A Classification of Spruce-fir and Mixed Conifer Habitat Types of Arizona and New Mexico

William H. Moir and John A. Ludwig

Research Paper RM-207
Rocky Mountain Forest and
Range Experiment Station
Forest Service
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Abstract

Nineteen major forest habitat types (HT's) are described on the basis of extensive reconnaissance data throughout the major mountain ranges and plateaus of Arizona and New Mexico. Eight of these HT's are within spruce-fir forests where either *Picea engelmannii* or *Abies lasiocarpa* are the climax dominants; the remainder are within mixed conifer forests where *Abies concolor, Picea pungens,* and *Pseudotsuga menziesii* are climax dominants or codominants. Sixteen other HT's are briefly described based on limited data, usually from one geographic

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Inside front cover - Abstract - last sentence should end with the word "location." after "geographic".

Page 9 - fifth line from bottom of left column - "*fransicana*" should be spelled "*franciscana*", so the entire line should read:

boides, S. bigelovii or *Mertensia franciscana* and may have a

Page 12 - sixth and seventh line from top of left column - Delete sentence "It is also . . . *superbus* HT." These lines should read:

New Mexico. On drier

Page 12 - seventh line from bottom of left column - "*franseriodes*" should be spelled "*franserioides*", so the entire line should read:

such as *Artemisia franserioides* and *Pachistima myrsinites* not

Page 16 - 21 lines from bottom of left column - add the words "*Picea pungens*-" before the words "*Picea engelmannii/*" so the entire line should read:

related to the *Picea pungens-Picea engelmannii/Senecio cardamine* HT of

Page 28 - first line of right column - add the words "*/Muhlenbergia virescens*" after the words "*Pinus strobiformis*", so the entire line should read:

Pseudotsuga menziesii-Pinus strobiformis/Muhlenbergia virescens HT and may be

Page 33 - 13 lines down from top of right column - "*metacalfei*" should be spelled "*metcalfei*", so the entire line should read:

Oxalis metcalfei (Small) Kunth (312)

Page 35 - 24 lines up from bottom of right column - the word "absent" should be changed to the word "present", so the entire line should read:

5. Species of *Acer* present 6

Resea

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A Classification of Spruce-fir and Mixed Conifer Habitat Types of Arizona and New Mexico[1]

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Rodeo, New Mexico

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INTRODUCTION

Spruce-fir forests occupy less than 0.5% of Arizona and about 2% of New Mexico. Despite this limited distribution, these high elevation forests are important and valuable resources, providing major snow catchement and watershed areas and serving as focal points for winter and summer recreation. The subtending mixed conifer forests, covering about 3% and 4% of Arizona and New Mexico, respectively, are intensively utilized for timber, range and wildlife production, watershed management, and recreation. These forest types respond in complex ways to many man-caused and natural impacts and treatments such as timber harvesting, fire, recreation usage, and foraging by livestock and game.

Scientists and land managers have recognized the need to classify these forests into units of like biological potential (Alexander 1974, Jones 1974, Layser 1974). This study gives a classification of the spruce-fir and mixed conifer forests based upon the concept of habitat types (Daubenmire and Daubenmire 1968). Each habitat type embraces a relatively narrow range of environmental variation and can be identified in old-growth forest stands (late seral to climax) by the dominant plants in each vegetation layer (canopy layer, tree regeneration, shrub, and herbaceous layers). The effects of management practices or natural impacts within a forest habitat type can be understood and predicted in terms of seral communities, growth rates and potentials for various tree species, and rates of succession. The biological potential and forest responses are more uniform within a habitat type than across different habitat types. By stratifying a forest region into habitat types, managers are given an ecological basis for predicting effects of forest treatments and attaining maximum productive potential (Layser 1974, Pfister 1974).

