravel/soil the dominant aspect. Closed canopy stands tended to border alpine grasslands while open canopy examples graded to cushion plant-dominated fellfields or other rocky habitats.

Only four shrub species were found on the 20 plots and only one plot had as much as 5% shrub cc. The graminoid component clearly dominated these sites (50% cc, SD=19%). Average forb canopy cover was 30% (SD=19%) and close to that of other physiognomic types. Though alpine turf coverage values for forbs and graminoids were very similar to those of alpine grasslands, the AT productivity for both life forms is much less (forbs, 364 versus 679 lbs/acre; graminoids, 449 versus 676 lbs/acre) due to the reduced stature of AT component species.

Turf-forming Carex elynoides with 90% constancy and 32% cc was the foremost graminoid. Other common species of Carex in order of decreasing importance were C. rupestris, C. scirpoidea and C. obtusata. Bunch-forming grasses had much lower coverages and constancy than in alpine grasslands with two exceptions: 1) Festuca ovina had high constancy, but low coverage, 2) Calamagrostis purpurascens and Hesperochloa kingii had moderate constancy and coverage. Plots with relatively high coverages of H. kingii and C. purpurascens occurred in the Lima Peaks and Beaverhead Ranges. These stands probably represent environments transitional to those described by Moseley and Henderson (1989) for east-central Idaho and Caicco (1983) for south-central Idaho.

The following forbs attained their highest constancy or coverage in alpine turf communities: Astragalus kentrophyta, Bupleurum americanum, Cymopterus bipinnatus, Mertensia oblongifolia, Oxytropis campestris, Phlox pulvinata, Potentilla ovina and Selaginella densa. All of these species occurred in at least two other c.ts. Forbs of high constancy, capable of attaining modest coverages (> 5%) were P. pulvinata, Potentilla diversifolia, Polemonium viscosum, Lomatium cous, Lupinus argenteus, and O. campestris. Most stands had a diverse forb assemblage with no expressed dominance. Presence of Zigadenus elegans and Polygonum bistortoides occurred in uncommon, vernal moist sites.

Fellfield/Cushion-plant (FFCP) physiognomic type:

Physical Site Description: The FFCP physiognomic type was, next to alpine turf, the most abundant in the study area. It occurred on all varieties of substrate in all four mountain ranges. Generally mid-latitude alpine fellfields are characterized as masses of exposed bedrock with steep slopes, subject to intense erosion. It is the cracks and crevices of the jointed or jumbled

bedrock that collect enough soil to support plant development. This site type spans a continuum of conditions from raw, shifting talus (not sampled) to stable lower slopes where appreciable soil has accumulated. We included these lower slope conditions because compensating environmental factors have produced vegetation distinguished by its short stature (mostly < 10 cm tall) and high proportion of cushion plants, not unlike that of the steeper slopes. Most often FFCP grades to alpine turf communities. We presume FFCP to constitute harsher sites in terms of exposure and lack of soil development.

Elevations of our stands ranged from 9,360 to 10,530 ft, averaging 9,860 ft. Our sampling reflects the general fact that this c.t. most often occurs on windward, west- to southeast-facing slopes but is capable of developing on any rocky exposure. The average slope inclination is moderate (34%) but was biased by our avoidance of steep, unstable slopes.

Exposed bare ground was much greater than for any other c.t., ranging from 40% to more than 95%. Soil coarse fragment content was the highest among all types, averaging 54%. pH values were uniformly high for both calcareous (7.85) and non-calcareous (7.05) substrates, probably reflecting poor development and reduced organic matter input.

Vegetation/Productivity: Cover values were 11% for graminoids and 28% for forbs. Our sampling was biased by avoiding steep, unstable slopes. Consequently, these values are higher than those cited for this environmental type in other areas. Nonetheless, of the 7 physiognomic types we recognize, FFCP had the lowest total canopy coverage and productivity (430 lbs/acre).

This physiognomic type is dominated by low-growing forbs. The only shrub sampled on these sites was Haplopappus suffruticosus. Considering the diversity of microsites, it is not surprising that herb diversity was appreciable (> 120 species). There were no graminoids characterizing these sites; however, those with the highest constancy (never exceeding 60%) or cover values were usually associated with turf or grassland communities, Carex elynoides, C. rupestris, Agropyron scribneri, Festuca ovina, F. idahoensis and Hesperochloa kingii. Koeleria cristata and Trisetum spicatum had their highest constancy in this c.t.

Members of the following two groups of forbs were found on at least one third of the plots and/or had the highest forb cc value of at least one plot; Group 1) including decumbent and cushion plants, typically with single root stalk with stems compactly arranged and usually spreading horizontally to form dense foliage: Anemone multifida, Arenaria congesta, A. obtusiloba, Astragalus kentrophyta, Besseya wyomingensis, Cerastium arvense, Cymopterus bipinnatus, Draba oligosperma, Erigeron compositus, Eritrichium nanum, Eriogonum ovalifolium, Lomatium cous, Phlox

multiflora, P. pulvinata, Silene repens, Smelowskia calycina, Townsendia montana and Selaginella densa, Group 2) upright plants: Achillea millefolium, Bupleurum americanum, Frasera speciosa, Hymenoxys grandiflora, Lupinus argenteus, Oxytropis campestris, O. viscidiflorus, Potentilla diversifolia, Potentilla ovina, Senecio canus and Senecio streptanthifolius.

Snowbed (SB) physiognomic type:

Physical Site Description: Snowbed (also referred to in the literature as snowflush, snow garland, snow-patch and snowbank habitat) vegetation was found throughout the study area. Its distinguishing feature is a persistent snow cover sufficient to limit the growing season. Eddleman and Ward (1984) and Isard (1986) have demonstrated that similar communities in the Colorado Front Range had a snow-free period of less than about two months. Patches of this vegetation, often forming on the lee side of ridges, are generally linear and seldom more than several hundred square meters. It is difficult to predict where snowbeds will form because they arise from downdrafts produced by the interaction of complex topography and prevailing winds. Time of release is determined mainly by intensity of solar insolation and amount of snow deposition. Sampling was made difficult by the linear patch shape and steep phenological gradients resulting from uneven snowmelt. Community patterns described by Marr (1961) for Niwot Ridge, Colorado also occurred in our study area.

