Effects of trail-use under forests in the Madison Range, Montana
by Donn Richard Dale

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Botany
Montana State University

Abstract:
This paper presents: (1) an inventory of the vegetation of the Spanish Peaks Area, Big Sky recreational complex, and surrounding areas (Gallatin and Madison Counties, Montana) which may be used at later dates to evaluate changes wrought by the complex, and (2) observations which -may help predict the effects of man on the back-country forests.

A 92 square mile area was surveyed and a vegetation map of the area was constructed. A literature review for each forest type was made. Lodgepole pine forest, Engelmann spruce-subalpine fir forest, and whitebark pine forest types covered 68% of the study area.

To suggest the general applicability of the studies of human trampling described below, the vegetation of the study area was compared with and showri to be representative of the Madison Range, a south-central Montana mountain range.

The prime effects of humans on back country forests are thought to be trampling and fire. The effects of trampling were studied in three forest types: (1) Pinus contorta Dougl. (lodgepole pine), (2) Picea engelmanni (Parry) Engelm. - Abies lasiocarpa (Hook) Nutt. (Engelmann spruce-subalpine fir) , and (3) Pinus albicaulis Engelm. (whitebark pine). Changes in vegetation quality were measured on transects (total of 64 sites) which crossed level trails from trampled to undisturbed vegetation in each forest type.

Plant species were found along trails which: (1) increased in frequency and/or cover with trail use at trail edge, i.e., Erythronium grandiflorum Pursh (dogtooth violet), Hieracium gracile Hook, (slender hawkweed); (2) decreased in frequency and/or cover under trail use, i.e., vaccinium scoparium Lieberg (grouse whortleberry) ; (3) increased midway between the trail and the undisturbed forest, i.e., Fragaria virginiana Duch. (Virginians strawberry); (4) were insensitive to trail use, i.e., Carex geyeri Boott (elk sedge). Speculations were made on factors responsible for their distribution patterns.

The factors controlling trail wear appeared to be degree of rockiness, soil moisture, and soil texture. Trails in whitebark pine forests were widest and trails in Engelmann spruce-subalpine fir forests were deepest.

Field data was collected in June-September 1971.

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by

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A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

of

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Approved:

Head, Major Department

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ABSTRACT

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Field data was collected in June-September 1971.

INTRODUCTION

This paper presents information from 1971 studies on the vegetation of the Spanish Peaks Area (Madison Range, Gallatin and Madison Counties, Montana) and discusses some effects of human trampling on these areas.

The Spanish Peaks Area lies in the northeastern section of the Madison Range. Recent development by Big Sky Inc. (a recreational complex) covering approximately 36 square miles [93.6 km^2] of private and public lands) adjacent to this area has created public interest in the present condition of and concern for possible future effects on the environment of this area. With recreational developments increasing in number, more trampling will occur in other natural roadless "back country" recreation areas than heretofore; studies here should be useful in the management of other areas.

The vegetational habitat types of the north central Rockies, with the exception of *Pinus albicaulis* Engelmann (whitebark pine), are well known and have been described in considerable detail (Daubenmire 1968, Habeck 1967, Larson 1930, and Patten 1963. Though studies of the effects of trampling have been carried out in other vegetation types, the effects of trampling on trail-side vegetation in forests of the northern Rocky Mountains is essentially unknown. Studies on the effects of human trampling and automobile traffic on the high alpine tundra, and alpine fellfields of Rocky Mountain National Park, Colorado, have been conducted (Willard and Marr 1970, 1971). Edwards (1967) observed the effects of foot trampling on the high alpine zones in western Canada. Griggs (1938, 1956) has studied the alpine fellfields in the high mountains of Wyoming, Colorado, Washington and Oregon. Habitats and plant species in all these above-timberline regions prove to be similar to those of the Madison Range and other alpine tundras of the northern Rockies. Results from the effects of foot trampling and compaction on the natural forest campground site are available from several studies including Appel (1950), Cole (1964), Dotzenko (1967), Jemison (1967), LaPage (1962, 1964, 1967), Lutz (1945), Magill (1970), Settergren and Cole (1970), and Wagar (1961, 1965, 1971). Some information on trampling of grassland habitats is also provided by Bates (1935), Chappell (1971), Davies (1936), and Reid (1941). Because this study is representative of a larger area, results will aid in future trail and campground management in the northern Rockies. They show the effects of trampling on trails within the forest understory in these areas. The Spanish Peaks area is particularly well suited to a study of this sort because: (1) major vegetation types on the eastern side of the northern Rockies are represented; and (2) recreation use of the area includes day hikers, back-packers, and horsemen, included within these groups are picnickers, sightseers, photographers, fishermen and hunters (Lucas 1972).

Permanent marking of the trail sites studied will provide a baseline for observation of the effects of increased trail use on forest vegetation.

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DESCRIPTION OF STUDY AREA

LOCATION

The Madison Range lies in southwestern Montana just north of Yellowstone National Park (latitude 40° 20' N, longitude 111° 20' W). It is approximately 55 miles (88.50 km) long and 20 miles (32.18 km) wide. The Madison River forms its north, south, and west boundaries while the Gallatin River and U.S. Highway 191 border the eastern edge. Those areas studied in summer 1971 include the northern half of the Madison Range which begins at the middle and west forks of the Gallatin River (Figs. 1 and 2).

Elevations vary from 5,500 feet (1676 m) in the broad Madison and Gallatin Valley floors to 11,293 feet (3442 m) at the highest peak.

GEOLOGY

Geologically, the study area is a complex combination of Pre-Cambrian metamorphics, Cretaceous sediments and Recent volcanics. Pre-Cambrian metamorphics make a core of crystalline interlaminated gneiss, schist, marble, and quartzite, overlaid by Cretaceous sedimentary beds (Ross et.al. 1955). The Spanish Peaks block was uplifted by a high angle reverse fault during the Laramide orogeny 50 to 65 million years ago (Hall 1960, Montagne 1971). Less resistant sedimentary beds of sandstone, limestone, and shale have been eroded away by alpine glaciers leaving a series of narrow ridges, steep slopes, and high open rocky

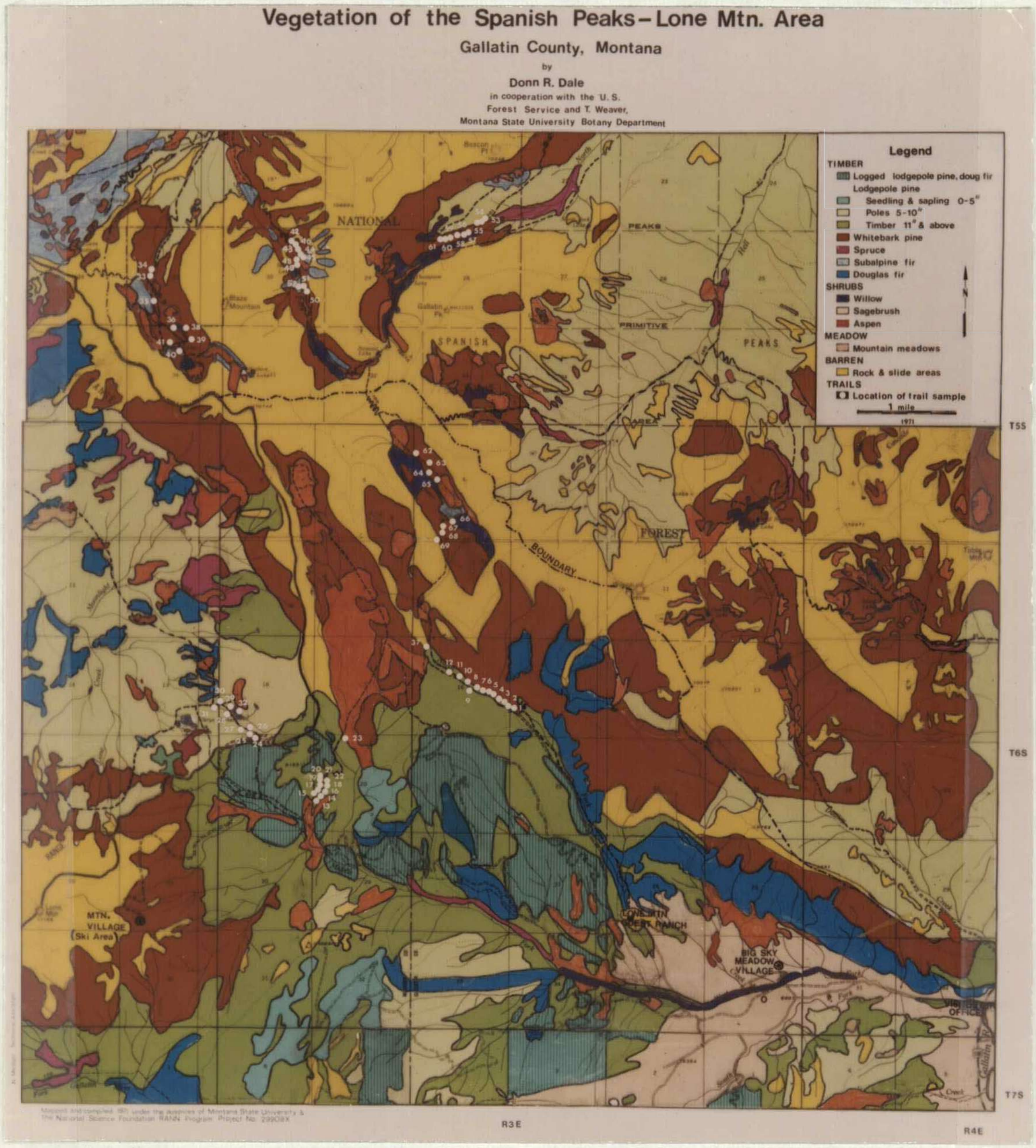

FIGURE 1

Vegetation map of the study area. White dots indicate location of permanent trail sites sampled. Data and photographs referring to each of these sample sites are deposited in the Montana State University Library at Bozeman, Montana.

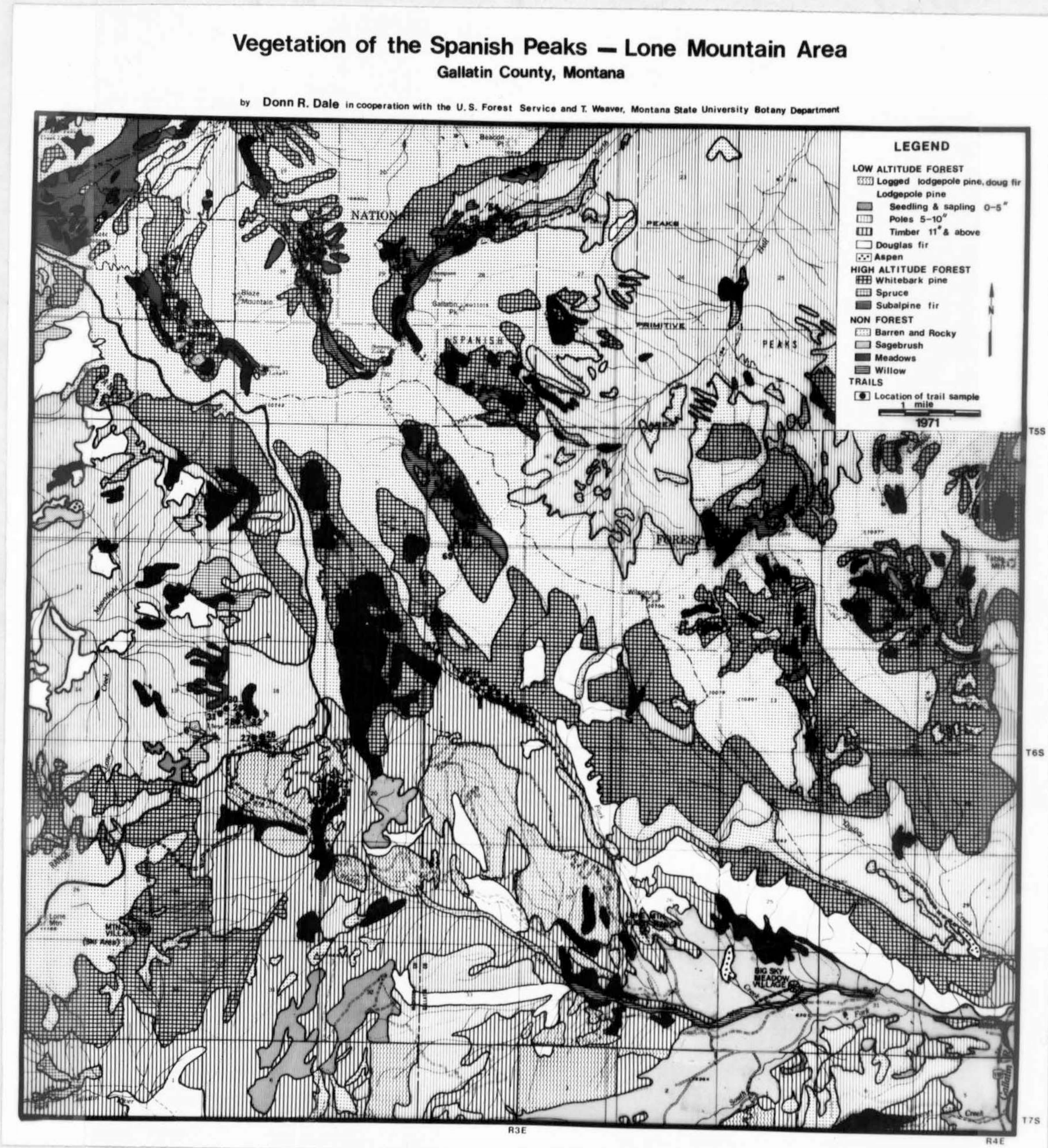

FIGURE 2

Vegetation map of the study area. Black dots indicate location of permanent trail sites sampled.

exposures with valleys of various widths and levels. Less resistant materials accumulated in the basins and in the south part of the study area forming vast areas of glacial till and outwash (Olsen et.al., 1971). Occasional small areas of igneous extrusives are evident as resistant outcrops of granite, andesite, diorite, and gabbro.

SOILS

Terrain above 9,000 feet (2743 m) is composed of undeveloped rocky soils with low moisture retention with whitebark pine as the predominant forest type. The majority of soils below 9,000 feet within the study area are Loberg stony loams which develop over unconsolidated glacial till, or Rambler cobbly loams which develop on steep talus colluvium (Leeson, 1972). Typically forested, Loberg soils are well drained, 50 to 60 inches (127-152 cm) deep and contain a thin duff layer with a light gray to grayish brown loam over a thick brown clayey subsoil; coarse fragments increase from 35% in the upper profile to over 60% in the substratum (Olsen et.al. 1971). Rambler soils are less well developed, excessively drained, 10 to 40 inches deep (25-102 cm), and have a profile under a thin mat of litter with a brown to very pale brown cobbly surface layer over a structureless sandy loam substrate; coarse fragments vary from 35% on top to 70% in the lower profile (Leeson, 1972). The Ulery Lakes area is a landslide with a mantle of loose clay over Kootenai shale bedrock. Soils in this vicinity are unstable, poorly drained, heavy wet clays with little horizon development (Montagne, 1971).

CLIMATE

The climate is cool. In 1971, June-September temperatures averaged about 76°F (24°C) with a maximum of 89°F (32°C) and a minimum of 29°F (-2°C), while 1972 December-March temperatures averaged 26°F (-3°C) with a minimum of -24°F (-31°C) and a maximum of 43°F (6°C). (M.S.U. Weather Research Station, Big Sky Meadow Village (6,000 ft or 1829 m elevation), 1971-1972). Two-thirds of the 30 to 80 inches (76-203 cm) of precipitation falls as snow (Weather Bureau, 1971). Frost occurs every month of the year and snow remains until July in the high areas, normally returning by late September. During the summer of 1971, several large snow drifts remained all year in the high mountain passes.

METHODS AND MATERIALS

MAPPING

In 1971 a vegetation map of the study area (Figs. 1 and 2) was constructed from 92 square miles (23,826 h) of land in proximity to the West Fork of the Gallatin River, including areas of the Big Sky Inc. development, and the southern half of the Spanish Peaks Primitive Area. Vegetational type delineation was made by field observations, U.S. Forest Service Series EIO aerial photographs (1961-1962, scale 4 inches per mile); Montana State University Soils Department infra-red aerial photographs (photographed 1970; scale 4 inches per mile); current U.S. Forest Service Squaw Creek District range surveys and timber records (1969-1971); and U.S. Forest Service timber type maps (1957-1959).

COMPARISON OF THE VEGETATION OF THE STUDY AREA TO THE VEGETATION OF THE MADISON RANGE

To compare the vegetation of the mapped area with vegetation of the Madison Range, whitebark pine, subalpine fir, willow, meadows, and barren areas, were grouped into the noncommercial forest category (NCF) as were used by the U.S. Forest Service, and similar data were gathered from U.S. Forest Service timber type maps (1957-1959).

Both maps were sampled with a systematic dot grid to obtain: (1) a comparison of the field mapped area to the Madison Range, (2) a comparison of the field mapped area to the same area on the Forest Service timber type map, (3) relative percents of timber and nonforested lands, (4) occurrence of species on particular slopes, (5) differences in timber populations on the east and west sides of the Madison Divide. No attempt was made to correlate timber type to elevation.