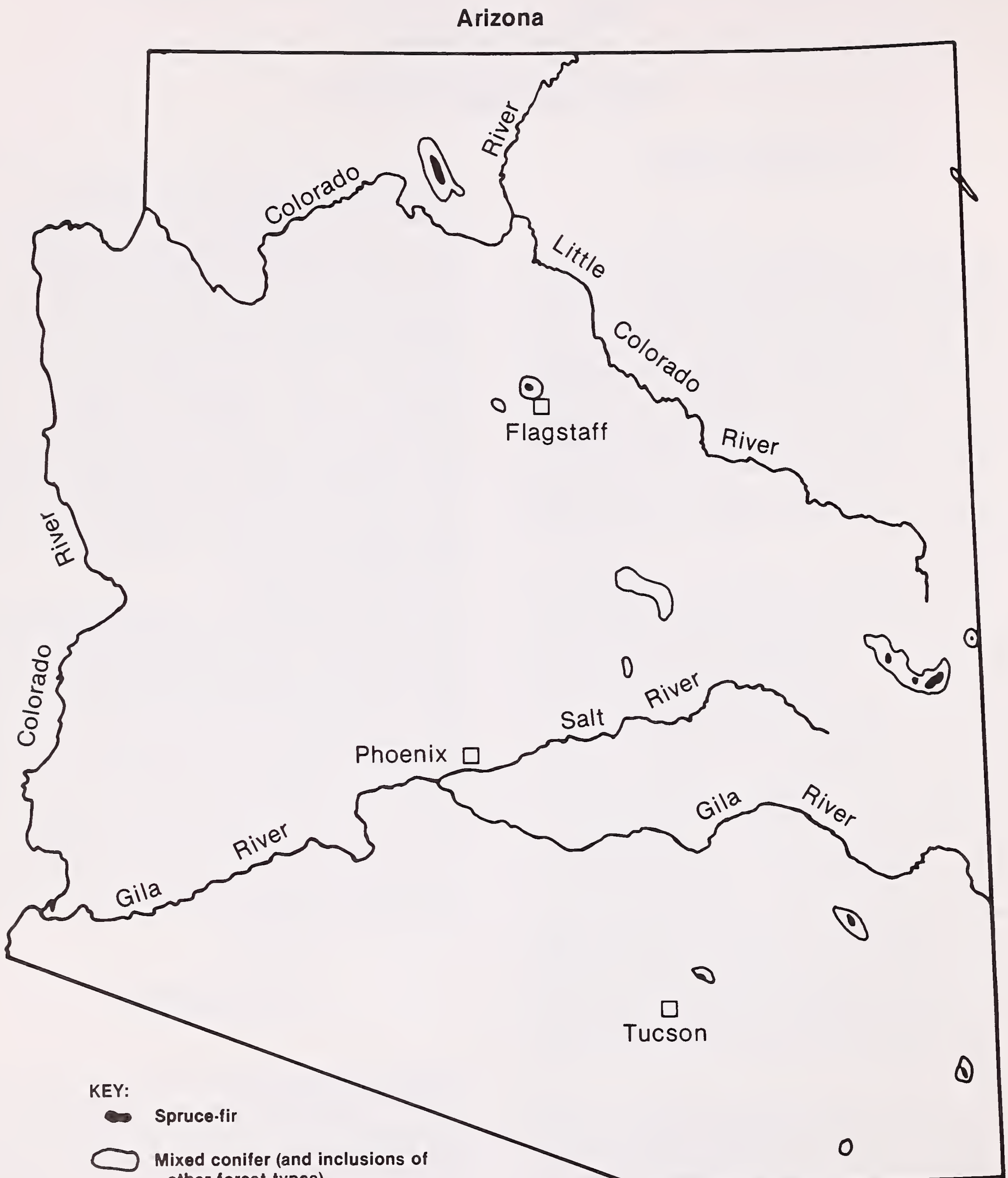
Existing knowledge of habitat types in spruce-fir and mixed conifer forests in Arizona and New Mexico is rudimentary. Regional vegetation maps are very generalized, usually including within a single mapping unit very different forest habitat types (New Mexico Agricultural Experiment Station 1957, Choate 1966, Kuchler 1964, Nichol 1937, Spencer 1966). Daubenmire (1943) reviewed generalized relationships of the elevational sequences of forests in the Rocky Mountains (including Arizona and New Mexico).