"If the ground first exposed by snow melt is fairly well drained, but is moist, lush sedges and grasses dominate. From this area inward to the site of last-melting snow, there may be a progressive decrease in the size and density of plants and a progressive change in species. In some sites a lichen-moss community occurs on the ground that is the last to be exposed by the melting snow."

Elevations of the nine plots ranged from 9,480 to 9,860 ft and averaged 9,685 ft. All plots occurred on slope shoulders and terraces. Slope shapes were straight, concave or undulating where high moisture content contributed to slumping. In our limited sample, no one slope aspect appeared to have a higher frequency but degree of slope steepness was mostly moderate to high.

When we initiated sampling in mid-July, some snow fields were still present or vegetation so phenologically retarded as to preclude sampling. Sampled sites were characterized by their retarded phenology, surface soils at or near saturation, and high percentages of exposed soil and gravel. In fact, a comparison of snowbeds with fellfields indicates that snowbeds tended to have both greater amounts of exposed soil and gravel and total exposed nonorganic substrate (Table 2). Values for these variables are probably underestimates because sites which were last to reach a

snow free condition also had more exposed substrate, and these sites could not be sampled given our narrow sampling window. The high degree of substrate exposure may result more from an environment favoring decomposition than to low productivity and small amounts of litter.

The lower pH values of snowbed soils compared to fellfields for both non-calcareous and calcareous substrates (Table 2) is probably attributable to the increased leaching and organic input in snowbed environment. The coarse fragment content (30%) was similar to that of AG and AT and considerably less than that of fellfields.

Vegetation/Productivity: Excepting fellfields, snowbed sites were the least productive environments, especially with regard to graminoids (Appendix I). Average forb canopy coverage (30%) was comparable to that of fellfields, but the upright form of SB forbs resulted in greater productivity. We probably overestimated productivity by undersampling the least productive, more phenologically retarded sites.

No shrubs occurred in this type. The moistest sites were characterized by Juncus parryi, Carex haydenii, C. petasata, C. microptera, Deschampsia cespitosa and Poa alpina. Agropyron scribneri was found on eroded or unstable slopes in environments very comparable to those described in the alpine of east-central Idaho (Moseley and Henderson 1988). Graminoids with high constancy values in this type were Agropyron caninum, Festuca idahoensis, C. haydenii, Poa alpina and P. pattersonii. These species seldom exceeded 10% cover.

Forbs with their highest constancy values in this type include Achillea millefolium, Agoseris glauca, Antennaria umbrinella, Arenaria congesta, Aster foliaceus, Erigeron ursinus, Lewisia pygmea, Lupinus argenteus, Pedicularis parryi, Phlox multiflora and Solidago multiradiata. Of these, A. umbrinella, L. pygmea and E. ursinus were especially characteristic of this habitat because of their relatively high coverages and occurrence in only one other type. Other species with high constancy or that dominated at least one stand include Erigeron rydbergii, Potentilla diversifolia, Polygonum bistortoides, Ranunculus eschscholtzii and Sibbaldia procumbens. Of these, R. eschscholtzii and S. procumbens are characteristic of snowbank habitats in other regions (Marr 1961, Eddleman and Ward 1984, Spence and Shaw 1981, Johnson and Billings 1962).

Dwarf Shrub (DS) physiognomic type:

Physical Site Description: This is one physiognomic type we defined for its life form composition rather than its habitat or structural uniformity. Nonetheless, habitats in our small 4 plot sample were strikingly similar. Substrates were exclusively

calcareous with amounts of exposed raw surface usually approaching those recorded for non-shrubby wet sites (Appendix 1). Plots spanned a 1,000 ft range (9,550 to 10,060 ft) but always occurred on moderately inclined (21-45% slope) north-facing slopes. Plot position (mid- to lower slopes) and saturated soils indicate that these sites may have delayed snow release and/or increased moisture input through seepage. Our observations confirmed that most similar stands occur in similar habitats. A possible exception was the occurrence Dryas octopetala patches on apparently well-drained and relatively dry north-facing slopes. Usually these patches were associated with the finer segregates of patterned ground and fellfields. The dwarf shrub type often had abrupt ecotones with other community types. It most frequently bordered sedge-dominated wet meadows.

Coarse fragment content of soils was mostly less than 10% (Table 2). However, even in a stand with 36% coarse fragment content, very little surface was exposed due both to abundant litter and high moss coverages. Despite the high moisture status and organic input of these sites, pH values were relatively high (mean=7.45). Solifluction lobes were present in all sampled stands. Wet meadows were the only other physiognomic type with obvious examples of this feature.

Vegetation/Productivity: Shrub cover was uniformly high, while that of graminoids was low (Appendix I). Forb cover averaged 30%, a value typical across many types. Shrub production (828 lbs/acre) was about 50 times that of any other alpine physiognomic type.

Salix nivalis had the highest constancy and coverage followed by Dryas octopetala, S. arctica, and S. dodgeana. Salix glauca, in a dwarfed condition, was dominant on one plot. It (or a very similar Salix spp.) also appeared to dominate narrow vertical patches on extremely steep north-facing slopes. From our data set, it is unclear what factors may distinguish sites dominated by Salix spp. from those dominated by Dryas. Isard (1986) and Komarkova and Webber (1978) state that D. octopetala is restricted to north-facing slopes in Colorado because of the attendant microclimate and soil disturbance regime associated with these "turf-banked" terraces. Isard (1986) suggests that dwarf Salix spp. may favor more protected sites with a shallow water table. He equates "moist shrub tundra" to "moist meadow" vegetation that lacks willows.

Poa alpina was the only graminoid characteristic of this type. Though lacking in constancy, Carex haydenii and C. nova attained modest coverages. On the basis of such a small sample, characterization is problematical, but forbs whose constancy or coverages were highest in the dwarf shrub type include Erigeron simplex, Hedysarum sulphurescens, Lloydia serotina, Polygonum viviparum, Ranunculus eschscholtzii, Senecio crassulus, Silene

acaulis, Synthyris pinnatifida, Trifolium haydenii and Zigadenus elegans. The high coverages of Caltha leptosepala indicate high moisture microsites within this type.