EFFECTS OF TRAMPLING ON FOREST UNDERSTORIES

Selection of Sites

Study plots were chosen in lodgepole pine (*Pinus contorta* Dougl.), spruce-subalpine fir (*Picea engelmanni* (Parry) Engelm., *Abies lasiocarpa* (Hook) Nutt), and whitebark pine (*Pinus albicaulis* Engelm.) forests which account for 68% of the total area. Level areas (0-3% slope) were chosen to eliminate the possible effects associated with changes in slope. Elevations of sample sites began at 7100 feet (2164 m) in lodgepole pine and progressed through spruce-fir forests and whitebark pine forests to 9100 feet (2774 m). Elevations were determined with a pocket altimeter and the U.S. Geological Survey 15-minute Spanish Peaks Quadrangle 40-feet contour interval map (1950).

Locations of the sample stations are indicated on the vegetation map (Figs. 1 and 2) and are documented with photographs and distances from permanent reference points as described in the following paragraph. This information is kept at the Montana State University Library and titled "Photographs and Trail Data of the Madison Range, Montana", D. Dale, 1971.

So sampling sites can be relocated for future study, each reference tree was permanently marked by placing a diamond (◈) or trail blaze ( ) on it (Fig. 3). Reference trees with diamond blazes were located outside of the proposed Spanish Peaks Wilderness boundary; reference trees with standard U.S. Forest Service trail blaze were located within the proposed wilderness. A 2-inch square (5 cm^2) imprinted galvanized metal tag was attached to each reference tree. The imprinted tags of series 330 were numbered 1 through 69. Each trail sample site was photographed in two directions: (1) along the axis of travel with reference tree included, and (2) along the axes of transect where samples were taken (Fig. 3). Measurements for location of the plot sites from their reference trees consist of: (1) an azimuth and distance from reference tree to center of first frame, and (2) an azimuth of transect.

Sampling of Understory Vegetation

At each site, the trampled vegetation of the trail center was compared with moderately trampled vegetation near the trail side and untrodden vegetation farther from the trail. Sixty-four trail sites were studied: twenty-nine represent lodgepole pine forests, sixteen in spruce-subalpine fir forests, and nineteen in whitebark pine forests.

Herbaceous understory was measured by a modification of the canopy coverage method (Daubenmire 1958). At each site a 2 x 5 dm frame was set with long axis parallel to the trail, along a line at right angle to the path, at distances of 0 cm (trail center), trail

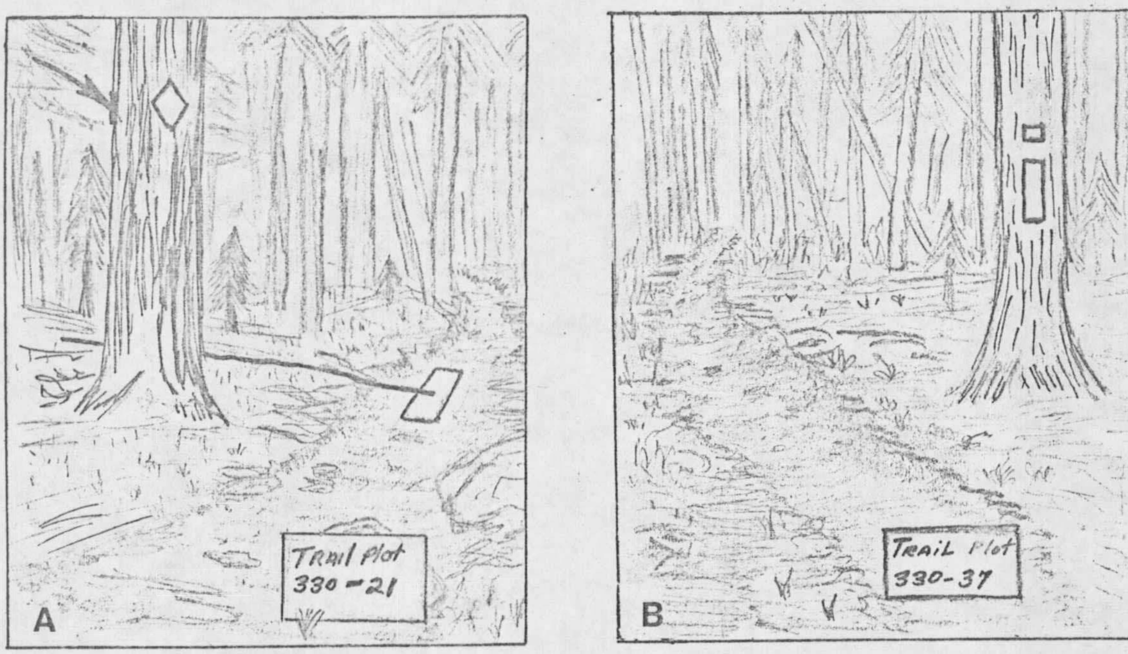

FIGURE 3

Method of documentation and establishment of permanent reference trees. Diamond blaze (illustration A) was used outside of proposed wilderness boundary and standard U.S. Forest Service trail blaze (illustration B) was used within. Sites were photographed: (1) along path of travel and (2) perpendicular to pathway along axes of transect. Series 330 galvanized metal tags were placed on the backside (indicated by arrow in illustration A) of each reference tree.

edge, 50 cm, 120 cm, 240 cm, and 460 cm from the trail center (Fig. 4).

Within each 2 x 5 dm frame, all plant species were identified and their canopy coverage classes were estimated and recorded. A representative sample of all plant species mentioned in this thesis was deposited in the Montana State University herbarium. Identifications were verified by Dr. W. E. Booth of the Montana State University Botany and Microbiology Department. Cover classes were determined by estimating the percentage of the 2 x 5 dm frame area that would be included within a delineation of the edge of the natural foliage. The cover classes used were: (1) 0-5%, (2) 5-25%, (3) 25-50%, (4) 50-75%, and (5) 75-100%. Cover classes of bare soil, forest litter, and rock were also recorded. Species of herbaceous cover outside of plot frames were recorded and are presented in Tables XI, XII, XIII and XIV in the appendix to provide a more complete description of the habitat.

Percent cover and frequency for each species were computed for each of the six frames along the gradient in each forest type. Distributions along the trail gradient were determined and plant species with similar distribution patterns were arranged in groups which: (1) show an increase in cover and/or frequency with trampling ("increasers", Fig. 5); (2) show a decrease in frequency and/or cover percent with trampling, ("decreasers", Fig. 5); (3) approximate a "bell" curve pattern with highest cover percent and/or frequency percent in the

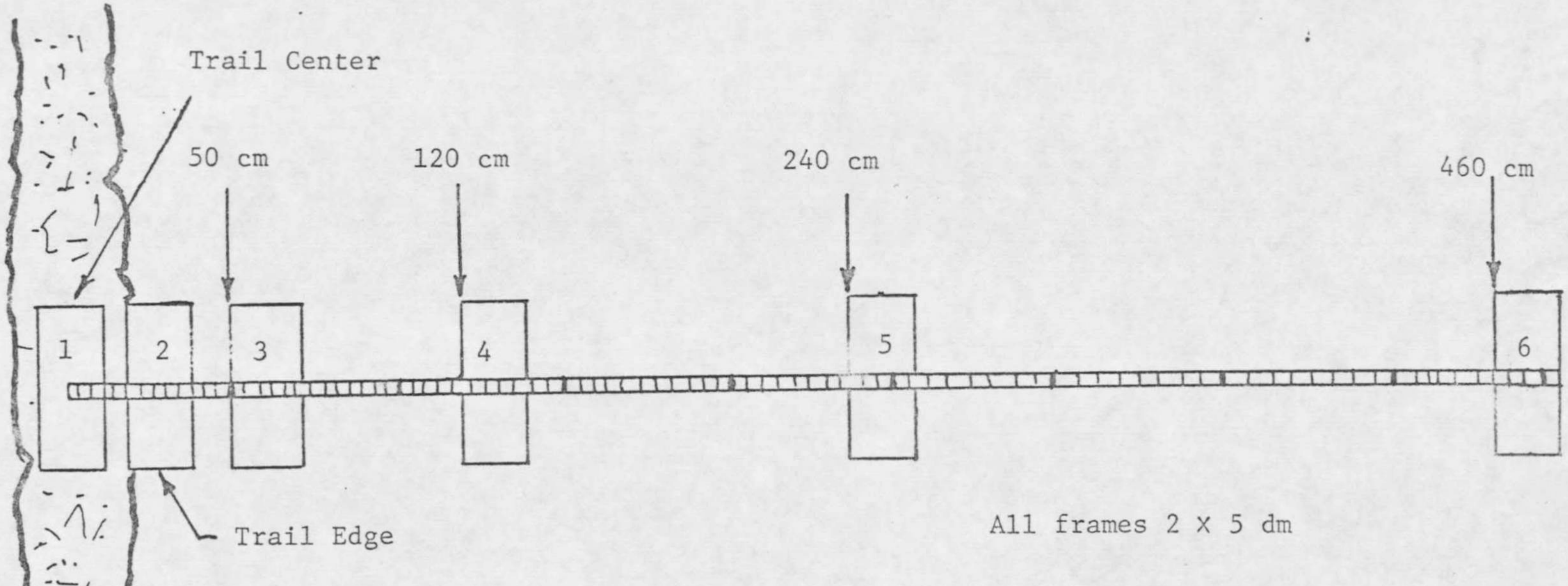

FIGURE 4

Method of arrangement of 2 X 5 dm frames for trail samples on 64 level sites under lodgepole pine, spruce-fir and whitebark pine forests. Species and percent coverage were recorded for each frame. Distances for sampling along transect were measured to the leading edge of each frame.

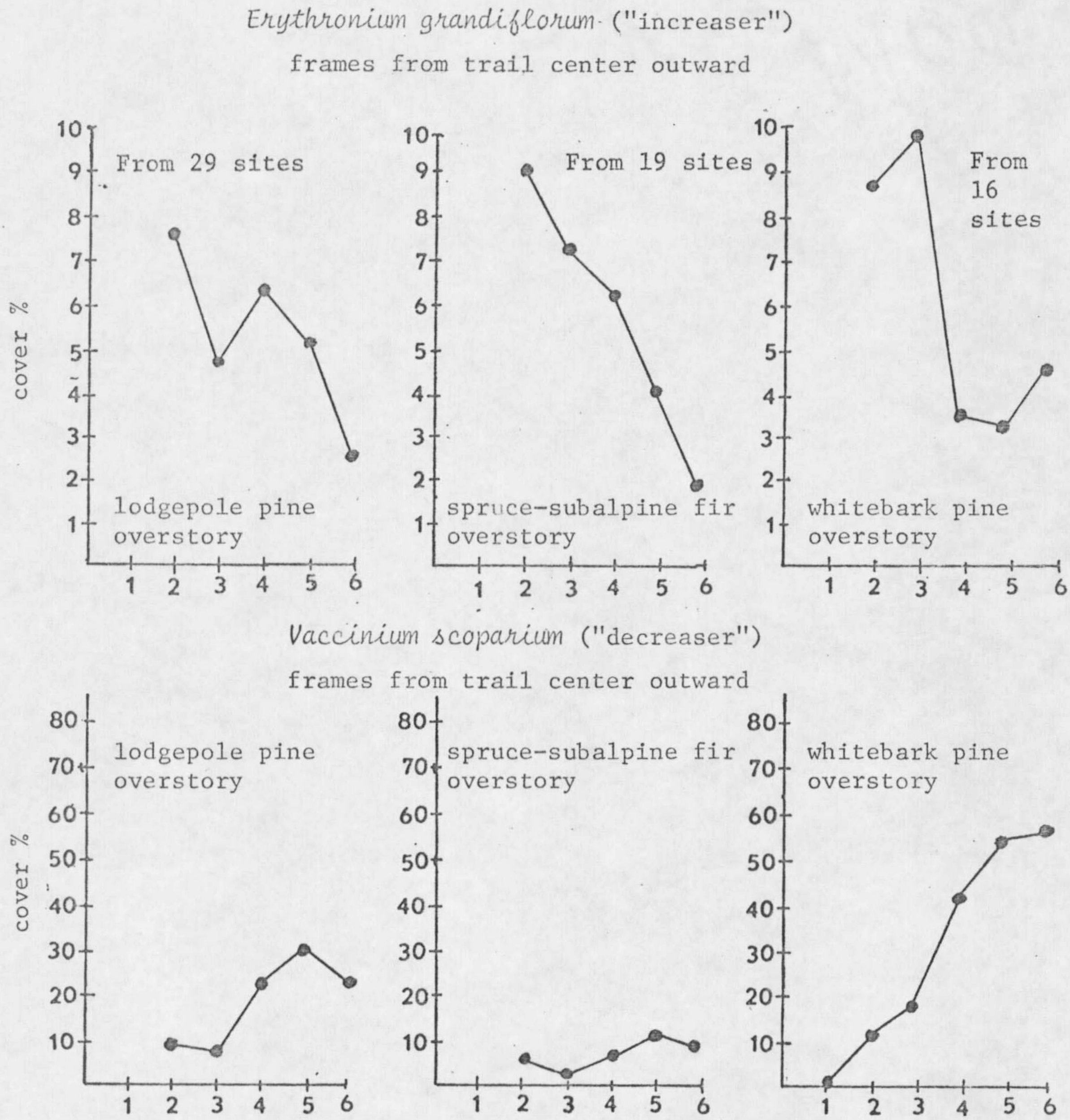

FIGURE 5

Relative pattern of occurrence of *Erythronium grandiflorum* ("increaser") and *Vaccinium scoparium* ("decreaser") along trails under three different forest types. Data taken from 64 sample sites within study area.

center frames, ("increaser-decreaser-bell" curve, Fig. 6); and (4) show no particular pattern with trampling in frames 2-6 ("unchanging").

Sampling of Overstory Vegetation

Nearly pure stands of each forest type were selected for sampling areas. Square feet of basal area per acre (m^2/h) of the timber overstory was determined by taking a prism count (5 diopter 27.25 factor prism) using the Bitterlich principle (Bruce et.al., 1962). Timber stand basal area measurements were taken from the center of the fifth frame (2.5 meters from trail center). Line of sight was measured at 4.5 feet (1.37 m) above ground level at the bole of each tree from plot center.

Species of dominant timber reproduction under the forest canopy were recorded. The ages of lodgepole pine, spruce fir and whitebark pine stands were determined by counting annual rings within eight, six and five sample sites respectively (Table X in the appendix).

Trail Wear

Width of trail wear and depth of trail wear were measured at each site. Trail width was measured as the linear distance of bare soil between the vegetation on both sides of the trail. Trail depth was determined by placing a straight edge across the trail and measuring the distance to the ground at the center point. Trail use was designated as: (1) "heavy", in scenic areas with main access trails;

"Increaser-Decreaser-Bell" Curve Species

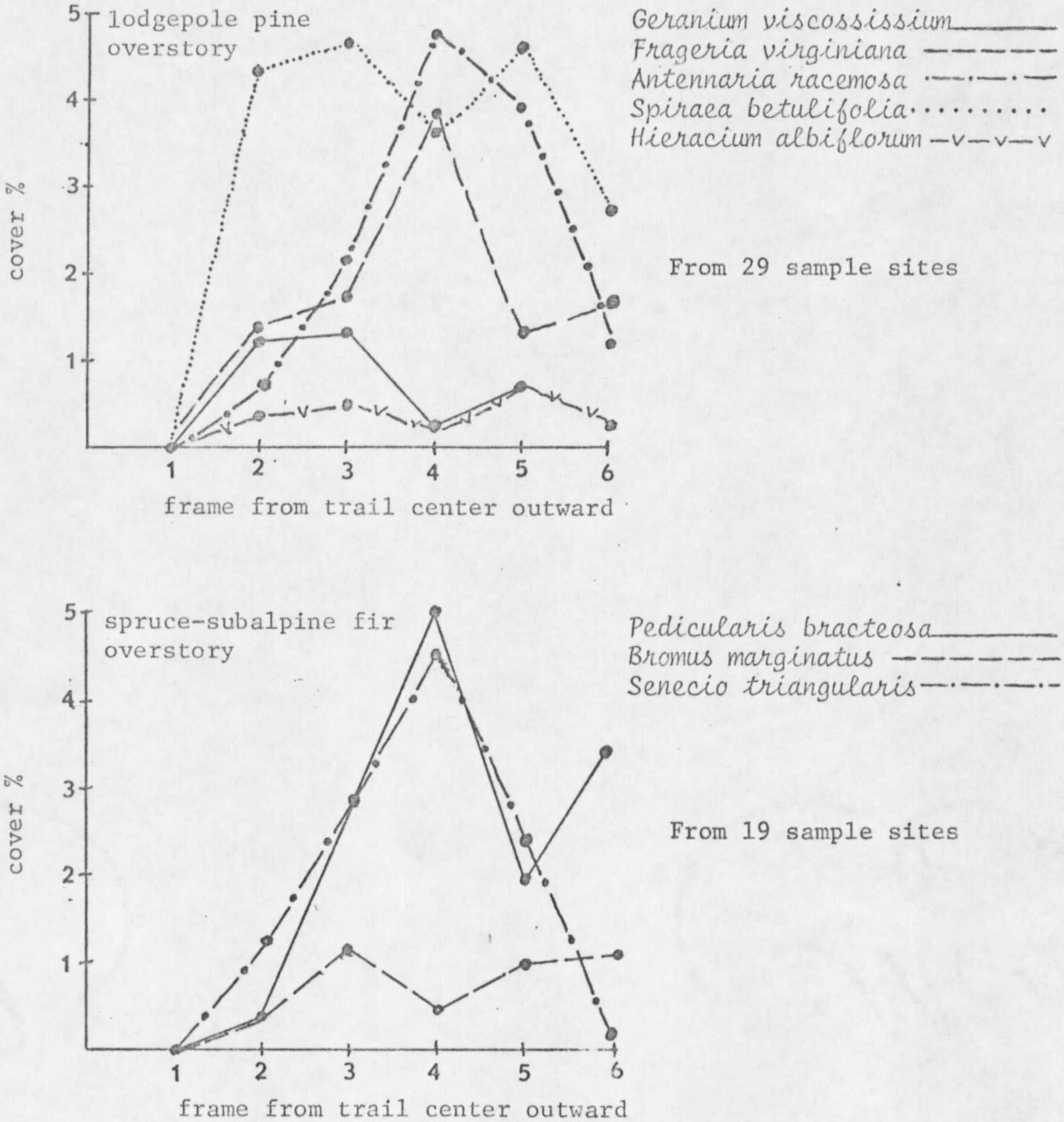

FIGURE 6

Relative pattern of "bell" curve species in lodgepole pine overstory and spruce-subalpine fir overstory. The whitebark pine forest type did not have species with the patterns of occurrence shown above.