Spruce-fir forests generally have been recognized by dominance or regeneration potential of either or both *Picea engelmannii* and *Abies lasiocarpa.* The lower boundary of these forests has been confused when *Abies concolor, Pseudotsuga menziesii, Picea pungens,* or species of *Pinus* command significant portions of either the overstory or understory. These trees constitute mixed conifer forests when occurring purely or in mixture but to the exclusion (or only accidental presence) of *Picea engelmannii* or *Abies lasiocarpa.* The lower forest boundary of the mixed conifer region is also poorly defined, with conflicting definitions in the literature. Much of this confusion arises from insufficient knowledge of the successional rates of forest communities and from preoccupation with canopy dominance or cover type rather than habitat type.

Descriptions of high elevation forest communities have been published for the North Kaibab Plateau (Merkle 1954), the Sierra Ancha Range (Pase and Johnson 1968), and the Pinaleno and Santa Catalina Mountains (Whittaker and Niering 1965). In New Mexico, Hanks and Dick-Peddie (1974) studied forest succession after fire in the mixed conifer forests of the Sacramento Mountains, and at higher elevations Dye and Moir (1977) described a spruce-fir forest type. However, little is known about the homogeneity of these forests or their relationship and similarity to other high elevation forests in Arizona and New Mexico. The objective of this paper, therefore, is to present stratification by habitat type of spruce-fir and mixed conifer forests in both states.

STUDY AREAS

Stands of spruce-fir and mixed conifer forests were sampled in major mountain ranges and plateaus of Arizona and New Mexico except the Chuska Mountains and Black Range (table 1). Generally, the more extensive the forest distribution was, the greater the number of stands that were studied. The many isolated and minor coniferous stands in canyons or north-facing slopes of minor mountain ranges were not visited. Figure 1 shows the location of spruce-fir and


Arizona
Colorado
River
Little
Colorado
River
Flagstaff
River
Colorado
Salt
River
Phoenix
Gila
River
Gila
River
Tucson
KEY:
Spruce-fir
Mixed conifer (and inclusions of other forest types)