Wet Meadow (WM) physiognomic type:

Physical Site Description: Wet meadows occurred in all mountain ranges but were of very limited extent (and unsampled) in those ranges dominated by calcareous substrates. This type is similar in habitat and composition to the Deschampsia cespitosa/ Carex spp. habitat type of Mueggler and Stewart (1980) (see Appendices I & II). Both wet meadow and alpine marsh types were scarce within our study area due to the predominance of limestone/dolomite which fractures deeply, allowing percolation of groundwater. These substrates mainly support vegetation that is not dependent upon a high or perched water table. The wet meadow type was sampled on the lower fringes of the alpine (9,250 to 9,630 ft). It was found mostly on terraces or rolling terrain, rather than steep slopes. According to Eddleman and Ward (1984), Deschampsia-dominated meadow communities develop in lee positions where snow accumulates but melts relatively early.

Exposed rock and gravel and soil were minimal, and organic cover was nearly complete (Table 2). Some sites had a continuous mat of moss (mean=40% cc). Coarse fragment content did not exceed 15% and averaged only 8%. The trend in pH (Table 2) was toward lower values than those of better drained sites.

Vegetation/Productivity: Shrubs were not present in this type. With a favorable moisture balance it is not surprising that total cover and productivity of WM is high (Appendix 1). Graminoids dominate with a mean c.c. of 80% and productivity of 1362 lbs/acre. The robustness of forbs is evidenced by the high productivity (552 lbs/acre) that is about 150 lbs/acre higher than for other c.t.s. with comparable coverage values. On the basis of limited data, Mueggler and Stewart (1980) suggest that Deschampsia cespitosa/Carex spp. h.t. is the most productive (2,595 lbs/acre) grassland type in western Montana. Their productivity value for this type were much higher than ours as they sampled only sites below the alpine tundra zone.

Deschampsia cespitosa was the dominant/co-dominant graminoid in all plots. Carex atrata and C. haydenii were the most common sedges. Neither of these species are cited by Mueggler and Stewart (1980) for their Deschampsia/Carex spp. h. t. Festuca idahoensis and Juncus balticus shared dominance with D. cespitosa in about half the stands. Phleum alpinum has its highest constancy (100%) in this type.

Wet meadow forb composition is in no way distinctive among other alpine types, but compared to the low elevation Deschampsia

Cespitosa/Carex spp. h.t. (Mueggler and Stewart 1980) our alpine sites showed the following notable differences in constancy:

	low elevation	alpine
<u>Potentilla gracilis</u>	100%	0%
<u>Potentilla diversifolia</u>	17%	100%
<u>Senecio crassulus</u>	0%	75%
<u>Myosotis sylvatica</u>	0%	75%
<u>Saxifraga oregana</u>	0%	50%

The mesic nature of both low and high elevation sites is reflected in high constancy and moderate c.c. for Polygonum bistortoides and Pedicularis spp.; Pedicularis parryi, P. cystopteridifolia and P. groenlandica are found in the high subalpine and alpine only.

Alpine Marsh (AM) physiognomic type:

Physical Site Description: Marshes were of very limited extent in the alpine zone, confined to sites that have a high water table and soils saturated throughout the growing season. These sites most often were poorly drained topographic lows or in shallow-sloped positions receiving runoff from late-persisting snowbanks. Elevations ranged from 9,480 to 10,040 ft with lower elevations (<9,800 ft) predominating. Slopes did not exceed 18%.

Because they occupy lower landscape positions, marsh habitats receive fine slopewash materials and colluvium. Soil coarse fragment content does not exceed 5%. The saturated conditions, often with standing water through the growing season, favor the high moss coverages (>70%, mean=82%). Soils we judged to be mostly alluvium had the lowest pH values (5.65) of all habitats. Soils developed from weathered-in-place limestone had values similar to other site types developed on calcareous materials (mean= 7.60).

Vegetation/Productivity: By definition the shrub component is minor; however, the wettest of dwarf shrub sites had a similar moisture regime and landscape setting. Regardless of whether sites were dominated by graminoids (2 plots) or forbs (4 plots) their productivity was high (mean=1,779 lbs/acre). We speculate that the somewhat lower alpine marsh productivity compared to that of wet meadows is due to decreased soil aeration.

Carex lenticularis and Juncus balticus each dominated one plot. Other graminoids with high constancy or coverage include C. haydenii, C. atrata, C. scopulorum, Deschampsia cespitosa, Phleum alpinum, J. mertensiana and J. drummondii. At 100% constancy and 45% c.c. Caltha leptosepala strongly dominated these sites; only Aster foliaceus and Pedicularis groenlandica are nearly as common. Forbs with their greatest prominence in alpine marshes

include Claytonia lanceolata, Montia chamassoii, Saxifraga oregana, Stellaria longipes and Veronica wormskjoldii.

DISCUSSION

TWINSPAN Analysis:

The above classification is based on structural and environmental similarity. In order to verify our classification, we compared it to one created objectively using TWINSPAN, a divisive, hierarchical sorting technique (Gauch 1982). Table 3 shows how level 3 and 4 TWINSPAN groupings of the sample plots correspond to the subjective allocation of plots to physiognomic types. The closer the correspondence between the two approaches, the greater the number of plots within a TWINSPAN class that are contained within a particular physiognomic type. Adjacent TWINSPAN classes are most vegetationally similar.

The wet meadow type shows a relatively high degree of agreement between the two approaches because 3 of the 4 plots are allocated to TWINSPAN class 9 (level 4) and the remaining plot grouped with the similar alpine meadow type. Alpine meadows (AM) and turf (AT) show the next highest agreement, their plots allocated to three adjacent level 4 classes. This result is readily understood in terms of the strongly expressed dominance of a few species (Caltha leptosepala, Pedicularis groenlandica and Deschampsia cespitosa within AM, D. cespitosa and Carex atrata within WM and Carex elynoides, C. rupestris, Festuca ovina and Calamagrostis purpurascens within AT).