(2) "medium", in areas with less scenic appeal or limited access; and (3) "light", in areas with established trails which are unmapped and relatively unknown.

RESULTS

VEGETATION MAPPING

Vegetative types mapped and their aerial extents were: lodgepole pine 29.2%, Engelmann spruce 2.1%, subalpine 1.1%, whitebark pine 29.2%, Douglas fir 5.9%, quaking aspen 0.3%, sagebrush 5.3%, willow 0.5%, mountain meadows 4.2%, and barren rocky exposures 22.8%.

DESCRIPTION OF MAJOR VEGETATION TYPES MAPPED

Lodgepole Pine Forests

Lodgepole pine trail sites were studied at elevations from 7100 ft (2164 m) to upper limits of 7750 ft (2362 m). Mean elevation was 7557 ft (2303 m).

Stands of lodgepole pine on sample sites were nearly pure in composition. Small amounts of Engelmann spruce, subalpine fir, and Douglas fir were occasionally seen.

Understory: Predominate plants in the lodgepole pine understory are *Vaccinium scoparium*, *Thalictrum venulosum*, *Arnica cordifolia*, and *Erythronium grandiflorum*. Smaller numbers of *Lupinus sericeus*, *Hieracium gracile*, *Achillea millefolium*, and *Viola orbiculatus* were also observed.

Reproduction: Young subalpine fir trees were established: 21 sites had subalpine fir, 6 sites had mixed Engelmann spruce and subalpine fir, and 2 sites had Engelmann spruce.

Basal Area: Basal area averaged 201 ft^2/acre (46 m^2/h) with a maximum of 354 ft^2/acre (81 m^2/h) and a minimum of 82 ft^2/acre (19 m^2/h).

Age: Annual ring counts from eight different sites indicated the stands to average 180 years (range 35-200).

Engelmann Spruce-Subalpine Fir Forests

Engelmann spruce-subalpine fir trail sites were studied at elevations from 7500 ft (2286 m) to 9100 ft (2774 m) with a mean elevation of 7500 ft (2286 m).

The overstory in this type is an Engelmann spruce-subalpine fir mixture. In most instances, the Engelmann spruce trees were of larger size than the subalpine fir.

Understory: *Erythronium grandiflorum*, *Vaccinium scoparium*, and *Arnica latifolia* were the predominant understory plants. Smaller numbers of *Epilobium alpinum*, *Hieracium gracile*, *Pedicularis bracteosa*, *Aquilegia flavescens*, *Erigeron peregrinus*, and *Arnica cordifolia* were also observed.

Reproduction: Only subalpine fir was observed in the 16 sites studied.

Basal Area: Basal area averaged 191 ft^2/acre (44 m^2/h) with a maximum of 300 ft^2/acre (69 m^2/h) and a minimum of 55 ft^2/acre (13 m^2/h).

Age: Annual ring counts from six different stands indicated that Engelmann spruce averaged 200 years (range 95-250) and subalpine fir averaged 150 years (range 35-180).

Whitebark Pine Forest Type

Level whitebark pine sites were studied at elevations from 8100 ft (2468 m) to 9100 ft (2774 m). Mean elevation was 8650 ft (2636 m).

Whitebark pine forest overstories were nearly pure with infrequent occurrences of subalpine fir and Engelmann spruce.

Understory: Dominant understory plants were *Vaccinium scoparium* with small numbers of *Arnica latifolia*, *Hieracium gracile*, and *Erythronium grandiflorum*.

Reproduction: Dominant reproduction was whitebark pine. Nine sites had whitebark pine, seven had subalpine fir, and three had Engelmann spruce.

Basal Area: Basal area measurements averaged 179 ft^2/acre (41 m^2/h) with a maximum of 300 ft^2/acre (69 m^2/h) and a minimum of 55 ft^2/acre (13 m^2/h).

Age: Increment readings from five different stands averaged 180 years (range 50-375).

Remaining forest types mapped were not intensively studied and are briefly discussed in the Discussion and Conclusion section.

COMPARISON OF THE VEGETATION OF THE STUDY AREA TO THAT OF THE MADISON RANGE

In the Madison Range, Douglas fir and lodgepole pine appear to have slightly lower amounts of areal coverage and noncommercial forest types (NCF) have slightly higher amounts of areal coverage than the field mapped area (Table I).

EFFECT OF ASPECT ON FOREST VEGETATION OF THE MADISON RANGE

The effects of slope direction (aspect) on timber species were recorded and are shown in Table II and Figure 7. Douglas fir forests had highest occurrence on south and west facing slopes; lodgepole pine favored north slopes; Engelmann spruce favored northwest slopes; whitebark pine favored east, south and southwest slopes and nonforest areas were equally distributed.

TRAIL EFFECT

Previous studies in campground areas indicate that trampling does affect growth of overstory timber (Cole 1964; Jemison 1967; LaPage 1962, 1967; Meinecke 1929; and Wagar 1969, 1971). I attempted no measurements of this effect.

TABLE I

Comparative Percentages of Forest Types and
Non-Forest Types on the Madison Range

	Douglas Fir	Lodgepole Pine	Subalpine Fir	Spruce	Rock	NCF[1] (WBP)	Willow	Sagebrush	Aspen	Meadows	Lake
1. Field Survey Map of Study Area (1971)	5.9	39.2		2.1	22.8	29.2			.3		.5
2. USFS Mapping of Study Area	4.9	25.4		1.0	25.7	42.4			.3		.3
3. Madison East of Divide	9.6	42.5	.4	2.1	25.3	20.1					
4. Madison West of Divide	21.7	16.6	.5	7.1	24.2	29.8					
5. Total Madison Range	12.3	36.7	.4	3.3	25.0	22.3					

[1] For adequate comparison with past Forest Service mapping methods, the noncommercial forest (NCF) was divided into subalpine fir, willow, sagebrush, and meadows. Percent of those areas field mapped in 1971 in the study area (Fig. 1) are subalpine fir 1.1%, willow .5%, sagebrush 5.3%, and meadows 4.2%. The remainder, after the above figures are subtracted from the NCF columns, is the percentage for whitebark pine.

TABLE II

Timber coverage (%) of various slopes in the Madison Range. (Data obtained from U.S. Forest Service timber type maps — 1957-1959)

	NW	N	NE	E	SE	S	SW	W
Douglas fir								
% E[1]	8.4	6.0	7.4	9.1	12.6	10.8	13.0	15.2
% W[2]	22.8	28.7	20.5	4.0	25.0	23.3	21.3	22.4
% Total	11.9	10.0	9.9	8.2	14.6	14.4	15.7	17.2
Lodgepole pine								
% E	51.2	47.3	47.3	36.4	47.1	22.2	33.5	41.7
% W	20.3	23.8	25.6	10.0	10.4	7.0	18.5	8.6
% Total	43.6	43.1	43.3	31.7	41.4	17.8	28.6	32.5
Subalpine fir								
% E	.3	.5	0	1.7	0	.5	0	0
% W	0	0	1.3	0	2.1	1.2	0	0
% Total	.2	.5	.2	1.4	.3	.7	0	0
Engelmann spruce								
% E	4.5	3.3	.9	0	2.7	.9	2.2	0
% W	15.4	8.7	12.8	2.0	2.1	4.7	1.9	1.7
% Total	7.1	4.2	3.1	.4	2.6	2.0	2.1	.5
Nonforest								
% E	18.6	27.2	25.7	22.5	27.6	30.7	29.0	23.2
% W	21.1	26.2	25.6	16.0	39.6	29.1	14.8	31.0
% Total	19.2	27.0	25.7	21.3	29.4	30.2	24.4	25.4
NCF (WBP)[3]								
% E	17.1	15.8	18.6	30.3	10.0	35.0	22.3	19.9
% W	20.3	12.5	14.1	68.0	20.8	34.9	43.5	36.2
% Total	17.9	15.2	17.8	37.0	11.6	34.9	29.2	24.4

[1]E=East side of Madison Divide.

[2]W=West side of Madison Divide.

[3]Noncommercial forest (NCF) is a Forest Service timber type classification which includes a majority of whitebark pine.

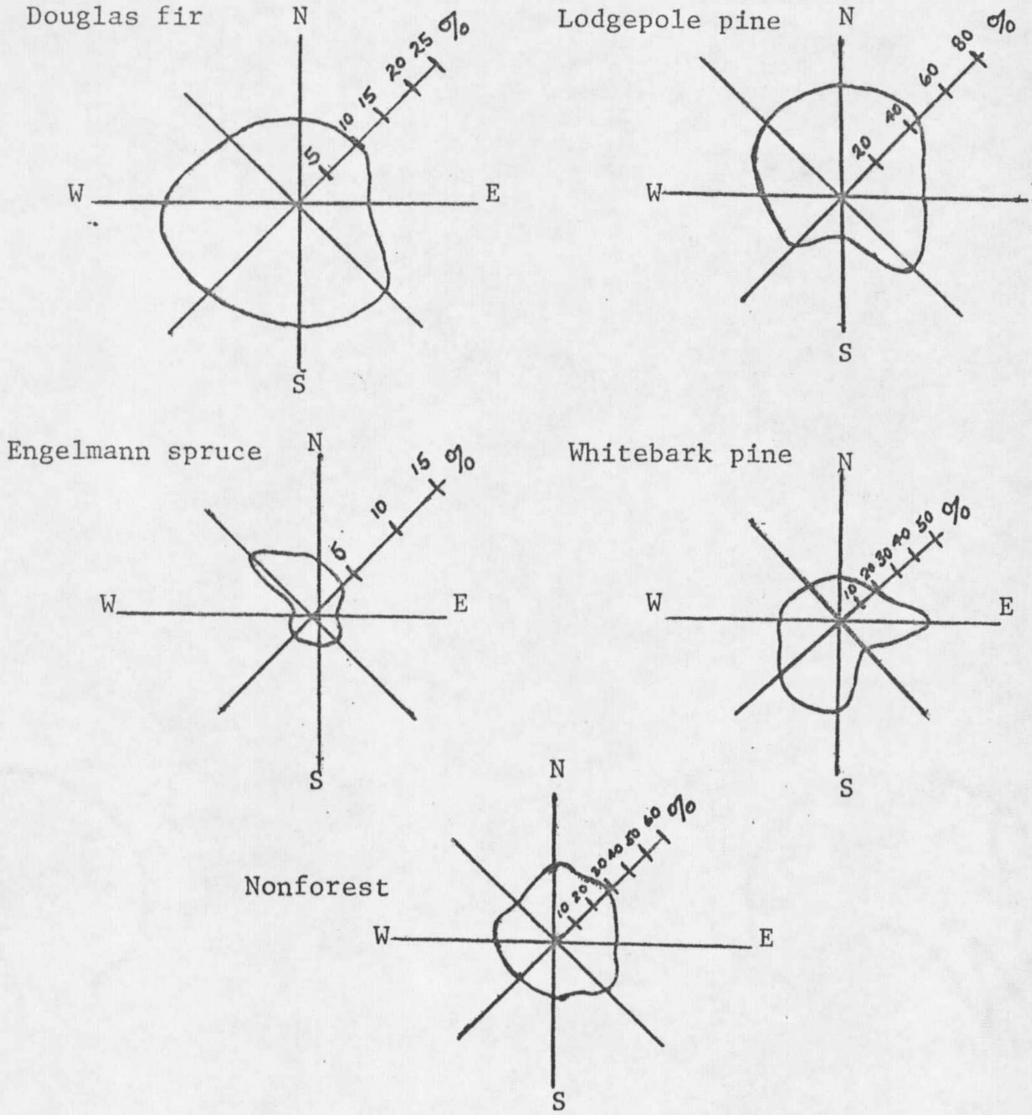

FIGURE 7

The distribution of four major vegetation types on various slopes and exposure directions on the Madison Range, Montana.

Lodgepole Pine Forest Trails

Generally the effects of trails on understory vegetation were obvious (Table III). Most plants were eliminated from the trail center. Among those persisting in the trail center (Frame 1) in low amounts were: *Erythronium grandiflorum*, *Thalictrum venulosum*, and *Spiraea betulifolia*.

Plants exhibiting increased cover and/or frequency percent ("increasers") approaching the trail center along the gradient were: *Erythronium grandiflorum*, *Lupinus sericeus*, *Hieracium gracile*, *Poa pratensis*, and *Arnica latifolia* (Table III).

Plants becoming less frequent ("decreasers") when approaching trail center along the gradient were: *Vaccinium scoparium*, *Thalictrum venulosum*, *Pyrola secunda*, and *Abies lasiocarpa* seedlings.

Plants approximating the "increaser-decreaser-bell" curve pattern along the gradient were: *Geranium viscossissimum*, *Fragaria virginiana*, *Antennaria racemosa*, *Spiraea betulifolia*, and *Hieracium albiflorum*.

Plants apprarently little affected by trails ("unchanging") were: *Viola orbiculatis*, *Carex geyeri*, *Arnica cordifolia*, *Astragalus alpina*, *Osmorhiza chilensis*, *Aster engelmanni*, *Claytonia lanceolata*, *Calamagrostis canadensis*, and *Achillea millefolium*.

Species presence, frequency, and cover within each frame for all plants discussed above are listed in Table III. These species which provided insufficient data for interpretation of the effects of trails

TABLE III

Understory vegetation at various distances from trail center in lodgepole pine (*Pinus contorta*) forests. Percent frequency and percent cover are derived from studies at 28 sites measured in June, July and August 1971.