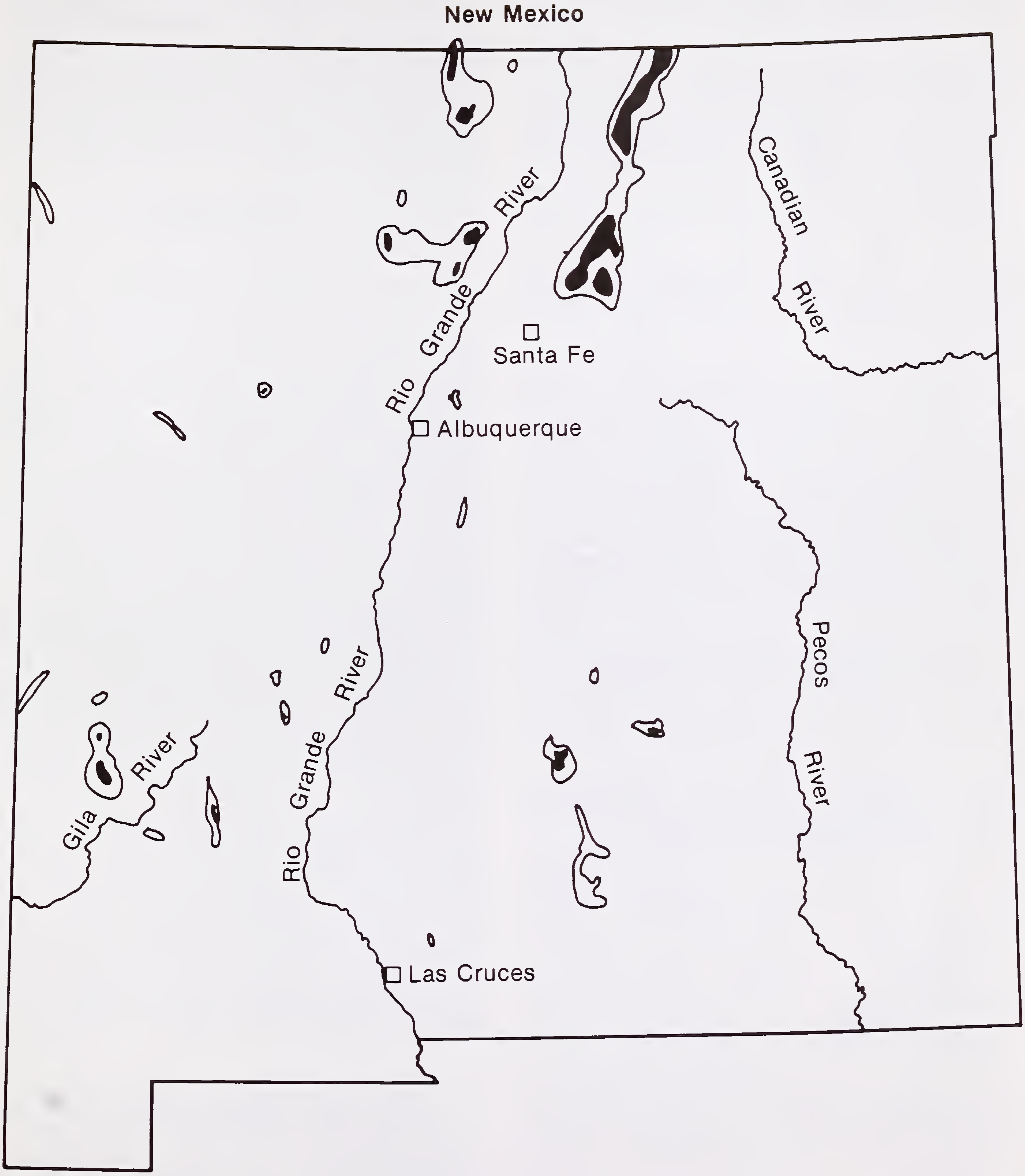


Figure 1.—Geographic location of spruce-fir and mixed conifer forests in Arizona and New Mexico (modified from Choate 1966 and Spencer 1964).

mixed conifer forests in the two states and identifies the sampled areas. Sampled stands vary in elevation from 7,100 feet (2,160 m) to 11,900 feet (3,630 m) with boundaries of spruce-fir and mixed conifer zones shifting with geographic locations (Daubenmire 1943).

The mountain ranges in table 1 occur over four physiographic provinces of Arizona and New Mexico recognized primarily as structural geological divisions (Wilson 1962). The Southern Rocky Mountain Cordilleran Province includes the Sangre de Cristo Range and San Juan Mountains, both extending into New Mexico from Colorado. The latter includes the San Pedro Mountains and Jemez Mountains. The Basin and Range Province includes many block faulted mountain ranges of southern New Mexico and southern Arizona. High elevation coniferous forests are found in the Capitan, Sacramento, and Black Ranges in New Mexico and Chiricahua, Pinaleno, Santa Catalina, and Sierra Ancha Mountains of Arizona.