In contrast to meadow and turf types, fellfield (FF) plots demonstrate considerable floristic diversity, being distributed across 5 non-contiguous level 4 classes, although 11 of the 14 plots are in two adjacent classes. Examination of the FF outliers can lead to insights that cause revision of the subjective classification. Plot 08, on the basis of field notes, was considered anomalous even at the time of field sampling. It should probably assigned to the snowbed p.t. Another fellfield outlier, plot 03, is a compositional hybrid between alpine grassland (having Festuca idahoensis) and fellfield (with Phlox spp. and Oxytropis viscida well represented). Its habitat characteristics, especially exposure, are more typical of fellfields. This process of examining outliers and major splits within subjectively defined physiognomic types is the crux of successive approximation that leads to a refined classification. We note that J.W. Marr (1961), studying just one alpine tundra landscape at Niwot Ridge on Colorado's Front Range spent more than eight years, mostly "on site", to produce a description of associations (termed by Marr stand types) and their site parameters.

Table 3. Comparison of plot allocation to subjectively recognized physiognomic types versus their objective assignment to TWINSPAN level three and four classes.

TWINSPAN classes sequentially arranged		Physiognomic Types							Total
		AM	DS	WM	SB	AG	AT	FF	
Level 3 1	Level 4 1	0	0	0	0	2	0	0	2
	2	0	0	0	0	2	0	4	6
2	3	0	0	0	0	1	4	7	12
	4	0	1	0	0	1	10	1	13
3	5	0	1	0	3	5	6	0	15
	6	0	0	0	0	5	0	1	6
4	7	0	0	0	3	0	0	0	3
	8	0	0	0	3	0	0	1	4
5	9	0	0	3	0	0	0	0	3
	10	2	0	0	0	0	0	0	2
6	11	3	0	0	0	0	0	0	3
	12	1	0	1	0	0	0	0	2
7	13	0	2	0	0	0	0	0	2
Total by physiognomic types		6	4	4	9	16	20	14	73

1 AM=alpine marsh, DS=dwarf shrub, WM=alpine meadow, SB=snowbed
AG=alpine grassland, AT=alpine turf, FF=fellfield

DECORANA Analysis:

We have only begun to explore the data set with this technique. Examination of preliminary runs (with rare species retained and lacking Wisconsin double standardization) shows DECORANA to have recovered, in arrangement of plots along axis 1 (Figure 2), the gradient of the hypothesized major controlling factor, moisture. Clearly the alpine marsh type is the wettest and, with the exception of plot 41 (dominated by Dryas octopetala), the dwarf shrub type is highly similar to alpine marsh. Wet meadows and snowbed physiognomic types are somewhat discrete, occupying intermediate (mesic) positions. The driest types, AT, FF, and AG show much intergradation; most alpine grasslands occupy the more mesic portion of the gradient but they also extend to the driest extremes. The AG stands representing the driest extremes are dominated by Hesperochloa kingii, Artemisia spp, and Poa sandbergii; these sites are warmer/drier than those dominated by Festuca idahoensis.

The gradient represented by Axis 2 of Figure 2 seems nonsensical. It appears that the uniqueness of plot 41 has constrained all variability to the center of the axis. DECORANA axis 3 (Figure 3), though giving greater separation of stands, provides no insight as to a possible gradient. The stands defining the extremes of this axis (plots 35 and 20) are both very wet sites. Most moist to wet sites occur near the center of this axis with plots from all other physiognomic types. This lack of interpretability of axes 2 and 3 probably reflects the high beta diversity of the data set. To reduce beta diversity the next step should be to construct separate DECORANA runs for the more moist sites (including snowbed communities) and the drier sites, including alpine turf, grassland and fellfields. This should achieve greater separation, at least along the newly derived primary axis.

Productivity and Floristics: Results from this initial sampling of southwest Montana alpine are not surprising. Our first approximation TWINSPAN and DECORANA analyses lend credence to our subjective physiognomic classification and its partitioning of environmental diversity. Results reaffirm the well documented observation (Scott and Billings 1964, Bliss 1966, Johnson and Billings 1962, Marr 1961) that the moisture gradient is the factor complex most strongly associated with alpine community composition and productivity. The net above ground productivity by physiognomic type is arranged below in the following order of types: fellfield (FF), snowmelt (SM), alpine turf (AT), dwarf shrub (DS), alpine grassland (AG), alpine marsh (AM) and wet meadow (WM).