Species List	Frame 1 Trail Ctr.		Frame 2 Trail Edge		Frame 3 50 cm		Frame 4 120 cm		Frame 5 240 cm		Frame 6 460 cm	
	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.
INCREASERS												
Bare Ground	93.0	48.0	43	6.3	25	7.4	18	2.1	11	2.8	7	.6
Hieracium gracile	4.0	.1	18	.4	21	1.4	18	.5	11	.7	14	.4
Poa pratensis			7	.6	4	.1	4	.1				
Arnica latifolia			7	3.2	7	3.2	7	.2	4	1.3	4	.1
Erythronium grandiflorum	11.0	.3	57	7.6	46	4.7	64	6.4	61	5.1	46	2.5
Lupinus sericeus			25	4.9	14	1.3	21	3.9	11	.7	14	1.6
DECREASERS												
Litter	93.0	16.0	54	12.9	64	21.6	75	22.6	54	21.9	54	20.9
Vaccinium scoparium			36	8.6	43	7.9	57	23.2	61	31.5	46	22.2
Thalictrum venulosum	4.0	.5	7	1.4	11	2.0	18	3.8	18	2.1	18	4.7
Vaccinium membranaceum			4	.1	7	.6	7	.6	14	4.6	7	3.6
Pyrola secunda			7	.2	7	.2	4	.1	14	1.6	11	1.2
Epilobium augustifolium			7	.2	7	.2	11	.3	7	.2	14	.8
Abies lasiocarpa			14	.4	25	2.8	14	.8	14	1.7	21	1.8
INCREASER-DECREASER-BELL												
Geranium viscossissimum	4.0	.1	[11	1.2	14	1.3]	7	.2	7	.6		
Fragaria virginiana			18	1.3	[32	1.7	32	3.8]	18	1.3	14	1.6
Antennaria racemosa			11	.7	18	2.1	[21	4.7	18	3.9]	11	1.2
Spiraea betulifolia	7.0	.2	[18	4.3	29	4.6	25	3.7	32	4.6]	21	2.7
Hieracium albiflorum	4.0	.1	[14	.4	18	.5	7	.2	25]	.6	11	.3
UNCHANGING												
Viola nuttallii					4	.1	7	.2	4	.1	4	.1
Viola orbiculatus	4.0	.1	25	1.1	25	1.5	36	1.3	14	.1	25	2.0
Carex geyeri			36	6.0	39	11.2	43	9.2	46	12.1	46	11.0
Arnica cordifolia			46	5.2	32	5.5	36	4.4	46	6.7	36	5.5
Astragalus alpina			7	.6	7	.2	7	.2	7	.2	4	.1
Osmorhiza chilensis			11	.3	11	.3	7	.2	11	.3	7	.6
Aster engelmanni			11	.7			14	1.3	7	.6	11	2.0
Claytonia lanceolata	4.0	.1	4	.1	4	.1	4	.1				
Calamagrostis canadensis			4	.1	4	.5	4	.1	4	.1	4	.5
Achillea millefolium			4	.1	4	.1	4	.1	4	.5	4	.1

OTHER SPECIES PRESENT (Insufficient frequency for interpretation)
Agoseris glauca (1), *Anaphalis margaritaceae* (1), *Antennaria rosea* (2), *Aquilegia flavescens* (1), *Arnica fulgens* (1), *Aster integrifolius* (2), *Berberis repens* (+), *Bromus anomalus* (2), *Bromus marginatus* (1), *Castilleja miniata* (+), *Carex podocarpa* (3), *Clematis columbiana* (+), *Erigeron peregrinus* (2), *Eriogonum umbellatum* (+), *Galium boreale* (+), *Geum macrophyllum* (2), *Hackelia floribunda* (1), *Mertensia oblongifolia* (+), *Picea engelmanni* (1), *Pedicularis racemosa* (3), *Pinus albicaulis* (+), *Potentilla gracilis* (2), *Sedum stenopetalum* (2), *Taraxicum officinale* (2), *Smilicina racemosa* (+)

( ) Parenthesis indicate number of occurrences.
\+ Plants observed near sample frames, but not within plot.
[ ] Brackets indicate a zone of high frequency and/or cover along gradient sample.

are listed at the bottom of Table III. Species recorded adjacent to plots studied are listed in Table VII in the appendix.

Engelmann Spruce-Subalpine Fir Forest Trails

Understory vegetation within trail pathways under spruce-fir forests approached 100% removal (Table IV). Plants persisting in the trail center (Frame 1) in low amounts were: *Arnica cordifolia* and *Arnica latifolia*.

Plants apparently favored by trail-side sites ("increasers", Frame 2) were: *Erythronium grandiflorum*, *Epilobium alpinum*, *Hieracium gracile*, *Poa pratensis*, and *Trifolium parryi*.

Plants becoming progressively less frequent as trail center is approached ("decreasers") were: *Vaccinium scoparium*, *Arnica cordifolia*, *Thalictrum venulosum*, *Pyrola secunda*, and *Abies lasiocarpa* seedlings.

Plants most significant in the center of the gradient ("increaser-decreaser-bell") were: *Pedicularis bracteosa*, *Bromus marginatus*, and *Senecio triangularis*.

Plants apparently not affected by trails along the gradient in Frames 2-6 ("unchanging") were: *Arnica latifolia*, *Erigeron peregrinus*, *Senecio serra*, *Carex geyeri*, and *Osmorhiza chilensis*.

Supporting data for the statements above as well as records of infrequent plants of the spruce-fir type appear in Table IV. Species recorded adjacent to plots studied are listed in Table XII in the appendix.

TABLE IV

Understory vegetation at various distances from trail center in spruce-subalpine fir (*Picea engelmanni - Abies lasiocarpa*) forests. Percent frequency and percent cover data are derived from studies at 16 sites measured in June, July and August 1971.

Species List	Frame 1 Trail Ctr.		Frame 2 Trail Edge		Frame 3 50 cm		Frame 4 120 cm		Frame 5 240 cm		Frame 6 460 cm	
	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.
INCREASERS												
Bare Ground	94	77.3	50	23.9	31	15.2	19	4.2	13	6.3	6	3.9
Erythronium grandiflorum			56	9.1	75	7.2	69	6.2	63	3.9	50	1.9
Epilobium alpinum			19	4.2	13	3.3	19	1.3	19	.5	13	.3
Hieracium gracile			31	3.8	25	2.8	44	2.7	25	.6	19	1.3
Poa pratensis			25	.6	13	.3	13	.3				
Trifolium parryi			6	2.3	6	.2	6	.2	6	.2		
DECREASERS												
Litter	56	8.1	50	22.0	75	33.3	94	31.9	94	35.9	88	34.5
Vaccinium scoparium			25	4.4	25	.6	25	5.8	31	10.5	31	9.8
Arnica cordifolia	6	.2	19	.5	25	.6	19	4.4	19	4.2	19	3.4
Aquilegia flavescens					13	.3	6	.9	6	5.5	6	3.9
Pyrola secunda							13	1.1	13	.3	13	.3
Abies lasiocarpa							6	2.3	44	7.0	19	6.6
INCREASER-DECREASER-BELL												
Pedicularis bracteosa			13	.3	25	2.8	50	5.0	44	1.9	19	3.4
Thalictrum venulosum			13	1.1	13	2.5	31	5.9	19	2.0	25	1.4
Senecio triangularis			13	1.2			[31	4.5]	6	2.3		
Bromus marginatus			13	.3	13	1.1	13	.5	6	.9	6	.9
UNCHANGING												
Rock	13	.3	6	1.1	6	.9	6	.9	19	4.2	6	2.3
Arnica latifolia	6	.2	56	11.1	50	15.5	63	20.5	50	8.0	63	15.0
Erigeron peregrinus			13	1.9	19	1.3	13	1.1	6	1.1	13	1.1
Senecio serra			6	.9	6	.9	6	.9	6	.9		
Carex geyeri			25	3.0	31	1.6	19	.3	25	1.4	6	.2
Osmorhiza chilensis					6	.9	6	.9	6	.2	6	.2

OTHER SPECIES PRESENT (Insufficient frequency for interpretation)
Agoseris glauca (1), *Antennaria alpina* (2), *Aster occidentalis* (3), *Aster engelmanni* (+), *Bromus anomalus* (3), *Campanula rotundifolia* (+), *Castilleja miniata* (3), *Claytonia lanceolata* (3), *Epilobium augustifolium* (2), *Festuca idahoensis* (+), *Fragaria virginiana* (1), *Geum macrophyllum* (2), *Pedicularis cystopteridifolia* (1), *Polygonum bistortoides* (2), *Potentilla diversifolia* (1), *Ranunculus acriformis* (2), *Ranunculus eschscholtzii* (2), *Sedum stenopetalum* (1), *Sibbaldia procumbens* (+)

( ) Parenthesis indicate number of occurrences.
\+ Plants observed near sample frames, but not within plot.
[ ] Brackets indicate a zone of high frequency and/or cover along gradient sample.

Whitebark Pine Forest Trails

Understory vegetation at the center of the trail (Frame 1) was eliminated except for minute amounts of *Erythronium grandiflorum*, *Hieracium gracile*, *Carex podocarpa*, *Lupinus sericeus*, and *Vaccinium scoparium* (Table V).

Plants exhibiting increased cover and/or frequency percent near the trail's edge were: *Erythronium grandiflorum*, *Hieracium gracile*, *Sibbaldia procumbens*, *Carex podocarpa*, *Lupinus sericeus*, *Arnica latifolia*, and *Erigeron peregrinus*.

Plants of the undisturbed forest floor (Frame 6) which were absent at the trail's edge ("decreasers") were: *Vaccinium scoparium*, *Phyllodoce empetriformis*, and *Abies lasiocarpa* seedlings.

Plant species approximating the "increaser-decreaser-bell" curve pattern were not found in this forest type.

Plant species apparently not affected by trails ("unchanging") were: *Carex geyeri*, *Agoseris glauca*, *Carex xerantica*, *Poa alpina*, *Juncus parryi*, *Castilleja rhexifolia*, and *Potentilla diversifolia*.

Data on whitebark pine understory composition appears in Table V. Other plant species recorded adjacent to plots studied are listed in Table XIII in the appendix.

TABLE V

Understory vegetation at various distances from trail center in whitebark pine (*Pinus albicaulis*) Forests. Percent frequency and percent cover data are derived from studies at 19 sites measured in June, July and August 1971.

Species List	Frame 1 Trail Ctr.		Frame 2 Trail Edge		Frame 3 50 cm		Frame 4 120 cm		Frame 5 240 cm		Frame 6 460 cm	
	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.
INCREASERS												
Bare Ground	100	68.7	79	19.1	63	23.2	21	1.2	16	2.9	5	.2
Erythronium grandiflorum	5	.1	53	8.8	74	10.1	58	3.4	53	3.3	53	4.5
Hieracium gracile	5	.1	26	2.0	37	1.6	21	1.2	21	1.2	11	.3
Sibbaldia procumbens			16	.4	5	.1	5	.8				
Carex podocarpa	5	.1	21	2.4	16	1.1	5	.8	5	.8		
Lupinus sericeus	5	.1	16	1.1	11	2.1	16	.4				
Arnica latifolia			37	4.7	53	8.3	74	6.7	63	6.7	53	1.4
Erigeron peregrinus			11	2.1	11	2.8	5	2.0			5	.1
DECREASERS												
Litter	84	14.2	84	26.7	89	23.2	95	28.2	79	25.5	68	20.3
Vaccinium scoparium			53	11.6	74	18.0	89	42.6	95	56.2	89	56.7
Phyllodoce empetriformis			5	.1	5	.1	11	1.6	5	.4	11	.8
Abies lasiocarpa							5	.1	5	.8	11	4.7
UNCHANGING												
Rock	5	.3	21	.5	11	3.4	16	2.9	11	.3	5	.1
Carex geyeri			5	.8			5	.1			5	.1
Agoseris glauca			5	.8	5	.1			5	.1	5	.1
Carex xerantica			5	.1	5	.1	5	.1	5	.1	5	.1
Poa alpina			5	.1			5	.1	5	.8		

OTHER SPECIES PRESENT (Insufficient frequency for interpretation)
Achillea millefolium (+), *Antennaria alpina* (+), *Antennaria lanata* (+), *Antennaria rosea* (1), *Arnica cordifolia* (+), *Castilleja rhexifolia* (2), *Claytonia lanceolata* (+), *Epilobium alpinum* (1), *Fragaria virginiana* (+), *Geum rossii* (+), *Juncus balticus* (1), *Juncus parryi* (2), *Pedicularis bracteosa* (1), *Pedicularis cystopteridifolia* (1), *Pinus albicaulis* (1), *Poa secunda* (+), *Potentilla diversifolia* (2), *Sedum stenopetalum* (+), *Trifolium haydenii* (+), *Trifolium parryi* (+)

( ) Parenthesis indicate number of occurrences.
\+ Plants observed near sample frames, but not within plot.

TRAIL WEAR

Lodgepole Pine Forest Trails

In heavily used sites, depths averaged 3.1 cm. Corresponding mean average depth for moderately used areas was higher at 4.8 cm while lightly used sites had a mean average depth of 1.6 cm.

Trail widths in heavily used sites averaged 96 cm and moderately used sites had a mean average width of 64.2 cm. Lightly used sites showed a higher mean average trail width of 66.7 cm.

Engelmann Spruce-Subalpine Fir Forest Trails

On heavily used sites the mean average depth of wear was 5.5 cm. Moderate mean average depth of wear was 4.2 cm. Corresponding mean average depth for lightly used trails in this type were not sufficiently sampled.

Mean average trail width for heavily used sites was 92 cm and moderately used sites averaged 86 cm. Lightly used trails in this type were not sufficiently sampled for average trail width determination.

Whitebark Pine Forest Trails

Average depth of trail wear is higher on the moderately used sites (4.2 cm) than on the heavily used ones (3.3 cm). Lightly used trails had a mean average depth of wear of 2.5 cm.

Mean width of trail wear was highest (111.7 cm) of all forest types studied for heavily used trails. The moderate averages of wear for trail width were lower than spruce-fir types (75 cm) and higher than lodgepole pine types (68 cm).

TRAIL WEAR SUMMARY

Mean and standard deviations for depth and width of trail wear in each forest type studied are itemized in Table VI and graphically shown in Figure 8.

TABLE VI

Variations in width and depth of trails with vegetation type using three subjective measures of use. (June, July and August 1971)

	Trail Width		Trail Depth	
	Mean (cm)	Standard Dev. (cm)	Mean (cm)	Standard Dev. (cm)
Lodgepole Pine				
Heavy use	96.0	39.3	3.1	1.9
Medium use	64.2	22.5	4.8	2.0
Light use	66.7	20.3	1.6	1.0
Spruce-Subalpine Fir				
Heavy use	92.0	36.5	5.5	2.4
Medium use	86.0	52.4	4.2	2.4
Light use	[1]50.0		[1]2	
Whitebark Pine				
Heavy use	111.7	32.5	3.3	.5
Medium use	71.0	27.9	4.2	2.3
Light use	56.9	13.4	2.5	1.3

[1]Insufficient data for adequate interpretation.

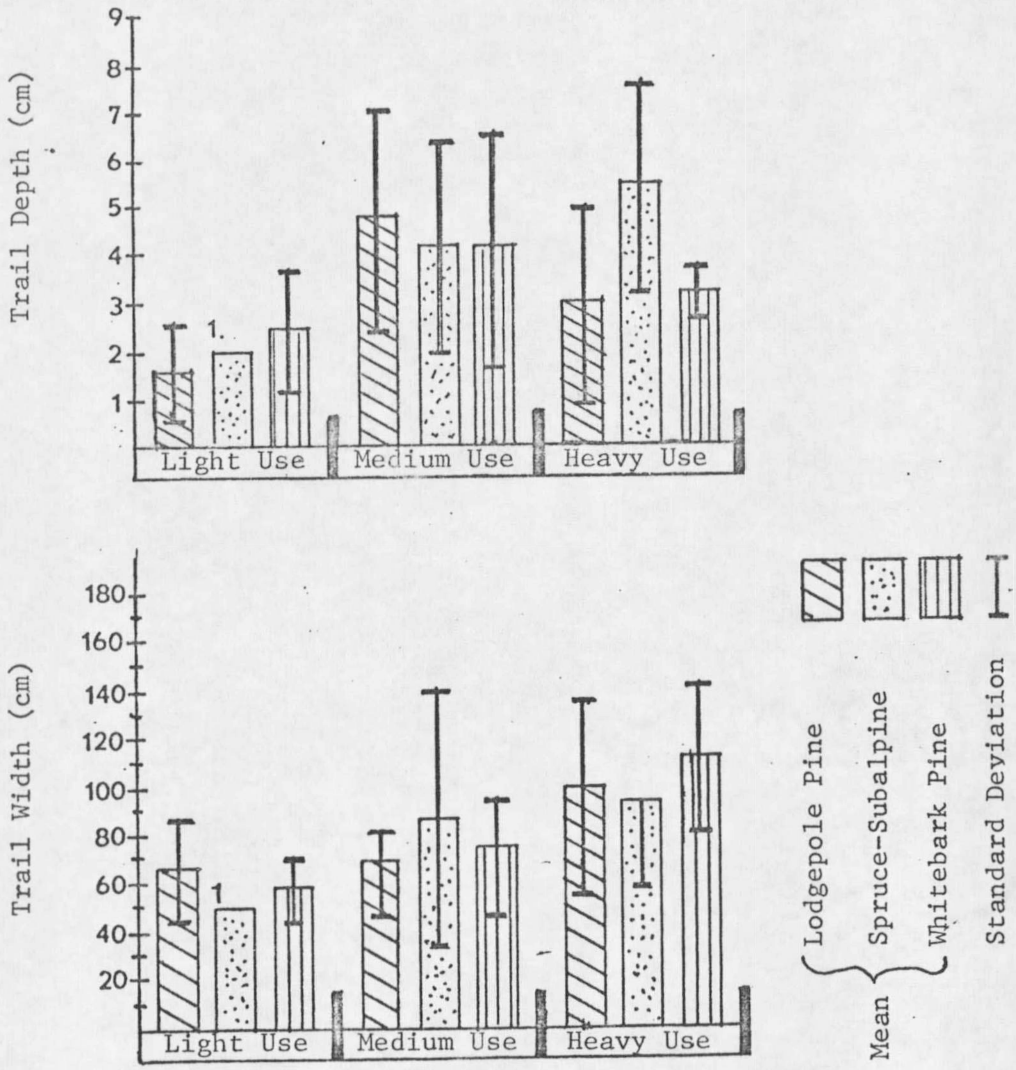

FIGURE 8

Mean and standard deviation for width and depth on trail under three forest types in the Spanish Peaks for three subjective levels of use. Use levels are light, medium and heavy.

[1] Insufficient data for adequate interpretation.

DISCUSSION AND CONCLUSIONS

MAPPED AREA

In 1971 the Madison Range was found to have a complex mixture of barren rocky exposures, coniferous forests, quaking aspen, alpine and subalpine meadows, sagebrush, and willow. These cover types are discussed in the following paragraphs. The entire range is dotted with lakes and channeled by streams which flow into the Gallatin and Madison Rivers.