The Mogollon Volcanic Province includes the high plateaus and summits of the Mogollon Plateau, White Mountains, and Mogollon Mountains. The Magdelena and San Mateo Mountains of central New Mexico are near the eastern border of this province. On the Mogollon Plateau, strata of basalt dip gently to the north and northeast; and in the White Mountains, volcanic ash covers the edge of the Plateau, and flows extend in tongues northward toward the Little Colorado Drainage (Wilson 1962). The Colorado Plateau Province includes the San Francisco Peaks and Bill Williams Mountain, both large central-type volcanic cones of the San Francisco volcanic field which lies on a broad structural dome in north-central Arizona. The North Kaibab Plateau, a system of uplifted sedimentary strata, is part of this dome. In New Mexico, the Chuska Mountains, Mount Taylor, and Zuni Mountains are part of the Colorado Plateau. At highest elevations and cooler, north-trending canyon drainages of these mountains, there are primarily mixed conifer forests not included in this study.[2]

Table 1.—Number of stands sampled in spruce-fir and mixed conifer forests as distributed by mountain ranges and plateaus in Arizona and New Mexico

	Spruce-fir	Mixed conifer
Arizona		
Chiricahua Mts.	1	18
Pinaleno Mts.	4	6
White Mts.	43	42
Mogollon Plateau	1	27
San Francisco Peaks	6	3
North Kaibab Plateau	7	20
Bill Williams Mt.	0	2
New Mexico		
Sangre de Cristo Mts.	69	36
San Juan Mts.	11	11
Sacramento Mts.	21	27
Capitan Mts.	4	5
Mogollon Mts.	18	13
Totals	185	210

Published climatological data for high elevation forests are very limited or generalized (Daubenmire 1943), except for the study by Beschta (1976). His studies in central Arizona suggest that most high elevation mixed conifer and spruce-fir forests occur where mean annual precipitation exceeds about 30 inches (762 mm), and mean snowfall depths exceed about 100 inches (2.5 m).

METHODS

FIELD SAMPLING

Forests eligible for study were those in which any of *Picea engelmannii, Abies lasiocarpa, A. concolor,* or *Picea pungens* exhibited at least some natural regeneration potential in relatively mature forest growth. Stands in late seral, near-climax, or climax condition (i.e., old growth relatively free of major disturbance effects) usually were sought. Often, however, judgments as to what constituted a ''major'' disturbance had to be compromised, especially in areas where man's influences were pervasive. Partial overstory cutting, grazing, long periods of fire suppression, and activities of early-day tie cutters (in the 1860's and 1870's) are examples of disturbances which may have altered the major dominance relationships of vegetation in each structural layer of the stand. In a few areas of intense utilization, we looked for least disturbed stands and then decided whether or not these revealed sufficient vegetation characteristics of the potential climax forest type.

To sample a large number of stands representing the spectrum of habitat types in Arizona and New Mexico, a relatively rapid reconnaissance method was used (Franklin et al. 1970). Circular plots, mostly 375 m^2, were located in areas of vegetation homogeneity (judged visually) and were surrounded by similar vegetation of the stand to ensure minimal edge effects. In each plot, all tree individuals from established seedlings (larger than about ankle height, or 1 dm tall) to the largest specimens were tallied by 2-inch (5-cm)

[2] A summary of the vegetation of Mount Taylor is given by N. L. Osborn, 1966. A comparative floristic study of Mount Taylor and Redondo Peak, New Mexico. Ph.D. Thesis, Univ. N.M., Albuquerque, 148 pp. See also W. C. Martin, C. R. Hutchins, R. G. Woodmansee, 1970. A flora of the Sandia Mountains, New Mexico, unpublished mimeo 319 pp., Dept. Bio., Univ. N.M., Albuquerque. Mixed conifer forests in the Chuska Mountains have been described by Wright et al. (1973).

diameter classes as measured at breast height (d.b.h). Trees under 2 inches d.b.h. were also tallied into height classes less than breast height (4.5 feet or 14 dm) and greater than or equal to breast height.