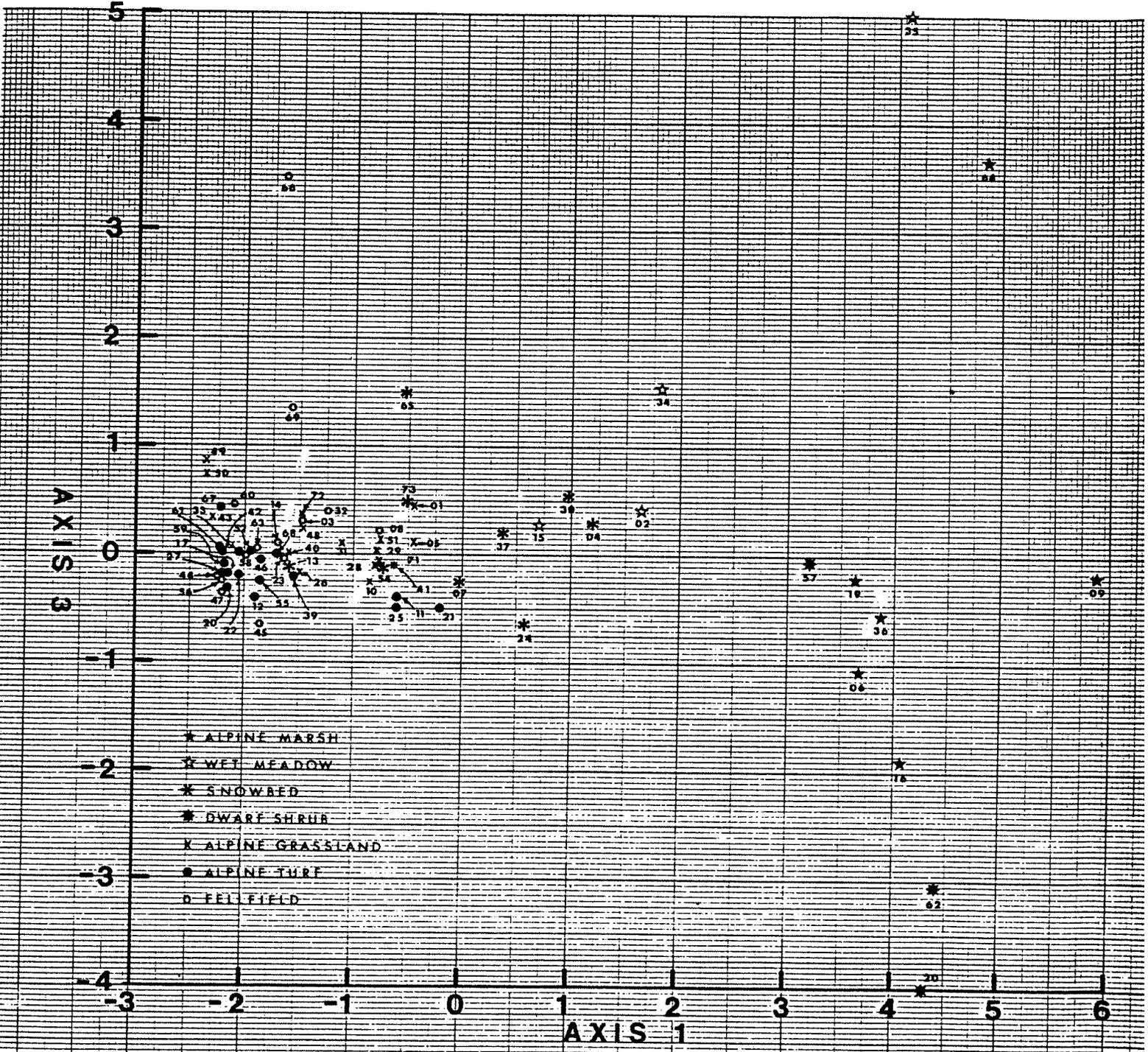


FIGURE 2.

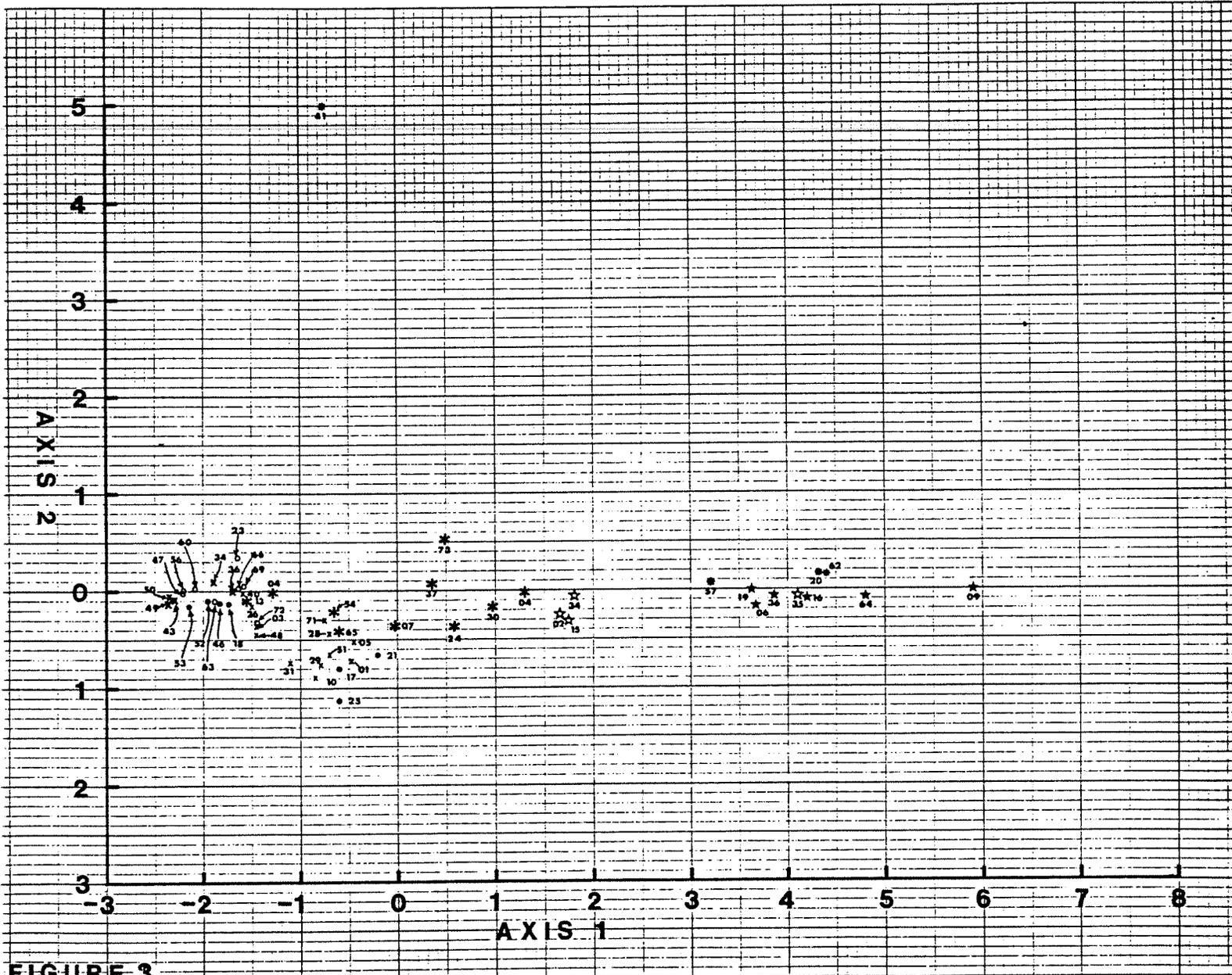


FIGURE 3.

	FF	SM	AT	DS	AG	AM	WM
grass	10	31	50	6	75	78	152
forbs	38	44	41	40	76	119	62
shrubs	0	0	0	93	2	2	0
Total	48	75	91	139	153	189	214

The above range in productivity values on a percentage basis is much greater than that of Colorado's Niwot Ridge (124 to 355 g/m², May and Webber 1982). The most floristically similar communities between the two studies, wet meadows, shows closely comparable productivities, 189 vs. 196 g/m².