Description of Mapped Area

Lodgepole Pine Forest: Nearly pure stands of *Pinus contorta* Dougl. dominate the study area. They occupied approximately 39.2% of the total land area mapped and were found at elevations between 5 000 ft (1520 m) up to 7750 ft (2362 m). Patten (1963) and Montagne (1971) observed that lodgepole pine favored landslides and earthflows on the more level areas and there appears to be a similar occurrence on the study area.

Lodgepole pine is a fire dependent subclimax forest type (Clements 1910, Mason 1915, and Tackle 1959) which serves as an intermediate to some succeeding species. In all sites studied, subalpine fir reproduction dominated the understory (Fig. 9); lodgepole pine occupies the *Abies lasiocarpa* - *Vaccinium scoparium* habitat type. (Daubenmire 1968)

FIGURE 9

Typical lodgepole pine stand with subalpine fir understory reproduction. Note the diamond blazed reference tree on right edge of trail.

Annual ring counts from eight different sites and old fire scars, show that a fire swept through much of the study area to create 142 year old even-aged stands. The 1830 fire is also mentioned by Patten (1963).

Mason (1915) observed that lodgepole pine in the Rockies was the fastest growing conifer in its range and was closely associated with Douglas fir at the lower elevations, and with spruce and subalpine fir in the higher elevations. Mason (1915) also determined that mature lodgepole pine forests at 140 years averaged 195 ft^2 of basal area/acre (45 m^2/h). Similar figures (200 ft^2/acre, 46 m^2/h) were recorded in the study area (Table X in the appendix). At maturity, lodgepole pine susceptibility to insect infestation increases due to its larger diameter and increased phloem size (Roe and Amman 1970).

Spruce-Subalpine Fir Forest

Alexander (1958), Habeck (1967), LeBarron and Jemison (1953), and Stahelin (1943) recognized spruce-subalpine fir forests of the northern Rocky Mountains as a high elevation climax association. Daubenmire (1968) labels these forests *Abies lasiocarpa - Vaccinium scoparium* habitat types.

Picea engelmanni (Parry) Engelm, and *Abies lasiocarpa* (Hook) Nutt. were usually found in close association except in areas near timberline. In most cases, subalpine fir trees greatly outnumbered the interspersed

Engelmann spruce although the latter were generally larger. Approximately 1.1% of the study area was mapped as subalpine fir forest.

Subalpine fir was observed from 5000 ft (1520 m) to 10,500 ft (3200 m), and was most sampled at a mean elevation of 8100 ft (2468 m). It often occurred in pure stands above the range of whitebark pine and assumed a dwarfed shrub-like "Krummholz" at elevations above 9500 ft (2896 m).

On eight sites examined, annual ring counts of subalpine fir indicated a mixture of age classes which averaged 150 years.

Though it is climax, Clements (1910), Mason (1915), Tackle (1959), and others, including the author, have observed that after fires climax spruce-subalpine fir forests are often replaced by subclimax lodgepole pine forests. In all spruce-fir sites examined, only subalpine fir trees were observed to reproduce in the understory which suggests an eventual elimination of Engelmann spruce.

Spruce stands with relatively few subalpine firs covered approximately 2.1% of the study area. There were very few trails found in these areas and reasonably so: Engelmann spruce occupies moist soils in cold valley bottoms adjacent to streams and bogs which are poor areas for trail location.

In the mapped area Engelmann spruce was commonly associated with subalpine fir up to elevations near 9100 ft (2774 m). It was not seen in the upper "krummholz" regions. As in Patten's (1963) studies in nearby areas, Engelmann spruce populations were observed to sharply decline above the 7500 ft (2286 m) level. Possibly its inability to endure severe moisture and temperature extremes, as discussed by LeBarron and Jemison (1953), would account for its limitation at higher elevations in these areas.

Most Engelmann spruce trees on the areas studied were larger and older than adjacent subalpine fir. Increment readings from six different sites within the study area indicate existing stands to vary in average age from 95-200 years with the oldest tree being 320 years old.

Whitebark Pine Forest

In the study area, groves of *Pinus albicaulis* Engelm. were found nearly everywhere at elevations of 8100 ft (2468 m) to 9500 ft (2896 m) at timberline. It occupied the second largest forest mapping unit (29.2%) and was found on rocky exposures and with gravelly soils. This study, in agreement with those of Sudworth (1908), Kirkwood (1922), Habeck (1967), and Harlow and Harrar (1958) shows that whitebark pine commonly occurs in pure stands.

Limber pine (*Pinus flexilus* James) is nearly indistinguishable from whitebark pine except in cone characters, but at these elevations there was little chance of confusing the two tree species. Cones were used for positive identification of pines; very few limber pine trees were detected above elevations of 6500 ft (1981 m). Those that were observed never occurred in amounts sufficient to warrant mapping. Patten (1963) likewise observed that whitebark pine occurred at elevations above the range of limber pine.

Little study has been made in whitebark pine forests. Daubenmire (1968) considers whitebark pine to share a climax status with subalpine fir. The whitebark pine sites studied had an essentially pure overstory, but nearly equal amounts of whitebark pine and subalpine fir reproduction were found in the understory, which suggests a trend toward Daubenmire's (1968) findings.

A mean basal area of 179 ft^2/acre (41 m^2/h) was lower than those found in other forest types studied. Finzer (1971) reported that whitebark pine stands on Wheeler Ridge in the adjacent Gallatin Range had an average basal area of 193 ft^2/acre (44 m^2/h).

Annual ring counts from these trees show them to be slow-growing, mostly even-aged forests. Typical stand ages sampled were found to be 180-200 years and growth averaged 50 rings per inch.

Douglas Fir

Interior Douglas fir (*Pseudotsuga menziesii* var. *glauca* (Beissn) France), forests occupy the third largest amount of timbered area within the Madison Range. Approximately 5.9% of the study area was Douglas fir forest.

They were observed to grow in pure stands on sunny, dry rocky exposures from the valley floor up to the 7500 ft (2286 m) level. Patten (1963) found that Douglas fir favored west facing steep rocky slopes of limestone bedrock.

Some lower elevation areas of lodgepole pine forest are believed to be climax Douglas fir sites which were occupied following fire (Mason 1915).

Buell (1958) describes Douglas fir as a low elevation shade intolerant open grown climax type of the Rocky Mountains. Douglas fir is commonly seen with *Juniperous scopulorum* Sarg., *Pinus flexilus* James, and *Artemisia tridentata* Nutt., at lower elevations than those studied here, and with *Pinus contorta* Dougl. at its upper extremes.

Patten (1963) observed that in the Madison Range the most common understory plants found in this forest type were *Vaccinium membranaceum* Dougl., *Pachistima myrsinites* (Pursh) Raf., *Ribes cereum* Dougl., *Prunus virginiana* L., *Amelanchier alnifolia* Nutt., *Physocarpus malvaceous* (Greene) Kuntze, *Acer glabrum* Torr., *Berberis repens* Lindl., and a considerable mixture of grasses. Stands of this type were not sampled in this study.

Aspen

Populus tremuloides var. *aurea* (Michx.) occupies 0.3% of the study area. It occurs in small groves near rocky volcanic outcrops and on glacial till hillsides. Contrary to Patten's (1963) findings, it appears to be limited to lower elevations and was not observed beyond the 8000 ft (2430 m) level. Reed (1971) describes aspen communities as fire subclimax communities of low elevations. As a result of past fires, aspen has established itself in small wet areas while lodgepole pine has invaded most areas.

Reed (1971) and Strothman and Zasada (1957) observed that aspen stands, once established, occur in clones which reproduce by root suckering. Rockiness most likely prevents greater underground reproduction and limits enlargement of the aspen groves.

Aspen groves are soil enrichers, (Strothman and Zasada 1957). They were observed to support a rich understory of grasses and herbs such as *Poa pratensis* L., *Festuca idahoensis* Elmer, *Melica bulbosa* Geyer., *Koeleria cristata* (L.) Pers., *Carex* spp., *Rosa woodsii* Lindl., *Geranium viscossissimum* Fisch & Mey., *Potentilla gracilis* Dougl., *Lupinus sericeus* Pursh, *Berberis repens* Lindl., *Amelanchier alnifolia* Nutt., and *Smilacina racemosa* (L.) Desf. (Patten 1963, Reed 1971).

Sagebrush

Artemisia tridentata Nutt. is the predominant species in all areas mapped as sagebrush, comprising 5.3% of the study area and occupying a variety of level flats and slopes at lower elevations. There seems to be a great occurrence of sagebrush communities on the more level glacial till soils. Contrary to Patten (1963), sagebrush was not seen above elevations of 7500 ft (2286 m).

Patten (1969) felt that some of these communities, which are presently invaded by lodgepole pine, were in a subclimax state.

In many cases, *Festuca idahoensis* Elmer., occurs in high amounts in these areas. Patten (1963) also found *Artemisia cana* Nutt. to occur in subordinate amounts up to 8%. Patten (1969) described the commonly found grasses and forbs in these areas to be *Agropyron spicatum* (Pursh) Scribn. and Smith, *Koeleria cristata* (L.) Pers., *Stipa* spp., *Taraxacum officinale* Weber, *Agoseris glauca* (Pursh) D. Dietr., *Eriogonum umbellatum* Torr., *Geum triflorum* Pursh, *Antennaria rosea* (Eat.) Greene, *Geranium viscossissimum* Fisch. & Mey., *Potentilla gracilis* Dougl. and *Cerastium arvense* L. *Potentilla fruticosa* L. was observed in low level areas of high moisture content.

Willow

Willows occupy approximately 0.5% of the recently mapped areas and were found at all elevations in swamps, bogs, wet meadows, lakeshores, and streamsides.

Dorn (1970) identified 15 different species of willow which exist in the various moist habitats of the Madison Range. Three of the most commonly found (Stevens 1967) are *Salix drummondiana* Barratt, *Salix myrtillifolia* Anderss., and *Salix geyeri* Anderss. Patten (1968) found *Salix lutea* Nutt. most frequently at the lower elevations of Gallatin Canyon.

At higher elevations, 7500-9500 ft (2286-2896 m) pure willow thickets with little herbaceous undercover were observed. In willow bottoms at lower elevations, Patten (1968) found herbs such as *Achillea millefolium* L., *Thalictrum sparsiflorum* Turcz., *Smilicina racemosa* (L.) Desf., *Fragaria virginiana* Duch., and *Potentilla fruticosa* L.

Alpine and Subalpine Meadows

Open meadows cover approximately 4.2% of the study area. They are found at all elevations with many grasses and forbs occurring in each opening; Patten (1963) found over 70 species of grasses and forbs in a single meadow south of the study area at the 8000 ft level.

Some species identified in meadows adjacent to the three forest types studied are found in Table XIV in the appendix.

The flora varies with elevation. Larson (1930) reported that mountain meadow plant species have a wider range of tolerance to temperature and moisture extremes than do forest understory plants.

Barren and Rocky Exposures

Barren and rocky areas comprise 22.8% of the land within the study area. They begin at elevations of 5000 ft (1520 m) and range up to 11,500 ft (3505 m). Included are steep cliffs, slides, scree slopes, and open rocky exposures. The majority of the rocky areas are above timberline; in these are such alpine species as *Sedum* *stenopetalum* Pursh, *Silene acaulis* L., *Sibbaldia procumbens* L., *Carex* spp., *Salix arctica* Pall., *Eritrichim nanum* (Vill.) Schrad., *Mertensia alpina* (Torr.) G. Don., *Geum rossii* (R.Br.) Ser., and high alpine grasses (Griggs 1956, Habeck 1967, Marr 1970, and Willard 1971). Trees at the upper elevations include whitebark pine and subalpine fir on the majority of slopes, and aspen, juniper, and limber pine at the lower elevations. Soils in these areas are dry, rocky, undeveloped pioneer soils such as the Highland Association (Southard 1969).

COMPARISON OF VEGETATION OF THE STUDY AREA WITH THAT OF THE WHOLE MADISON RANGE

Mapped Area vs. Madison Range

Comparison of percentages from Table I for each type in line 1 with each type in line 5 indicates that the vegetation within the study area is typical of the entire Madison Range.

East/West Comparison of Madison Range

Figures from Table I in lines 3 and 4 suggest that slightly greater areas are covered by lodgepole pine east of the Madison divide than west of it, and by more Douglas fir, Engelmann spruce, and white-bark pine west of the Madison divide than east of it. Areas covered by rock and subalpine fir are nearly equally distributed.

Effects of Aspect

Figure 7 presents the effects of aspect on major forest types.

Douglas fir was most prevalent on south, southeast, southwest, and West slopes (Table II). This is contrary to Patten's (1963) report of Douglas fir on east facing slopes.

Lodgepole pine was most prevalent on north, northwest, northeast and southeast facing slopes with nearly equal coverage for each of these areas. South facing slopes had the smallest amount of lodgepole pine cover. It is speculated that climax Douglas fir forests remain in sparse open grown stands almost exclusively on the south slopes. This is thought to be so because fires are common in north slopes but not in south slopes where fires cannot travel. The north slopes burn often because they support greater densities of both understory and overstory vegetation which provide an adequate continuous fuel supply which often burns off completely and provides a means by which fire dependent lodgepole pine is able to readily reoccupy these sites.

Subalpine fir was not mapped accurately in Forest Service Type Mapping and therefore data is insufficient for adequate interpretation.

Engelmann spruce favored the northern slopes where moisture contents were higher. The author found greatest occurrence on the northwest facing slopes while Patten (1969) found Engelmann spruce to favor the northeastern slopes.

Whitebark pine appeared in highest amounts on east and south facing slopes and appears to avoid the southeast, north, northeast, and northwest slopes.

Nonforested rocky exposures include cliffs, scree slides, and barren alpine areas. Percent coverage on all aspects was nearly equal. The mapped study has a high proportion (0.5%) of lakes as compared to the entire Madison Range.

TRAIL EFFECT

Review of Literature

Understory Vegetation: Effects on vegetation from trampling along trails in forests in the Rocky Mountains has been previously unstudied. Meinecke (1929) studied trail use in the coastal redwood forests of California. Edwards (1967) worked with trails in coastal British Columbia, Canada. Westhoff (1967) discussed trampling effect on trails in Holland. Burden and Randerson (1972), Ryle (1967), Davies (1936), and Bates (1935) studied the nature of changes to trails from trampling in England.

Forest Overstory: The effects of foot traffic and soil compaction on the adjacent forest overstory as well as the understory vegetation in camp and picnic sites have been studied in several areas. Wagar (1971, 1965) noted the effects on spruce, Douglas fir, subalpine fir, and aspen stands in northern Utah. Jemison (1967) observed trampling effects on Engelmann spruce and subalpine fir in the northern Rockies of Canada. Cole (1964) conducted studies in black oak stands in the Missouri Ozarks. LaPage (1962 and 1967) studied effects of trampling over a three year period on eastern white pine, red pine, spruce, and hemlock in three state parks of New Hampshire. Appel (1950) observed the trampling effect in camp and picnic sites in New Jersey. Magill (1970) investigated the trampling effect on recreation sites within ponderosa pine, jeffrey pine, and white fir stands in California. And, Meinecke (1929) studied the trampling effect on coastal redwoods in California. With the exception of Magill (1970), in all cases it was found that heavy soil compaction from recreational use reduced increment growth and in some cases (Cole 1964) created crown dieback of overstory trees. Compaction often reduced or killed roots of overstory trees (Appel 1950, Cole 1964, Meinecke 1929). Some inhibitory effects on trees adjacent to trails is possible but was not studied.

Ecology of the Trailside Gradient

In the following paragraphs, I introduce the idea that forest understory vegetation changes as one approaches a trail and review information available on factors which may be responsible for these changes. Vegetation changes will be discussed in detail in a later section.

Plant Zonation: A complex gradient of environmental conditions extends from the trail into the adjacent forest. Along it, different plant species repeatedly assumed specific positions. Bates (1935), Burden and Randerson (1972), and Davies (1936) recognized that footpaths contained a distinctive plant sequence due to the various changes in habitat brought about in the establishment and continued use of footpaths. They observed a gradient of "zones" where variations in soil compaction, soil moisture, and light intensity correlated with distinctively different vegetaion types progressing from the center of the pathway into adjacent undisturbed areas. Waring (1964) observed that: "Although few if any species respond identically to a given intensity of an environmental factor, plants may still be grouped in relation to the location of their ecological optima along various effective environmental gradients". In all three forest types studied, a similar trail plant "zonation" was observed: the trail center was denuded and in the adjoining vegetation specific plants repeatedly assumed certain positions along the gradient.

Soil Compaction: Westhoff (1967) observed in Holland that "when situated in more or less natural or seminatural areas such as woodland heaths, moorlands, and dry pastures, such tracks present a type of diversified gradient--a gradient from being constantly trodden to being rarely or never trodden. This corresponds with a gradient of decreasing soil compaction. Many plants are ecologically specialized or present their optimum in this special gradient type". Bates (1935) determined that soil compaction within the pathway created greater soil bulk densities in the top 5 cm layer, and below this depth soil conditions were comparable to areas at similar depths in the adjacent untrodden areas. In campsite and picnic areas, Cole's (1964) studies indicated similar effects down to 8 cm and LaPage (1967, 1962) observed subsurface compaction down to 15 cm. Apparently, in all trails the variation in compaction depth is correlated at least with differences in trampling intensity, soil moisture, content, and soil texture (Bates 1935, Burden and Randerson 1972, Davies 1936, and Willard and Marr 1971).