In each plot, visual estimates of canopy coverage were made (Daubenmire 1968) for each vascular species of understory shrubs and herbs. These estimates were made to the nearest percentage up to 10% cover and to the nearest 5% thereafter. The visual estimates occasionally were calibrated with the more precise mensuration technique of using forest macroplots 25 by 15 m in rectangular dimension and a grid of 50 microplots each 2 by 5 dm within the macroplot for measuring canopy coverage (Daubenmire 1968). Species of coverage less than 1% but of frequent occurrence were recorded as 0% and arbitrarily assigned a cover value of 0.1% on summary sheets. Infrequent or rare species within the plots were recorded as -1 and assigned the cover value of 0.01%; species in the stand but outside the plot were recorded for presence by -2 but were not used in summary tables or analysis. About 350 taxa were involved in these tree and understory measurements (see appendix). Voucher specimens have been deposited at the USDA Forest Service Herbarium, Fort Collins, Colo., as primary depository, and at herbaria at New Mexico State University, University of Colorado, and University of Wyoming.

Site data recorded for each plot included elevation (from topographic maps), slope, aspect, and landform and position in the landscape (ridge, upper slope, midslope, lower slope, bench, streamside). Soil mapping units or profile features, if available for the site, were recorded. Soil surface characteristics of litter, exposed soil and rocks, cryptogams, and vascular plant basal area were visually estimated in such manner as to total 100%. Effects of fire, insects, erosion, browsing, or other disturbances were recorded if sufficiently apparent and thought to influence vegetation composition as either pertubation or sustained site influence.

Several trees in most plots were aged at breast height (by increment coring and counting rings in the field) and measured for height. Trees were selected to reveal site potential (optimal growth rates under field condition). Other individuals, usually of the larger sizes, were chosen to indicate stand age, or period since last major disturbance (usually fire). Recent stumps in logged stands were used for ring-count estimates of stand age, also.

DATA ANALYSIS

For purposes of forest classification, tree data for each plot were summarized into stem densities per 500 m^2 of young regeneration (d.b.h. less than 2 inches), advanced regeneration (d.b.h. 2-10 inches), and mature (d.b.h. greater than 10 inches). For *Populus tremuloides, Quercus gambelii, Robinia neomexicana,* and several other less common tree species, the size class data were summarized into two classes: regeneration (0-10 inches d.b.h.), and mature (d.b.h. greater than 10 inches).

The relative importance of understory shrubs and herbs was computed by multiplying percentage presence (number of plots of occurrence as percent of all plots) and cover index (the percent cover of each species summed over all plots of occurrence). Shrubs with importance greater than 250 and herbs with importance greater than 200 were used in subsequent analyses.

Plot data were sorted into groups based on similarities in the tree, shrub, and herb layers (Shimwell 1971). Emphasis of the tree regeneration and survivorship data was used in grouping the plots, since reproductive success of a species is a factor of great importance in judging the seral status of vegetation types (Daubenmire and Daubenmire 1968). An agglomerative-hierachial classification method also was used to further clarify the groupings (Lance and Williams 1967). The grouping of plots thus obtained were then analyzed by generating plot tables. However, there were instances where the computed groupings were overriden or modified based on ecological judgments. The final habitat type plot tables[3] reflect both computational methodology and ecological judgments.

RESULTS AND DISCUSSION

A listing of all forest habitats defined in this study and grouped into series (Hoffman and Alexander 1976) is given in table 2. The following sections contain brief, synoptic descriptions of each habitat type. The descriptions are essentially summaries and abstractions from the final habitat type plot tables. Diagnostic vegetation consists of only those vegetative features of the habitat type that are essential for field identification and distinction from other habitat types. The geography encompasses our knowledge of geographic range in Arizona and New Mexico either from actual location of plots or from literature, field notes, and miscellaneous sources of information. Topography summarizes the physical site features from the stand tables. Information on soils are primarily references to Soil Resource Inventories of the Southwestern Region, USDA (Carleton 1971, Dunstan and Johnson 1972, Gass 1972). However,

[3] These plot tables along with a list of the species used in the data analysis are deposited at the USDA Forest Service data depository at Flagstaff, Ariz.