With the exception of snowbed and alpine marsh types, there is an obvious correlation between productivity and moisture status. The moisture status of alpine communities is seldom a consequence of direct input but results from wind redistribution of winter and early spring snowfall. Fellfields/cushion plant communities, with the lowest productivity, inhabit rocky terrain and windswept ridges with thin soils. Numerous authors have documented that these positions are nearly swept free of snow (snow depth seldom exceeds 10 cm), receiving their only growing season precipitation as late spring and summer rain. Alpine turf and cushion plant communities occur in a complex mosaic, but we speculate that cushion plant communities are more exposed to prevailing winds. Greater exposure results in considerably higher coarse fragment content, 54 versus 28% (Table 2), and exposed substrate (76 versus 16%).

The relatively low productivity of the snowmelt community is a result of reduced growing season. Scott and Billings (1964), May and Webber (1982) and Isard (1986) have identified snowpack duration as the second most important variable in determining productivity and composition of alpine tundra. We expect that had we been able to sample areas with the most persistent snowpack they would have been less productive than even cushion plant communities. Positions experiencing a snowpack-shortened growing season coupled with rapid soil moisture depletion due to exposure have the most reduced productivity of all.

There is considerable variation in the productivity of the dwarf shrub type because it includes both relatively dry Dryas-dominated and mesic to hydric Salix-dominated communities. Taken alone, the willow stands have a mean productivity of 168 g/m², higher than the alpine grassland type as one would expect based on their respective compositions and landscape positions.

Wet meadows are the most productive alpine types, having a more favorable moisture balance than either grasslands or marshes (bogs). We speculate the marsh type has decreased productivity caused by reduced soil aeration and reduced soil temperatures due to year-long soil saturation. The increased acidity of marsh

soils relative to that of wet meadows is probably not sufficient to lower nutrient availability and productivity. Wet meadows are most productive because they generally have sufficient available moisture and are located in positions protected from drying winds. Wet meadows frequently grade to snowmelt patches and occasionally to marshes where drainage is restricted. Drainage on calcareous sedimentary formations is seldom impeded which accounts for the relative rarity and reduced areal extent of marsh communities within the study area.

Floristic and vegetation type comparisons are beyond the scope of this report. However, our area shows greater floristic and community type affinity with the east-central Idaho alpine (Caicco 1983, Moseley and Henderson 1988) than with the Beartooth Plateau of south-central Montana (Johnson and Billings 1962). One significant difference between our area and Idaho is the very weak representation of both phases of Leucopoa kingii (= Hesperochloa kingii) grasslands. The Beaverhead Range would seem to be the northeasternmost extension of L. kingii dominated community types.

Forest Service personnel indicated that the Gravelly and Snowcrest Ranges had long been used for sheep pasturage. We wanted to assess the impact of livestock on composition and productivity of alpine vegetation but were unable to do so because we found no exclosures. We were surprised to find numbers of cattle drifting up into the alpine zone to graze. Impacts have apparently been concentrated in the riparian zone where they have churned soils, introduced weedy species and generally changed community composition. We observed an abundance of Juncus balticus, Juncus spp. and Poa pratensis in cattle impacted areas as well as increased turbidity and downcutting of streams. In these same areas we have noted heavy use by elk and thus possible resource competition between these two species.

LITERATURE CITED

- Bamberg, S.A. and J. Major. 1968. Ecology of the vegetation and soils associated with calcareous parent materials in three alpine regions of Montana. *Ecological Monographs* 38:127-167.
- Billings, W.D. 1988. Alpine vegetation. pp. 391-420 in M.C. yBarbour and W.D. Billings (eds.), *North american terrestrial vegetation*. Cambridge University Press, Cambridge, U.K.
- Brunsfeld, S.J. 1981. Alpine flora of east-central Idaho. M.S. thesis, University of Idaho, Moscow. 205 pp.
- Caicco, S.L. 1983. Alpine vegetation of the Copper Basin area, south-central Idaho. M.S. thesis, University of Idaho, Moscow. 99 pp.
- Choate, C.M. and J.R. Habeck. 1967. Alpine plant communities at Logan Pass, Glacier National Park, Montana. *Proceedings of the Montana Academy of Sciences* 27:36-54.
- Eddleman, L.E. and R.T. Ward. 1984. Phytoedaphic relationships in alpine tundra of north-central Colorado, USA. *Arctic and Alpine Research* 16(3):343-359.
- Gauch, H. G. 1982. *Multivariate analysis in community ecology*. Cambridge University Press, Cambridge.
- Holway, J.G. and R.T. Ward. 1963. Snow and meltwater effects in an area of Colorado alpine. *The American Midland Naturalist* 69:189-197.
- Isard, S.A. 1986. Factors influencing soil moisture and plant community distribution on Niwot Ridge, Front Range, Colorado, U.S.A. *Arctic and Alpine Research* 18(1):83-96.
- Johnson, P.L. and W.D. Billings. 1962. The alpine vegetation of the Beartooth Plateau in relation to cryopedogenic processes and patterns. *Ecological Monographs* 32:105-135.
- Komarkova, V. and P.J. Webber. 1978. An alpine vegetation map of Niwot Ridge, Colorado. *Arctic and Alpine Research* 10:1-29.
- May, D.E. and P.J. Webber. 1982. Spatial and temporal variation of the vegetation and its productivity, Niwot Ridge, Colorado. pp. 35-62 in J. Halfpenny (ed.), *Ecological studies in the Colorado alpine, festschrift for John W. Marr*. Institute of Arctic and Alpine Research, University of Colorado, occasional paper no. 37.

Moseley, R.K. and D.M. Henderson. 1988. Synecological relationships of alpine spike-fescue (Leucopoa kingii [Wats.] grasslands in east-central Idaho, U.S.A. Submitted to Arctic and Alpine Research.

Mueggler, W.F. and W.L. Stewart. 1980. Grassland and shrubland habitat types of western Montana. USDA For. Serv. Gen. Tech. Rep. INT-66, 154 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Pfister, R.D., B.L. Kovalchik, S.F. Arno and R.C. Presby. 1978. Forest habitat types of Montana. USDA For. Serv. Gen. Tech. Rep. INT-34, 174 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Scott, R.W. 1966. The alpine flora of northwestern Wyoming. M.S. thesis, University of Wyoming, Laramie. 64 pp.