Soil Moisture: Moisture can be regarded as one of several factors responsible for the existence of a particular trail gradient structure. Generally, a soil moisture gradient exists with high moisture contents near the trail center and gradually declining moisture contents at greater distances from the trail. Vegetation varies along the gradient into the forest according to the individual requirements of each plant.

It is well known that plant communities change along a moisture gradient. Bates (1935) and Davies (1936), for example, observed that footpaths in relatively dry sites exhibited a different flora than nearby moister trail habitats. Bates (1935) and Waring (1964) found that the greatest number of plants did not necessarily occur where highest moisture was present.

Some reasons why the trail is a moister habitat than the surrounds are presented below. The surface of the trail is pressed down to a lower level than the surrounds and gravitation supplies greater quantities of water to these areas. Burden and Randerson (1972) determined that compaction within pathways created proportionately "wetter" soils due to reduced air filled pore space. Lutz (1945) determined that soil compaction in picnic areas reduced pore volume, air space, and increased soil field capacity. The shading of adjacent overstory timber reduces solar exposure, soil temperature, and consequent surface evaporation. The understory vegetation and thick needle duff layers on the forest floor often retain greater quantities of water at the surface which are subject to evaporation for longer periods of time. Cole (1964) determined that recharge of soil moisture was greater in undisturbed areas, but overall moisture losses were greater due to evapotranspiration by plants and litter. In a pathway habitat, there is no aerial interception of precipitation or plants to transpire moisture. The "mat layer" is removed and free access of water is possible.

The factors which might make a trail site relatively dry are presented below. Daubenmire (1968), Lane and McComb (1948), Rowe (1955), and Waring (1964), determined that grassland types and low herb communities depleted soil moisture content at a faster rate than forested areas

Bates (1935) and Waring (1964) noted that when high clay content is present, "puddling" often occurs and prohibits the infiltration of water. The result is an impenetrable surface with high amounts of runoff and evaporation rendering the soil drier than its surrounds. Trails studied were not on clay-rich soils.

Light Intensity: From various studies, it appears that though light does not singly control the occurrence of plants along the trail gradient, there is a strong correlation between light intensity and levels of plant response.

Where a trail pathway passes through a forest, a thoroughfare is usually established and the shading effect is partially removed. Right-of-way clearing along these trails is often done in initial trail construction and illumination near the path becomes greater than in its surrounds. Gatherum (1961) determined that 100 percent removal of the overstory with uniform removal of two-thirds of the understory in a black oak stand increased available light to the ground by approximately 33 percent. Jemison (1967), Magill(1970), and Wagar (1971), discovered that partial removal of the overstory crown within campgrounds stimulated growth and recovery of understory vegetation.

In many cases, the main pathway will receive partial shading from the overshadow of adjacent timber on one side and maximum illumination will occur on the opposite side at some distance from the trail center. In this study it was obvious that light intensities were greatest within 1.2 m to 2.4 m from the trail center.

Comparison of Tables I, II, and III indicates the gradient effect expressed by plant frequencies and cover values is greatest in spruce-fir forests; this may be due to the light factor. Clements (1910) determined that spruce-fir forests restrict sunlight more than any other forest habitat in the Rocky Mountains. Waring (1964) determined that several plants were specifically adapted to certain levels of light intensity. For example, he found that *Bromus mollis* had optimum occurrence at 100% illumination while *Elymus glaucus* had its optimum in partially shaded openings of 55% of total sunlight. Bates (1935) observed that *Trifolium repens* occurred only in areas where considerable sunlight was present. Jemison (1967), Magill (1970), and Wagar (1971, 1970) found that opening of the forest canopy to a certain level stimulated undergrowth and increased species diversity.

Soil Nutrition: The soil substratum is nearly identical at all points along the cross-trail gradient and it would appear that plant nutrition does not account for vegetation changes (Burden and Randerson 1972). Local fertilization can occur where droppings and urine are left by animals, but this appears to be at a low level in the study area and its effect was probably not detectable. Wagar (1971) found that fertilization of understory plants under coniferous forests produced almost no differences in overall herbage yields. There was, in some cases, a greater accumulation of soil organic matter from decayed litter on the surrounds than in the pathway, but this was not always the case. In many instances high amounts of litter were found in the trail as well as in the adjacent areas; Bates (1935) found slightly lower pH values in areas of heavy accumulation along trails, but these were not significant.

GENERAL DESCRIPTION OF THE VEGETATION GRADIENT

Trail Center

A few plants persisted in low amounts within the extreme trampling of trail center (Frame 1), Figure 4. They are apparently adapted to trampling. Although no attempts were made to determine how various plants are or are not adapted to trampling, speculations are presented in the following paragraphs.

Plants found in heavily compacted areas (Frame 1) were often observed to be dwarfed. Bates (1935) also observed dwarfing of *Poa pratensis* and *Trifolium repens* along footpaths in England.

Increasers

Bates (1935), Burden and Randerson (1972), and Davies (1936) recognized that trailsides develop their own unique flora which is distinctly different from the surrounds. Burden and Randerson (1972) attributed the change with the plant species' ability to survive under trampling pressures and termed them as trail "indicator" species. The author observed the same patterns of persistence: along forested trails within the study area, certain plants were observed to consistently favor sections adjacent to the pathway. Such plants (increasers) had highest frequency and/or cover values in disturbed areas of the trail (Frames 2 and 3) and successively lower values in the undisturbed forest (Frames 5 and 6). This concept is graphically illustrated in Figure 6 and photographed in Figure 10.

Erythronium grandiflorum and *Hieracium gracile* typically were common in with high frequency and/or cover percent in all three forest types and assumed the "increaser" distribution pattern.

Apparently the success of *Erythronium grandiflorum* is due to its ability to avoid the harsh conditions of the trail habitat: it produces flowers and fruits soon after snow melts and before trampling begins. It survives the trampling season as hard, black, durable seeds and large storage bulbs 20 cm to 30 cm deep.

FIGURE 10

Both photographs show *Erythronium grandiflorum* as the dominant plant species in areas where heavy camping use recently occurred. *Vaccinium scoparium* (under the timbered areas) was removed in both of the trampled sites. The top photograph is a "tent pad site" under lodgepole pine forest, and the lower photograph is a commercial outfitter's camp in a whitebark pine forest near Lower Spanish Lake.

Hieracium gracile was consistently observed to have highest numbers in open bare spots where neighboring competition was low. The trailside zone provides such a habitat. Field examination revealed a large tap root which may store moisture and enable it to withstand periods of drought. It is also a prolific fruit producer. Unlike *Erythronium grandiflorum*, this plant completes its life cycle in late summer. An explanation of its hardiness is not possible: it should be investigated further.

Decreasers

Field data indicated that some plant species, adapted to undisturbed forest understory conditions, were eliminated by the effect of trails or adjacent openings. Their frequency and/or cover values decreased as one moved from the undisturbed forest (Frame 6, Figure 4) into the area of use near trail center. Plant species which consistently assumed this pattern along the gradient were termed "decreasers". *Vaccinium scoparium* and *Abies lasiocarpa* seedlings were decreasers commonly found in all three forest types studied.

Vaccinium scoparium was the dominant understory shrub species in all of the sites studied; it assumed that position after fires and maintains itself under climax conditions (Daubenmire 1968 and Habeck 1967). *Vaccinium scoparium* was intolerant to trampling in all forest types studied (Figure 5), perhaps because of its brittle stems and foliage which rapidly breaks down under foot and horse traffic (Fig. 10).

Abies lasiocarpa seedlings favored the untrampled shaded habitat of the forest with highest number occurring in Frame 6 (460 cm from trail center).

Obviously, physical pounding and wear from trampling are the strongest and most direct method of eliminating vegetation. Burden and Randerson (1972) support this concept in their statement that: "It was found that certain species occurred more frequently in the trampled zones, indicating a tolerance to high levels of pressure. In the untrampled areas, however, these species appear to be at a competitive disadvantage and are overgrown by the trampling sensitive species of the untrodden community."

Increaser-Decreaser-Bell

Initial establishment and/or construction of the trail creates an opening where sunlight and moisture conditions are altered. As previously mentioned, maximum light intensities were found not in the undisturbed forest but along the main pathway. Certain plant species favored trail edge conditions in a pattern which approximated a near "bell" curve (Figure 6). Apparently trampling effects control their occurrence adjacent to the trail (Frames 1 and 2) while low soil moisture content and heavy shading reduce their success on the undisturbed forest floor. Their optimum is expressed most often in the midrange of the sample in Frames 3 and 4 (50 to 120 cm from trail center). Plants assuming this pattern along the gradient were termed "increaser-decreaser-bell" species. Burden and Randerson (1972) found that certain plants were stimulated by low amounts of trampling pressure; this may enter into the habitat conditions which create the "bell" pattern.

Unchanging

Some plant species had a wide range of tolerance to the gradient of conditions at the trail side. These plants were essentially constant in occurrence at all levels; they were termed "unchanging".

Carex geyeri assumed the "unchanging" pattern along the trail gradients in all forest types studied; it apparently resists both trampling and shading. Larsen (1929) considered *Carex geyeri* to be a subclimax understory species following fires. Bates (1935) suggested that plants with underground perennating buds, subsurface rhizomes, and folded or flat leaves were most resistant to trampling. Magill (1970) also found certain *Carex* species resistant to trampling. In his study of campground site deterioration in California, *Carex* species increased twofold in one site and threefold in another, while other species rapidly declined. *Carex geyeri* has the ability to resist trampling as mentioned above and also has a "shade tolerance" which permits it to grow in the forest interior; if these were not the case, *Carex geyeri* would be an increaser like *Poa pratensis* (Bates 1935, Burden and Randerson 1972, and Davies 1936).

Other Species Present

Several plants of the area were not observed in the sample frames or were present in low amounts within the sampled gradient. Many of these appeared to be "accidental" species which were more frequent in their optimum habitats at higher or lower elevations or within adjacent meadows. For example, some species present in low amounts in the lodgepole pine forest appeared with higher frequency in the spruce-subalpine fir forest and provided enough data for interpretation. Certain plant species found in low amounts within the spruce-subalpine fir forest re-occurred in sufficient amounts within the whitebark pine forest to provide enough data for interpretation. In addition, some plants found in the sample gradient were observed to have greatest populations in nearby meadows while others were found exclusively in very low amounts in one specific forest type.

Forest Litter

Forest litter assumed the decreaser pattern along the trail gradient with fairly constant values in Frames 3, 4, 5, and 6 and rapidly declined in Frames 1 and 2 at all sites within the three forest types studied. Cover values showed this best: little was present on trails, more was present in forests. Among forests, litter was least in lodgepole pine, greater in whitebark pine, and greatest in spruce-subalpine fir.

Bare Ground

Barren areas closely followed the increaser pattern with lots of bare ground on trails and relatively little in untrampled forests (48% in lodgepole pine, 68% in whitebark pine, and 77% in spruce-subalpine fir).

Rock

Exposed rock remained relatively constant along the entire gradient sample. Bare rock was most extensive in whitebark pine forests and less plentiful in subalpine fir forests and lodgepole pine forests.

DETAILED DESCRIPTIONS OF THE VEGETATION GRADIENT IN EACH FOREST TYPE

Data for the following discussion appears in Tables III, IV, and V, pages 27, 29, and 31.

Lodgepole Pine Trails

Trail Center: The main pathways were essentially denuded except for minor amounts of *Erythronium grandiflorum*, *Thalictrum venulosum*, *Viola orbiculatus*, *Claytonia lanceolata*, *Geranium viscossissimum*, *Spiraea betulifolia*, *Hieracium albiflorum*, and *Hieracium gracile*. These species appear to persist for several reasons: (1) delicate-leaved forbs such as *Erythronium grandiflorum*, *Thalictrum venulosum*, *Viola oribculatus*, and *Claytonia lanceolata* were seen to complete their life cycles quickly after snow melt, thus avoiding the trampling effect, further they perennate by subsurface stems; (2) *Spiraea betulifolia* is a shrubby plant with thick woody rhizomes which are capable of withstanding considerable trampling pressure and undergoes lateral bud proliferation when the terminal bud is damaged; (3) *Geranium viscossissimum*, *Hieracium albiflorum*, and *Hieracium gracile* had greater frequencies in forest openings with greater sunlight. Westhoff (1967) mentioned a preference for high sunlight intensity in certain species of *Geranium* in Holland.

Increasers: Plants having increased frequency and/or cover next to the trail edge were *Erythronium grandiflorum*, *Hieracium grandiflorum*, *Arnica latifolia*, *Poa pratensis*, and *Lupinus sericeus*.

The ecologic requirements of *Erythronium grandiflorum* were discussed above. In this forest type, it exhibits the increaser pattern quite effectively. For example, along the edge of the trail (Frame 2), *Erythronium grandiflorum* had a cover percent of 7.6 and a frequency of 57 percent which declined to 2.9 cover percent and 46 frequency percent in the undisturbed section at 460 cm from the trail center at Frame 6 (Table III).

Hieracium grandiflorum and *Arnica latifolia* were observed to occur specifically within the forest environment where patches of sunlight and open ground were found. They were found in highest numbers in trail openings with considerable sunlight (Frame 2).

Poa pratensis (Bates 1936, Burden and Randerson 1972, and Davies 1935) is particularly well adapted to trampling because: (1) it has natural seeding ability as well as an extensive underground root system with numerous rhizomes capable of vegetative reproduction; (2) it has short, flat leaves with low susceptibility to mechanical damage; and (3) the perennating buds (growing points) are underground, thus pro tected from trampling damage. Bates (1935) and Davies (1936) found that disturbed and compacted trailsides were often dominated (30 to 60% cover) by stands of *Poa pratensis*. Wagar (1970) also recognized the trampling resistant properties of *Poa pratensis* and used it for reseeding heavily trampled campsites in northern Utah.

Lupinus sericeus is often called lodgepole lupine due to its common occurrence in light areas such as trailsides in lodgepole pine stands. It played this role in a variety of habitats. For example, *Lupinus sericeus* plants were observed in great numbers in meadows at low elevations while at higher elevations their greatest frequency occurred within the partially shaded forest floor of lodgepole pine and whitebark pine forests. Occurrence in whitebark pine stands was much less than in lodgepole pine.

Decreasers: Those plants which favored the undisturbed, untrodden section of the gradient were *Vaccinium scoparium*, *Vaccinium membranaceum*, *Epilobium angustifolium*, *Pyrola secunda*, and *Abies lasiocarpa*.

Vaccinium scoparium, the principal climax understory shrub, gave the best example of the decreaser pattern. Along the trail edge (Frame 2), frequency was 36 percent and average cover was 8.6 percent. These values increased gradually to a frequency of 46 percent and an average cover value of 22.2% as the undisturbed and more shaded section of the gradient was approached (Frame 6). *Vaccinium membranaceum* appeared to have habitat requirements similar to *Vaccinium scoparium* but appeared in smaller amounts.

Epilobium angustifolium is frequently seen along roadsides and is called "fireweed" due to its ability to invade disturbed soils resulting from fires (Craighead, Craighead and Davies 1963). It is a weak decreaser on trailsides; it does not, then, increase with all types of disturbance.

Abies lasiocarpa seedlings exemplified intolerance to trampling and/or sunlight by showing a high increase from 14 percent frequency, 0.36 percent average cover along the trailside (Frame 2) to 21 percent frequency, 1.8 average cover at the shaded undisturbed part of the gradient.

Pyrola secunda was seen to consistently favor the moist shaded areas of lodgepole pine and spruce-fir forests. Larsen (1929) maintained that *Pyrola* spp. occurs in the dense forests where climax understory conditions exist.

Increaser-Decreaser-Bell: Those plants having highest values in the midrange along the gradient were *Geranium viscossissimum*, *Fragaria virginiana*, *Antennaria racemosa*, *Spiraea betulifolia*, and *Hieracium albiflorum*.

Geranium viscossissimum and *Fragaria virginiana* were frequently observed in nearby meadows. They apparently require high levels of sunlight and can withstand low levels of trampling.

Antennaria racemosa, *Spiraea betulifolia* and *Hieracium albiflorum* were similarly distributed along the gradient. They were seen primarily in small sunny openings within the forest habitat, suggesting that they too require considerable light but cannot tolerate trampling.

Unchanging: Plant species having a wide tolerance to many conditions with no significant differences in occurrence along the sample gradient were: *Viola nuttallii*, *Viola orbiculatis*, *Claytonia lanceolata*, *Carex geyeri*, *Arnica cordifolia*, *Osmorhiza chilensis*, *Astragalus alpina*, *Aster engelmanni*, *Calamagrostis canadensis*, and *Achillea millefolium*. Such plants are seemingly hardy or have specific adaptations which enable them to survive in a variety of conditions.

Viola nuttallii, *Viola orbiculatis*, and *Claytonia lanceolata*, like *Erythronium grandiflorum*, complete their life cycle early in the spring season before adverse trampling or moisture stress begin.

Carex geyeri, as previously mentioned, is resistant to trampling and appears to be resistant to other stress conditions under the forest overstory.