Table 2. Spruce-fir and mixed conifer forest habitat types of Arizona and New Mexico. Habitat types are listed by series, with name abbreviations and the number of plots representing each type given

Forests	Abbreviation	No. plots
Picea engelmannii Series		
1. *Picea engelmannii/Vaccinium scoparium/Polemonium delicatum* HT	PIEN/VASC/PODE HT	14
2. *Picea engelmannii/Moss* HT	PIEN/MOSS HT	13
Abies lasiocarpa Series		
3. *Abies lasiocarpa/Vaccinium scoparium* HT	ABLA/VASC HT	46
4. *Abies lasiocarpa/Vaccinium scoparium/Linnea borealis* HT	ABLA/VASC/LIBO HT	10
5. *Abies lasiocarpa/Rubus parviflorus* HT	ABLA/RUPA HT	7
Vaccinium myrtillus Phase	VAMY Phase	
Acer glabrum Phase	ACGL Phase	
6. *Abies lasiocarpa/Erigeron superbus* HT	ABLA/ERSU HT	35
7. *Abies lasiocarpa/Juniperus communis* HT	ABLA/JUCO HT	8
8. *Abies lasiocarpa/Senecio sanguisorboides* HT	ABLA/SESA HT	10
Picea pungens Series		
9. *Picea pungens-Picea engelmannii/Senecio cardamine* HT	PIPU-PIEN/SECA HT	23
Abies lasiocarpa Phase	ABLA Phase	
Abies concolor Phase	ABCO Phase	
10. *Picea pungens-Picea engelmannii/Erigeron superbus* HT	PIPU-PIEN/ERSU HT	5
11. *Picea pungens/Poa pratensis* HT	PIPU/POPR HT	3
12. *Picea pungens/Carex foenea* HT	PIPU/CAFO HT	18
Pseudotsuga menziesii Phase	PSME Phase	
Pinus ponderosa Phase	PIPO Phase	
13. *Picea pungens-Pseudotsuga menziesii* HT	PIPU-PSME HT	10
Arctostaphylos uva-ursi Phase	ARUV Phase	
Valeriana acutiloba Phase	VAAC Phase	
Linnaea borealis Phase	LIBO Phase	
Juniperous communis Phase	JUCO Phase	
Abies concolor Series		
14. *Abies concolor-Pseudotsuga menziesii/Acer glabrum* HT	ABCO-PSME/ACGL HT	41
Berberis repens Phase	BERE Phase	
Holodiscus dumosus Phase	HODU Phase	
15. *Abies concolor-Pseudotsuga menziesii/Quercus gambelii* HT	ABCO-PSME/QUGA HT	62
Typical Phase	typical Phase	
Muhlenbergia virescens Phase	MUVI Phase	
Festuca arizonica Phase	FEAR Phase	
16. *Abies concolor-Pseudotsuga menziesii* HT	ABCO-PSME HT	37
Berberis repens Phase	BERE Phase	
Robinia neomexicana Phase	RONE Phase	
17. *Abies concolor/Acer grandidentatum* HT	ABCO/ACGR HT	5
18. *Abies concolor/Festuca arizonica* HT	ABCO/FEAR HT	7
Pseudotsuga menziesii Series		
19. *Pseudotsuga menziesii-Pinus strobiformis/Muhlenbergia virescens* HT	PSME-PIST/MUVI HT	11

field notes, unpublished soil profile descriptions, and miscellaneous sources of information are included when available.

A section on ecotones and related habitats follows the soils summary. Descriptions of ecotones for each habitat type are based upon field reconnaissance for forest habitats adjoining stands where plots were described. Related habitats extend our knowledge of these habitat types to other geographic locations, including other western states. A discussion includes general comments and observations within each habitat type from field notes. We also survey existing literature pertinent to the habitat type, describe our observations (or those from the literature) on succession or other ecological dynamics, and comment about tree growth potential for commercial species and other land use practices that appear of major importance within the habitat.

The entire synoptic description of each habitat type is intended to be only preliminary familiarization or state-of-knowledge. Data necessary for in-depth understanding of ecological processes and management prescriptions in these habitat types are often lacking. Also, this study is primarily a classificatory stratification of the spruce-fir and mixed conifer forest types.