Spence, J.R. and R.J. Shaw. 1981. A checklist of the alpine vascular flora of the Teton Range, Wyoming, with notes on biology and habitat preference. Great Basin Naturalist 41(2):232-242.

APPENDIX I.

***** AVERAGES OF SITE VARIABLES TABLE *****
 ***** STANDARD DEVIATIONS IN PARENTHESIS *****

SITE VARIABLES	COMMUNITY TYPE NAMES													
	* FFCP	* N = 14	* AT	* N = 20	* AG	* N = 16	* SM	* N = 9	* WM	* N = 4	* DS	* N = 4	* MA	* N = 6
COMMUNITY SIZE (AC)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)
SLOPE SHAPE	1.6	(1.1)	1.9	(1.2)	2.3	(1.4)	2.7	(2.0)	2.5	(1.9)	2.8	(1.7)	2.3	(2.1)
ASPECT (DEGREES)	166.8	(53.2)	138.9	(112.7)	195.9	(112.8)	161.7	(107.8)	222.7	(154.5)	357.5	(2.9)	74.7	(137.5)
SLOPE (%)	34.1	(20.2)	17.6	(14.0)	38.0	(20.7)	33.1	(15.6)	14.2	(14.9)	33.5	(9.8)	8.2	(8.0)
ELEVATION (MSL)	9862.1	(337.5)	9926.5	(248.1)	9645.0	(158.0)	9685.6	(137.3)	9472.5	(160.0)	9825.0	(206.8)	9625.0	(328.5)
BARE/GRAVEL COVER-%	53.0	(28.0)	13.2	(21.7)	10.0	(8.0)	70.8	(25.4)	1.3	(.5)	3.5	(1.9)	1.0	(.9)
ROCK COVER (%)	23.1	(20.7)	2.6	(2.7)	2.8	(4.7)	8.0	(12.5)	.0	(.0)	5.5	(5.2)	.7	(1.2)
ORGANIC COVER (%)	11.8	(14.2)	78.1	(24.7)	85.7	(15.0)	17.6	(25.5)	95.0	(3.4)	89.7	(10.1)	93.5	(2.3)
BASAL VEG COVER (%)	2.3	(1.0)	5.6	(6.4)	6.5	(3.6)	2.3	(1.0)	4.8	(3.5)	6.5	(4.0)	4.2	(2.9)
WOODY COVER (%)	.1	(.3)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)
LITTER COVER (%)	9.1	(13.2)	57.6	(29.1)	66.4	(25.0)	11.8	(15.7)	50.0	(40.8)	40.7	(41.5)	7.7	(3.6)
BASAL AREA (SQ FT)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)
AVERAGE DBH (IN)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)
TREE COVER (%)	.1	(.3)	.1	(.2)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)
SHRUB COVER (%)	.9	(2.6)	.1	(.3)	.8	(2.5)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)
GRAMINOID COVER (%)	11.4	(7.4)	50.0	(19.2)	51.2	(17.1)	21.1	(11.7)	80.0	(14.1)	72.5	(12.6)	.3	(.5)
FORB COVER (%)	28.6	(12.9)	30.0	(19.7)	35.0	(13.7)	30.0	(12.2)	32.5	(5.0)	30.7	(28.4)	63.3	(17.5)
DOMINANT AGE (YRS)	.0	(.0)	.8	(3.4)	.0	(.0)	.1	(.3)	.0	(.0)	.0	(.0)	.0	(.0)
STAND AGE (YRS)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)	.0	(.0)
GRASS PROD (LBS/AC)	90.5	(89.9)	449.1	(217.9)	675.7	(307.3)	261.2	(223.2)	1362.8	(669.3)	52.0	(48.5)	700.0	(441.4)
FORB PROD (LBS/AC)	339.6	(342.6)	363.7	(161.5)	678.6	(408.3)	375.1	(252.6)	552.0	(297.5)	360.0	(374.9)	1065.0	(600.0)
SHRUB PROD (LBS/AC)	.0	(.0)	.1	(.3)	15.8	(63.2)	.1	(.3)	.0	(.0)	827.8	(333.2)	13.8	(32.4)
DUFF DEPTH (IN)	.1	(.1)	.4	(.2)	.3	(.2)	.1	(.2)	1.1	(.8)	.6	(.3)	2.1	(3.8)
LITTER DEPTH (IN)	.1	(.2)	.5	(.3)	.6	(.3)	.1	(.1)	.5	(.3)	.6	(.3)	.5	(.5)
FUEL DEPTH (FT)	.1	(.0)	.2	(.1)	.3	(.1)	.2	(.1)	.5	(.1)	.3	(.1)	.4	(.2)