Other Species Present: Some plants that were sampled in low amounts had higher occurrence in other forest types.

Aquilegia flavescens and *Bromus marginatus* occurred in significant amounts in the Englemann spruce-subalpine fir trail samples and *Agoseris glauca* and *Erigeron peregrinus* were in sufficient amount for trail gradient analysis within the whitebark pine type.

Sedum stenopetalum remained in low amounts in all areas studied and was observed in the dry valley bottoms (5000 ft, 1524 m) and in the alpine meadows (10,500 ft, 3200 m). Daubenmire (1941) found that *Sedum stenopetalum* had a deep fibrous root system and thick fleshy water storage leaves which enabled it to survive in open rocky dry sites.

Engelmann Spruce-Subalpine Fir Trails

Climax spruce-fir forest appeared to have the highest amount of shading of any forest type within the study area (Clements 1910). This high degree of shading created a set of environmental conditions that were somewhat different from adjacent lodgepole pine and whitebark pine forests. For example, Clements (1910) determined that mature spruce-fir forests admitted an average of two to four percent of full sunlight while lodgepole pine stands admitted seven to eight percent. For this reason, the habitat change was more extreme along the trail gradient than in other forest types studied.

Trail Center: The main pathways were essentially bare with minor persisting amounts of *Arnica cordifolia* and *Arnica latifolia*. Both plants were seen to be extremely prolific and by nature of their occurrence suggest a high degree of tolerance to differences in light, temperature, and moisture stress.

Increasers: Those plants with highest occurrence at the trail edge were *Erythronium grandiflorum*, *Epilobium alpinum*, *Hieracium gracile*, *Poa pratensis*, and *Trifolium parryi*.

Erythronium grandiflorum exhibited a strong increaser pattern in all three forest types, with an average cover percent of 1.9 at Frame 6 graduated up to 9.1 average cover in Frame 2 in this forest type.

Epilobium alpinum was found to have a sharp decline at Frames 5 and 6. It was rarely observed in the lodgepole pine or whitebark pine sites. *Epilobium alpinum* is a low succulent plant which appears to favor moist shaded areas that are denuded or disturbed by trampling or erosion. It was also seen to invade heavily used high alpine campsites.

Hieracium gracile also exhibits a very strong increaser effect with low amounts within Frames 5 and 6.

Poa pratensis acts in the same manner in both spruce-fir and lodgepole pine sites. It increases near the trail's edge at Frames 2, 3, and 4, and completely disappears at Frames 5 and 6. Bates (1935), Burden and Randerson (1972), and Davies (1936) observed that *Poa pratensis* appeared in an identical pattern in England.

Trifolium parryi is a native mountain clover (Booth 1958) which appeared to favor trailsides in the spruce-fir forest (Table II). Bates (1935) thought certain *Trifolium* species favored trails for two reasons: (1) they are closely linked to a light stimulus, and (2) they have deep tough prostrate rhizomes which exhibit a resistance to trampling. Daubenmire (1941) examined *Trifolium parryi* and found similar root characteristics. Bates (1935) and Davies (1936) found *Trifolium repens* to strongly favor the edge of trodden paths. In the study area, *Trifolium parryi* became less important in the upper whitebark forests and was not seen within those lodgepole pine forests studied.

Decreasers: Those plants which favored the undisturbed climax forest conditions under spruce-fir forests were *Vaccinium scoparium*, *Arnica cordifolia*, *Thalictrum venulosum*, *Aquilegia flavescens*, *Pyrola secunda*, and *Abies lasiocarpa*.

Vaccinium scoparium, the principal climax understory shrub, (Daubenmire 1968, Habeck 1967) indicated the strongest decreaser pattern in this type. Along the trail's edge (Frame 2), average frequency was 25 percent and average cover was 4.4 percent. These values increased gradually to an average frequency of 31 percent and an average cover value of 9.8 percent as the undisturbed section of the gradient was approached (Frame 6).

Arnica cordifolia and *Thalictrum venulosum* were also observed to strongly favor the undisturbed forest habitat. Their exact requirements for their positioning along the gradient are unknown.

Aquilegia flavescens may be linked to a light relationship more than other factors. It was also seen in large amounts along the opening of meadows and less shaded sections within small forest openings.

Pyrola secunda and *Abies lasiocarpa* appeared in Frames 4, 5, and 6, and occurred in a similar pattern within the lodgepole pine forest trails.

Increaser-Decreaser-Bell: Those plants which assumed the "bell" curve pattern of occurrence were *Pedicularis bracteosa*, *Bromus marginatus*, and *Senecio triangularis*.

Pedicularis bracteosa was never seen in lodgepole pine forests, and was rarely seen in whitebark pine forests. It appeared to favor those areas with good moisture availability in small sunlit openings.

Bromus marginatus is commonly found in open meadows. It evidently is more adapted to meadows within high light exposure but is poorly adapted to trampling.

Habeck (1967) classified *Senecio triangularis* as a wet meadow plant, suggesting its light requirement. Its decline near trails points to trampling intolerance. In this study it was more frequently found in sunny openings along trails within spruce-fir forests.

Unchanging: Even with the dense shade in this forest type, some plants continued to show no particular sensitivity to the sharp changes along the gradient. They were *Arnica latifolia*, *Erigeron peregrinus*, *Senecio serra*, *Carex geyeri*, and *Osmorhiza chilensis*.

Arnica latifolia and *Erigeron peregrinus* appear in all forest types studied and occur as increasers in whitebark pine forests. They may be encouraged by great amounts of sunlight and disturbed soils.

Senecio serra was also seen in higher amounts in openings with high sunlight intensity along creeks and fringe areas of meadows.

Carex geyeri and *Osmorhiza chilensis* occur in an identical pattern along the gradient sample within the lodgepole pine and spruce-fir forests. They are apparently insensitive to extreme differences in their environment.

Other Species Present: Plants sampled in low amounts are listed in Table II. Most are more important in other nearby habitats.

Agoseris glauca and *Sibbaldia procumbens* had high densities at high elevations in the whitebark pine forest while *Aster engelmanni*, *Epilobium augustifolium* and *Fragaria virginiana* had high occurrence in the lower elevations within the lodgepole pine types. Species such as *Antennaria alpina*, *Festuca idahoensis*, *Campanula rotundifolia*, *Polygonum bistortoides* and *Potentilla diversifolia* were seen in greater amounts in nearby meadows.

The remaining species listed possibly occur in low amounts within the spruce-fir forest exclusively. Their requirements and frequency is indeterminable from the data available.

Whitebark Pine Trails

From a comparison of basal area measurements (Tables VII, VIII, and IX) and field observations, it was obvious that whitebark pine stands on the most part were the most open of the forest types studied. The trees rarely exceed 60 ft (18 m) in height and have branches of heavy girth with a sparse crown. The tree grows in a very open-branched condition. This accounts for the more open and less shaded condition of the forest floor. Consequently, the gradient from shaded to open areas is less than for other types studied.

Trail Center: The main pathways were essentially denuded except for minor persisting amounts of *Erythronium grandiflorum*, *Hieracium gracile*, *Carex podocarpa*, and *Lupinus sericeus*. The habits and requirements of the above were discussed in the previous two sections and they act similarly in this type.

Increasers: Plants with greatest occurrence near the trail were: *Erythronium grandiflorum, Hieracium gracile, Sibbaldia procumbens, Carex podocarpa, Lupinus sericeus, Arnica latifolia,* and *Erigeron peregrinus.*

Erythronium grandiflorum, Hieracium gracile, Lupinus sericeus, and *Arnica latifolia* within this type are indigenous forest understory species which appear to increase in number with trail openings and soil disturbance as was observed in the lodgepole pine and spruce-fir types, and already discussed.

In some instances, plants from open tundra and fellfields encroach into the openings and trailsides of adjacent forest habitats. The trail openings approach an open high alpine meadow-like environment and species such as *Sibbaldia procumbens* and *Erigeron peregrinus* appear. Cox (1933) and Marr and Willard (1970) found certain fellfield areas in the 11,000 ft (3353 m) level to be dominated by *Sibbaldia procumbens.* In Colorado, Marr (1970) determined the *Erigeron peregrinus* was the most prolific plant along trailsides in the tundra at 11,500 ft (3509 m).

Decreasers: The understory vegetation in whitebark pine stands was nearly pure *Vaccinium scoparium.* Daubenmire (1968) briefly discussed this forest type and classified it as a *Pinus albicaulis - Vaccinium scoparium* habitat type.

In the undisturbed portion of the trail gradient, *Vaccinium scoparium* provided the greatest amount of cover of all forest types studied--56% cover.

Abies lasiocarpa seedlings were consistently absent from the disturbed open sites (Frames 1, 2, and 3) and appeared in the undisturbed sections of the gradient (Frames 4, 5, and 6) in both whitebark pine and spruce-subalpine fir sites. Whitebark pine sites had smaller numbers of *Abies lasiocarpa* seedlings than did lodgepole pine or Engelmann spruce-subalpine fir forests.

Phyllodoce empetriformis is apparently an "accidental" species which favors certain untrampled areas of late snow-melt. It was observed in higher populations above timberline in open, late snow-melt areas.

Increaser-Decreaser-Bell: Within this forest habitat, no plants were observed to follow the bell curve pattern.

Unchanging: Those plants which appeared to be insensitive to the trail effect were *Carex geyeri*, *Agoseris glauca*, *Carex xerantica*, and *Poa alpina*.

Carex geyeri, as previously discussed, was found in all types and consistently shows no reaction to the trail effect. *Carex xerantica* apparently favors the high elevations and reacts in a similar manner.

Agoseris glauca and *Poa alpina* were observed in nearly equal amounts in meadows and whitebark pine forests. They apparently were tolerant to many different habitats.

Other Species Present: Plants sampled in insignificant amounts are recorded in Table V. Most of these are accidental species from nearby levels above, below, or adjacent to this type.

Castilleja rhexifolia, *Potentilla diversifolia*, *Antennaria alpina*, *Antennaria lanata*, *Geum rossii*, *Juncus balticus*, *Pedicularis cystopteridifolia*, and *Trifolium haydenii* were observed in great numbers in nearby meadows. *Epilobium alpinum*, *Pedicularis bracteosa*, and *Trifolium parryii* had significant occurrence in the spruce-fir habitat, while *Antennaria rosea*, *Arnica cordifolia*, *Fragaria virginiana*, and *Poa secunda* had significant populations with the lodgepole pine habitat.

TRAIL WEAR

Trail use within the study area was limited to foot and equestrian traffic with nearly equal levels of each (Lucas 1972). The effects of trail wear from other forms of travel such as four-wheel-drive vehicles, trail bikes, snowmobiles, and bicycles were not studied.

Data for trail wear is recorded on Table VI and is graphically illustrated in Figure 8.

Lodgepole Pine

Width: Data indicates that trails grew wider with heavier use and that average widths in lodgepole pine and spruce-fir trails are nearly equal in heavily used areas.

Depth: For reasons unknown, average depth of wear for lodgepole pine trails is nearly identical with those sites within the whitebark pine areas studied but less than those seen in spruce-fir trails. Greater amounts of exposed rock were observed in the whitebark pine trails than in other types, which should have resulted in least depth of wear.

Engelmann Spruce-Subalpine Fir

Width: These areas were observed to have the highest amounts of soft wet soils within the pathway. Data suggests that in areas of loamy or soft soils, average widths remain fairly constant (87 cm) with heavy use. When the amounts of trampling are lower, such widths become less, provided there is no obstruction or excessive moisture.

Depth: The moist spruce-fir sites show a trend toward greater depths of wear. Studies (Willard and Marr 1971, 1970) in the high altitude tundra (11,500 ft, 3490 m) of Rocky Mountain National Park showed that moist sites were heavily damaged and drier areas suffered the least damage at equal levels of use. Apparently, one could expect to get deepest trail erosion in forests occupied by spruce and subalpine fir.

Whitebark Pine

Width: All whitebark pine trail sites were in the higher elevations (8100-9500 ft, 2468 m to 2774 m) where rocky, poorly developed soils existed (Leeson 1972). High amounts of rock and slow revegetation rate in whitebark pine areas (Kirkwood 1922) possibly explains why whitebark pine trails became widest of all types examined.

Depth: Use on whitebark trails is more erosive and lasting (2.5 cm) than in lodgepole pine (1.6 cm) and spruce-fir sites (2.0 cm).

Factors Controlling Wear

In most cases, heavy traffic increased widths and depths in all areas examined.

Data and field observation indicated that different forest types did not control respective widths and depths of wear on level trails. Instead, respective levels of use, rockiness, soil moisture, and soil texture appeared to be the controlling forces.

Trails in whitebark pine and lodgepole pine sites were deeper in areas with medium use levels than in corresponding areas of heavy use (Table VI). This may be due to horse behavior. It is believed that up to a certain level of use, horses and hikers stay within the same established trail until rocks begin to show. Most hikers follow and remain in established footpaths almost entirely (Bayfield 1971, Burden and Randerson 1972, Edwards 1967, Meinecke 1929, Willard and Marr 1970). However, when natural impediments such as rocks appeared, horses and hikers used the softer "cushioned" trailsides and created a wider trail. On level sites, this often caused the "berm" or outside trail edge to be sloughed back into the main pathway, which partially refilled the once deeper rut.

Meadow Trails

Although mountain meadows were not studied, it was observed that trails within meadows rapidly revegetated and became quite narrow or undefined. As previously mentioned, Jemison (1967), Magill (1970), and Wagar (1971) found that greater amounts of sunlight provided greater herbage production with adequate moisture levels. Possibly the unlimited supply of light and moisture as compared to the shaded forest canopy could explain the rapid recovery of meadow trails (Figure 11).

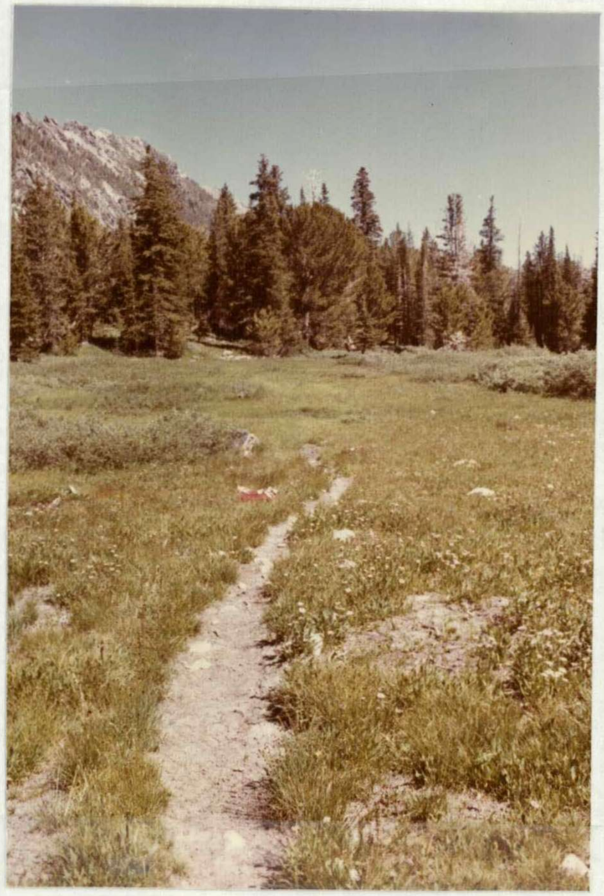

FIGURE 11

Indian Ridge Trail 3/4 mile northeast of Thompson Lake in the Spanish Peaks Primitive Area. The trail completely revegetated itself in the meadow areas (opening in background) and became well defined again as it entered the timbered areas.

APPENDIX

VEGETATION DATA TABLES

TABLE VII

Stand description for lodgepole pine (*Pinus contorta*) on 29 sample sites. (June, July and August 1971)

Plot No.	Elev. feet	Sq.Ft. BA/Acre	Understory Reproduction	Dominant Herbaceous Ground Cover
1	7500	245.25	*Abies lasiocarpa*	*Thalictrum venulosum* *Erythronium grandiflorum*
4	7550	54.50	*Abies lasiocarpa*	*Arnica cordifolia* *Erythronium grandiflorum*
5	7600	218.00	*Abies lasiocarpa*	*Arnica cordifolia* *Thalictrum venulosum*
6	7600	[1]	*Abies lasiocarpa*	*Arnica cordifolia* *Erythronium grandiflorum*
7	7650	81.75	*Abies lasiocarpa* *Picea engelmanni*	*Arnica cordifolia* *Erythronium grandiflorum* *Carex geyeri*
8	7650	245.25	*Abies lasiocarpa* *Picea engelmanni*	*Arnica cordifolia* *Erythronium grandiflorum*
9	7700	275.25	*Picea engelmanni*	*Thalictrum venulosum*
10	7700	163.50	*Abies lasiocarpa*	*Thalictrum venulosum* *Arnica cordifolia*
11	7750	[1]	*Abies lasiocarpa* *Picea engelmanni*	*Erythronium grandiflorum*
12	7750	245.25	*Abies lasiocarpa*	*Arnica cordifolia* *Carex geyeri*
13	7500	245.25	*Abies lasiocarpa*	*Vaccinium scoparium* *Arnica cordifolia*
14	7550	275.25	*Abies lasiocarpa*	*Vaccinium scoparium* *Arnica cordifolia*
15	7550	327.00	*Abies lasiocarpa*	*Vaccinium scoparium*
16	7600	354.25	*Abies lasiocarpa* *Picea engelmanni*	*Vaccinium scoparium* *Arnica cordifolia*
17	7650	354.25	*Abies lasiocarpa*	*Vaccinium scoparium*
18	7650	245.25	*Abies lasiocarpa*	*Vaccinium scoparium*
19	7650	81.75	*Abies lasiocarpa*	*Vaccinium scoparium*
20	7650	50.54	*Abies lasiocarpa*	*Vaccinium scoparium*
21	7650	218.00	*Abies lasiocarpa*	*Vaccinium scoparium* *Arnica cordifolia*
22	7650	292.75	*Abies lasiocarpa*	*Vaccinium scoparium*
23	7400	109.75	*Abies lasiocarpa*	*Vaccinium scoparium*

[1] Data Not Available

TABLE VII- CONTINUED

Stand description for lodgepole pine (*Pinus contorta*) on 29 sample sites. (June, July and August 1971)

Plot No.	Elev. feet	Sq.Ft. BA/Acre	Understory Reproduction	Dominant Herbaceous Ground Cover
24	7300	299.75	*Picea engelmanni*	*Vaccinium scoparium* *Arnica cordifolia* *Carex geyeri*
25	7300	180.75	*Abies lasiocarpa* *Picea engelmanni*	*Vaccinium scoparium* *Arnica cordifolia*
26	7700	81.75	*Abies lasiocarpa*	*Vaccinium scoparium*
27	7100	109.75	*Abies lasiocarpa* *Picea engelmanni*	*Vaccinium scoparium*
29	7200	[1]	*Abies lasiocarpa*	*Vaccinium scoparium* *Arnica cordifolia*
30	7200	81.75	*Abies lasiocarpa*	*Vaccinium scoparium* *Carex geyeri* *Thalictrum venulosum* *Arnica cordifolia*
31	7700	190.75	*Abies lasiocarpa*	*Vaccinium scoparium* *Thalictrum venulosum*
37	7700	272.50	*Abies lasiocarpa*	*Vaccinium scoparium* *Thalictrum venulosum*

	Elev. feet	Sq.Ft. BA/Acre
Maximum	7750 (2362 M)	354.25 (81.30 M^2/H)
Minimum	7100 (2164 M)	81.75 (18.76 M^2/H)
Mean	7557 (2303 M)	200.76 (46.07 M^2/H)
Standard Deviation		95.30 (21.87 M^2/H)

[1]Data Not Available

TABLE VIII

Stand description for engelmann spruce - subalpine fir (*Picea engelmanni - Abies lasiocarpa*) on 16 sample sites (June, July and August 1971).

Plot No.	Elev. feet	Sq.Ft. BA/Acre	Understory Reproduction	Dominant Herbaceous Ground Cover
10	7500	163.50	*Abies lasiocarpa*	*Erythronium grandiflorum* *Thalictrum venulosum* *Arnica latifolia*
33	7800	299.75	*Abies lasiocarpa*	*Vaccinium scoparium*
42	8000	81.75	*Abies lasiocarpa*	*Vaccinium scoparium*
43	7900	163.50	*Abies lasiocarpa*	*Vaccinium scoparium* *Arnica latifolia*
44	7900	272.50	*Abies lasiocarpa*	*Vaccinium scoparium* *Arnica latifolia*
45	7900	136.25	*Abies lasiocarpa*	*Vaccinium scoparium* *Arnica cordifolia*
46	8300	272.50	*Abies lasiocarpa*	*Vaccinium scoparium* *Erigeron peregrinus*
48	8300	136.25	*Abies lasiocarpa*	*Vaccinium scoparium* *Erigeron peregrinus*
49	8350	190.75	*Abies lasiocarpa*	*Arnica latifolia*
50	8500	218.00	*Abies lasiocarpa*	*Vaccinium scoparium* *Arnica latifolia*
51	8500	218.00	*Abies lasiocarpa*	*Vaccinium scoparium*
52	8500	163.50	*Abies lasiocarpa*	*Vaccinium scoparium*
61	9100	245.25	*Abies lasiocarpa*	*Arnica latifolia* *Vaccinium scoparium* *Thalictrum venulosum*
67	8000	218.00	*Abies lasiocarpa*	*Arnica latifolia* *Vaccinium scoparium* *Thalictrum venulosum*
68	7800	218.00	*Abies lasiocarpa*	*Arnica latifolia* *Vaccinium scoparium* *Thalictrum venulosum*
69	7600	54.50	*Abies lasiocarpa*	*Arnica latifolia* *Vaccinium scoparium* *Thalictrum venulosum*

	Elev. feet	Sq.Ft. BA/Acre
Maximum	9100 (2774 M)	299.75 (68.79 M^2/H)
Minimum	7500 (2286 M)	54.50 (12.50 M^2/H)
Mean	8109 (2472 M)	190.75 (43.77 M^2/H)
Standard Deviation		68.22 (15.66 M^2/H)

TABLE IX

Stand description for whitebark pine (*Pinus albicaulis*) on 19 sample sites. (June, July and August 1971)

Plot No.	Elev. feet	Sq.Ft. BA/Acre	Understory Reproduction	Dominant Herbaceous Ground Cover
34	8300	136.25	*Abies lasiocarpa*	*Vaccinium scoparium*
35	8100	218.00	*Abies lasiocarpa*	*Vaccinium scoparium*
36	8650	136.25	*Pinus albicaulis*	*Vaccinium scoparium*
38	8600	54.50	*Picea engelmanni*	*Vaccinium scoparium*
39	8450	81.75	*Picea engelmanni*	*Vaccinium scoparium*
40	8260	272.50	*Pinus albicaulis*	*Vaccinium scoparium*
53	9100	190.75	*Pinus albicaulis*	*Vaccinium scoparium*
54	9100	163.50	*Pinus albicaulis*	*Vaccinium scoparium*
55	9100	163.50	*Picea engelmanni*	*Vaccinium scoparium*
56	9100	81.75	*Abies lasiocarpa*	*Vaccinium scoparium*
57	9100	190.75	*Pinus albicaulis*	*Vaccinium scoparium*
58	9100	136.25	*Pinus albicaulis*	*Vaccinium scoparium*
59	9100	[1]	*Pinus albicaulis*	*Erythronium grandiflorum* *Arnica latifolia* *Agoseris glauca*
60	9100	299.75	*Pinus albicaulis*	*Vaccinium scoparium*
62	8290	163.50	*Abies lasiocarpa*	*Vaccinium scoparium*
63	8270	327.00	*Abies lasiocarpa*	*Vaccinium scoparium*
64	8260	190.75	*Abies lasiocarpa*	*Vaccinium scoparium*
65	8250	190.75	*Abies lasiocarpa*	*Vaccinium scoparium*
66	8100	218.00	*Pinus albicaulis*	*Vaccinium scoparium*

	Elev. feet	Sq.Ft. BA/Acre
Maximum	9100 (2774 M)	299.75 (68.79 M^2/H)
Minimum	8100 (2468 M)	54.50 (12.51 M^2/H)
Mean	8650 (2636 M)	178.64 (40.99 M^2/H)
Standard Deviation		72.5 (16.64 M^2/H)

[1] Data Not Available

TABLE X

Elevation, basal area and age for lodgepole pine, spruce-subalpine fir, and whitebark pine forests sampled on the Madison Range.

	Lodgepole Pine	Spruce-Fir	Whitebark Pine
Maximum elevation (ft.)	7750 (2362m)	9100 (2774m)	9600 (2920m)[1]
Minimum elevation (ft.)	5000 (1520m)[1]	7500 (2286m)	8100 (2468m)
Mean elevation (ft.)	7557 (2303m)	8109 (2472m)	8650 (2636m)
Maximum ft^2 BA/acre	354 ($81\ m^2/h$)	300 ($69\ m^2/h$)	300 ($69\ m^2/h$)
Minimum ft^2 BA/acre	82 ($19\ m^2/h$)	54 ($12\ m^2/h$)	54 ($12\ m^2/h$)
Mean ft^2 BA/acre	200 ($46\ m^2/h$)	191 ($44\ m^2/h$)	179 ($41\ m^2/h$)
Approximate maximum age[2] (years)	200	450 Spruce 200 Subalpine fir	375
Approximate average age on study area[3] (years)	142	200 Spruce 150 Subalpine fir	180

[1]Observed in areas adjacent to sample sites.

[2]Average maximum ages as indicated by Harlow and Harrar, 1958.

[3]Ages of Engelmann spruce, subalpine fir and whitebark pine are estimated by counting rings in stands of similar size in adjacent areas to sample sites and by use of data obtained from the Forest Service.

TABLE XI

Species collected or observed under lodgepole pine (*Pinus contorta*) forests in Spanish Peaks - Lone Mountain study area. (Summer 1971)

Achillea millefolium L.
Agrostis scabra Willd.
Amelanchier alnifolia Nutt.
Anaphalis margaritaceae (L.) Benth & Hook
Antennaria racemosa Hook
Antennaria rosea (Eat.) Greene
Arabis drummondi Gray
Arctostaphylos-uva-ursi (L.) Spreng
Arnica cordifolia Hook
Arnica fulgens Pursh.
Arnica latifolia Greene
Aster engelmanni Gray
Aster integrifolius Nutt.
Aster occidentalis Nutt. T. & G.
Astragalus alpinus L.
Astragalus dasyglottis Fisch.
Aquilegia flavescens S. Wats.
Berberis repens Lindl.
Bromus anomalus Rupr.
Calamagrostis canadensis (Michx.) Beauv.
Carex geyeri Boott.
Castilleja miniata Dougl.
Claytonia lanceolata Pursh.
Clematis columbiana (Nutt.) T. & G.
Epilobium augustifolium L.
Erigeron peregrinus (Pursh.) Greene
Eriogonum umbellatum Nutt.
Erythronium grandiflorum Pursh.
Equisetum arvense L.
Fragaria virginiana Duch.
Galium boreale L.
Geranium viscossissimum Fisch & Mey.
Geum macrophyllum Willd.
Hieracium albiflorum Hook
Hieracium gracile Hook
Lupinus sericeus Pursh.
Mimulus lewesii Pursh.
Osmorhiza chilensis Hook & A.
Pedicularis racemosa Dougl.
Physocarpus malvaceus (Greene) Kuntze
Poa pratensis L.
Pochyistima myrsinitas (Pursh.) Raf.
Pyrola secunda L.
Rosa woodsii (Lindl.)
Rubus parviflorus Nutt.
Sedum stenopetalum Pursh.
Senecio triangularis Hook
Smilacina racemosa (L.) Desf.
Spiraea betulifolia Pall.
Thalictrum venulosum Trel.
Thlaspi arvense L.
Vaccinium membranaceum Dougl.
Vaccinium scoparium Lieberg
Veronica americana Schwein
Viola adunca J.E. Sm.
Viola nuttallii Pursh.
Viola orbiculatus Geyer

TABLE XII

Species collected or observed on plot and/or under spruce - subalpine fir (*Picea engelmanni - Abies lasiocarpa*) forests in Spanish Peaks - Lone Mountain study area. (June, July and August 1971)

Achillea millefolium L.
Agoseris glauca (D. Dieth)
Antennaria rosea (Eat.) Greene
Aquilegia flavescens S. Wats.
Arnica cordifolia Hook
Arnica latifolia Greene
Aster engelmanni Gray
Berberis repens Lindl.
Bromus anomalus Rupr.
Carex geyeri Boott.
Carex podocarpa R. Br.
Carex xerantica Bailey
Castilleja miniata Dougl.
Castilleja rhexifolia Rydb.
Claytonia lanceolata Pursh.
Epilobium alpinum L.
Epilobium augustifolium L.
Erigeron peregrinus (Pursh.) Greene
Erythronium grandiflorum Pursh.
Fragaria virginiana Duch.
Hieracium albiflorum Hook
Hieracium gracile Hook
Juncus balticus Wild.
Juncus parryi Engelm.
Lupinus sericeus Pursh.
Mimulus lewesii Pursh.
Osmorhiza chilensis Hook & A.
Pedicularis bracteosa Benth
Pedicularis cystopterifolia Rybg.
Pedicularis racemosa Dougl.
Phyllodoce empetriformis (Sw.) Don.
Poa pratensis L.
Poa secunda Presl.
Polygonum bistortoides Pursh.
Potentilla diversifolia Lehm.
Pyrola secunda L.
Ranunculus eschscholtzii Schl.
Rubus parviflorus Nutt.
Salix drummondiana Barratt
Sedum stenopetalum Pursh.
Senecio integerrimus Nutt.
Senecio serra Hook
Senecio triangularis Hook
Sibbaldia procumbens L.
Spiraea betulifolia Pall.
Thalictrum venulosum Trel.
Trifolium haydenii Porter
Vaccinium membranaceum Dougl.
Vaccinium scoparium Lieberg
Viola nuttallii Pursh.
Viola orbiculatus Geyer

TABLE XIII

Species collected or observed on plot and/or under whitebark pine (*Pinus albicaulis*) forests in Spanish Peaks - Lone Mountain study area. (June, July and August 1971)

Achillea millefolium L.
Agoseris glauca (Pursh.) D.Dietr.
Antennaria alpina (L.) Gaertn.
Antennaria lavata (Hook) Greene
Arnica latifolia Greene
Carex geyeri Boott.
Carex podocarpa R.Br.
Carex xerantica Bailey
Castilleja rhexifolia Rydb.
Claytonia lanceolata Pursh.
Epilobium alpinum L.
Epilobium augustifolium L.
Erigeron peregrinus (Pursh.) Gr.
Erythronium grandiflorum Pursh.
Fragaria virginiana Duch.
Geum rossii (R.Br.) Ser.
Hieracium albiflorum Hook
Hieracium gracile Hook
Juncus balticus Wild.
Juncus parryi Engelm.
Lupinus sericeus Pursh.
Mertensia alpina (Torr.) G.Don.
Pedicularis bracteosa Benth.
Phyllodoce empetriformis (Sw.) Don.
Poa alpina L.
Poa secunda Presl.
Polygonum bistortoides Pursh.
Potentilla diversifolia Lehm.
Rubus parviflorus Nutt.
Salix drummondiana Barratt
Sedum stenopetalum Pursh.
Sibbaldia procumbens L.
Trifolium parryi Gray
Vaccinium scoparium Lieberb.

TABLE XIV

Species collected or observed in adjacent meadows to spruce - fir forests, lodgepole pine forests and whitebark pine forests. (June, July and August 1971)

Achillea millefolium L.
Agastache urticifolia (Benth) Rydb.
Agoseris glauca (Pursh.) Greene
Allium brevistylum A. Wats.
Antennaria rosea (Eat.) Greene
Aquilegia flavescens S. Wats.
Arabis drummondi Gray
Arabis nuttallii Robin
Arnica cordifolia Hook
Arnica rydbergii Greene
Aster integrifolius Nutt.
Astragalus miser Dougl.
Bromus anomalus Rupr.
Callomia linearis Nutt.
Campanula rotundifolia L.
Carex geyeri Boott.
Castilleja miniata Dougl.
Castilleja rhexifolia Rydb.
Cerastium arvense L.
Claytonia lanceolata Pursh.
Clematis hirsutissima Pursh.
Collinsia parviflora Lindl.
Delphinium bicolor Nutt.
Dodecatheon conjugens Greene
Epilobium augustifolium L.
Erigeron peregrinus (Pursh.) Greene
Eriogonum umbellatum Nutt.
Erysimum asperum (Nutt.) D.C.
Erythronium grandiflorum Pursh.
Festuca idahoensis Elmer
Fragaria virginiana Duch.
Galium boreale L.
Geranium viscossissimum Fisch.& Mey.
Geum triflorum Pursh.
Hackelia floribunda (Lehm) Jtn.
Helianthella uniflora (Nutt.) T.& G.
Koeleria cristata (L.) Pers.
Lithophragma parviflora (Hook) Nutt.
Lithospermum ruderale Dougl.
Lomatium ambiguum (Nutt.) T.& R.
Lupinus sericeus Pursh.
Melica spectabilis Scribn.
Mertensia oblongifolia (Nutt.)G.Don.
Microsteris gracilis (Dougl.) Gr.
Myosotis sylvatica Hoffm.
Oxytropis logopis Nutt.
Pedicularis groenlandica Retz.
Phleum alpinum L.
Phlox longifolia Nutt.
Poa pratensis L.
Polygonum bistortoides Pursh.
Potentilla glandulosa Lindl.
Potentilla gracilis Dougl.
Ranunculus acriformis A. Gray
Ranunculus eschscholtzii Schl.
Ranunculus inamoenus Greene
Rumex paucifolius Nutt.
Sambucus melanearpa A. Gray
Saxifraga arguta D. Don.
Sedum stenopetalum Pursh.
Senecio triangularis Hook
Taraxicum officinale Webr.
Thlaspi glaucum A. Nels.
Tragopogon dubius Scop.
Trollius laxus Salisb.
Viola adunca J. E. Sm.
Viola nuttallii Pursh.

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