***** CONSTANCY (AVERAGE COVER) TABLE *****
APPENDIX II

COMMUNITY TYPE NAMES

SPECIES	* FFCP	* N = 14	* AT	* N = 20	* AG	* N = 16	* SM	* N = 9	* WM	* N = 4	* DS	* N = 4	* MA	* N = 6
ABBREVIATIONS														
***** TREES *****	14:3(.5)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
PINALB														
***** SHRUBS *****														
ARTFI	.0(.0)	.0(.0)	.0(.0)	.0(.0)	18.7(2.2)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
ARTTSV	.0(.0)	.0(.0)	.0(.0)	.0(.0)	6.3(10.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
CHRVIS	.0(.0)	.0(.0)	5.0(.5)	.0(.0)	12.5(.5)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
DRYOCT	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	50.0(41.5)	.0(.0)	.0(.0)	.0(.0)
HAPSUF	28.6(2.9)	.0(.0)	5.0(.5)	.0(.0)	6.3(.5)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
POTFRU	.0(.0)	.0(.0)	5.0(3.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
SALARC	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	25.0(10.0)	.0(.0)	.0(.0)	.0(.0)
SALDOD	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	25.0(3.0)	.0(.0)	.0(.0)	.0(.0)
SALGLO	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	25.0(60.0)	.0(.0)	.0(.0)	.0(.0)
SALIXX	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	16.7(.5)	.0(.0)
SALNIV	.0(.0)	.0(.0)	5.0(.5)	.0(.0)	.0(.0)	.0(.0)	11.1(.5)	.0(.0)	.0(.0)	.0(.0)	75.0(47.7)	.0(.0)	16.7(.5)	.0(.0)
***** GRASSES *****														
AGRCAN	28.6(1.1)	35.0(.9)	.0(.0)	.0(.0)	56.2(5.8)	.0(.0)	77.8(3.6)	.0(.0)	.0(.0)	.0(.0)	25.0(.5)	.0(.0)	.0(.0)	.0(.0)
AGROST	.0(.0)	5.0(.5)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
AGRSOR	42.9(.9)	10.0(.5)	.0(.0)	.0(.0)	6.3(.5)	.0(.0)	11.1(3.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
AGRSPI	.0(.0)	5.0(.5)	.0(.0)	.0(.0)	18.7(3.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
ALOALP	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	16.7(3.0)	.0(.0)
BROPUM	.0(.0)	20.0(1.1)	.0(.0)	.0(.0)	31.2(12.7)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
CALPUR	21.4(7.8)	30.0(13.6)	.0(.0)	.0(.0)	6.3(3.0)	.0(.0)	11.1(.5)	.0(.0)	.0(.0)	.0(.0)	25.0(.5)	.0(.0)	.0(.0)	.0(.0)
CARALB	.0(.0)	5.0(.5)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
CARATR	.0(.0)	.0(.0)	.0(.0)	.0(.0)	18.7(.5)	.0(.0)	.0(.0)	.0(.0)	100.0(12.7)	.0(.0)	25.0(.5)	.0(.0)	50.0(4.5)	.0(.0)
CARELY	50.0(1.9)	90.0(32.4)	.0(.0)	.0(.0)	50.0(5.3)	.0(.0)	33.3(7.8)	.0(.0)	.0(.0)	.0(.0)	25.0(.5)	.0(.0)	.0(.0)	.0(.0)
CAREXX	7.1(.5)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	33.3(.5)	.0(.0)
CARHAY	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	75.0(7.8)	.0(.0)	50.0(5.3)	.0(.0)	50.0(5.3)	.0(.0)
CARLEN	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	16.7(90.0)	.0(.0)
CARLEP	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
CARMIC	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	11.1(.5)	.0(.0)	.0(.0)	.0(.0)	25.0(3.0)	.0(.0)	.0(.0)	.0(.0)
CARNOV	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	25.0(10.0)	.0(.0)	.0(.0)	.0(.0)
CAROBT	.0(.0)	20.0(2.4)	.0(.0)	.0(.0)	25.0(40.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
CARPAC	.0(.0)	.0(.0)	.0(.0)	.0(.0)	6.3(.5)	.0(.0)	.0(.0)	.0(.0)	25.0(40.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
CARPET	.0(.0)	10.0(.5)	.0(.0)	.0(.0)	25.0(2.9)	.0(.0)	.0(.0)	.0(.0)	25.0(.5)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
CARRUP	35.7(9.2)	35.0(14.9)	.0(.0)	.0(.0)	37.5(1.3)	.0(.0)	22.2(1.8)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
CARSCT	.0(.0)	20.0(35.1)	.0(.0)	.0(.0)	6.3(40.0)	.0(.0)	11.1(3.0)	.0(.0)	.0(.0)	.0(.0)	25.0(3.0)	.0(.0)	16.7(.5)	.0(.0)
CARSCO	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	50.0(23.7)	.0(.0)
DANINT	.0(.0)	5.0(20.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
DANTHO	.0(.0)	.0(.0)	.0(.0)	.0(.0)	6.3(.5)	.0(.0)	.0(.0)	.0(.0)	25.0(.5)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
DESCES	.0(.0)	5.0(.5)	.0(.0)	.0(.0)	31.2(.5)	.0(.0)	33.3(8.7)	.0(.0)	100.0(30.0)	.0(.0)	25.0(3.0)	.0(.0)	100.0(10.7)	.0(.0)
FESIDA	35.7(6.7)	20.0(5.9)	.0(.0)	.0(.0)	75.0(24.7)	.0(.0)	66.7(5.3)	.0(.0)	50.0(30.0)	.0(.0)	25.0(.5)	.0(.0)	.0(.0)	.0(.0)
FESQVI	42.9(2.6)	70.0(3.6)	.0(.0)	.0(.0)	18.7(14.3)	.0(.0)	11.1(.5)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
HESKIN	57.1(1.4)	55.0(6.7)	.0(.0)	.0(.0)	43.7(14.5)	.0(.0)	22.2(.5)	.0(.0)	25.0(50.0)	.0(.0)	25.0(.5)	.0(.0)	.0(.0)	.0(.0)
JUNBAL	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	16.7(50.0)	.0(.0)
JUNDRU	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	16.7(30.0)	.0(.0)
JUNMER	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	33.3(1.8)	.0(.0)
KOECRI	28.6(.5)	5.0(.5)	.0(.0)	.0(.0)	12.5(.5)	.0(.0)	22.2(25.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
LUZCAM	.0(.0)	.0(.0)	.0(.0)	.0(.0)	6.3(.5)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
LUZSPI	.0(.0)	10.0(.5)	.0(.0)	.0(.0)	6.3(.5)	.0(.0)	11.1(.5)	.0(.0)	25.0(.5)	.0(.0)	25.0(10.0)	.0(.0)	.0(.0)	.0(.0)
LUZULA	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	16.7(.5)	.0(.0)
PHLALP	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	11.1(.5)	.0(.0)	100.0(1.1)	.0(.0)	100.0(3.5)	.0(.0)	50.0(1.3)	.0(.0)
POAALP	21.4(.5)	20.0(1.1)	.0(.0)	.0(.0)	31.2(1.0)	.0(.0)	44.4(.5)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	50.0(.5)	.0(.0)
POACUS	7.1(3.0)	15.0(.5)	.0(.0)	.0(.0)	18.7(2.2)	.0(.0)	22.2(1.8)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)
POAFEN	7.1(.5)	5.0(.5)	.0(.0)	.0(.0)	6.3(.5)	.0(.0)	.0(.0)	.0(.0)	25.0(3.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)	.0(.0)