DESCRIPTION OF SPRUCE-FIR HABITAT TYPES

Picea engelmannii Series

1. *Picea engelmannii/Vaccinium scoparium/Polemonium delicatum* HT

Diagnostic vegetation.—At least moderate (more than 300 stems/ha) and sometimes heavy (more than 1,000 stems/ha) regeneration of *Picea engelmannii*. Regeneration of *Abies lasiocarpa* varies from light (fewer than 100 stems/ha) to heavy. Crown dominance usually by *Picea*; less commonly *Abies lasiocarpa* is codominant. No *Pseudotsuga menziesii* is present. *Vaccinium scoparium* is the understory dominant, ranging from 10%-95% cover (mean 53%) in the plots.

A well developed herbaceous layer can be dominated by any of several species: *Polemonium delicatum, Senecio amplectens,* or *Senecio sanguisorboides*. Species characteristic of tundras or forest-tundra ecotones are usually present: *Deschampsia caespitosa, Poa reflexa, Sibbaldia procumbens, Trifolium dasyphyllum,* and *Podistera eastwoodae*.

Geography.—Sangre de Cristo Mountains.

Topography.—High elevation forested slopes to timberline. Our 14 plots varied between 10,900 feet (3,320 m) and 11,900 feet (3,630 m) at all exposures. Landforms included cirque basins, moraines, alluvial streamsides, gentle upland ridges, and a variety of talus slopes.

Soils.—Soil mapping units included Angostura, Latir, and Nambe Cobbly Loams, Alpine Rockland, Stony Lands, and glacial outwash complexes.

Ecotones and related habitat types.—The *Picea engelmannii/Vaccinium scoparium/Polemonium delicatum* HT has ecotones with tundra at higher elevation and with *Abies lasiocarpa/Vaccinium* HT at lower elevation. This habitat type probably extends northward along the Sangre de Cristo Mountains at timberlines into Colorado. Langenheim (1962) describes a spruce-fir community type in the Crested Butte area of high floristic similarity (including dominance by *Vaccinium* and appreciable cover in certain plots of *Polemonium delicatum, Senecio amplectens,* etc.). Steen and Dix[4] describe a high elevation forest in Colorado dominated by *Picea engelmannii* (their *Picea-Abies/Polemonium delicatum-Polygonum bistortoides* type) with good representation of *Deschampsia caespitosa* and other tundra or high elevation subalpine herbs.

Discussion.—This habitat is restricted to glaciated recesses and slopes of New Mexico's highest peaks. Many stands occur in the Pecos and Wheeler Peak Wildernesses. A few areas are used for skiing and other winter recreation. The forests, therefore, have high scenic and recreation values. They are also important habitat for such wildlife of the forest-tundra ecotone as Rocky Mountain bighorn sheep and ptarmigan.

Aspen is absent from all plots, and some stands near the heads of sheltered cirque basins seem very old (ring counts on *Picea engelmannii* exceeding 500 years). Although fires can sweep up to timberline, many stands of this habitat have escaped serious fire for centuries. The watershed value of this forest, principally for snow and water storage, may be highly variable. Steen and Dix suggested that sites in Colorado where spruce occurs to the exclusion of *Abies lasiocarpa* may represent the drier of timberline conditions. There is no evidence that the same can be said for such stands where *Abies lasiocarpa* is minor or absent in this HT in New Mexico. The high coverage of both *Vaccinium scoparium* and herbs in most plots and the infrequent occurrence of fire suggest well watered (or deep snowpack) conditions. But snow blowoff and redesposition from tundra slopes into lower, sheltered forests can be highly variable, and snow hydrology patterns as related to this and other spruce-fir habitat types need much clarification.

2. *Picea engelmannii/Moss* HT

Diagnostic vegetation.—All sizes of *Picea engelmannii;* usually moderate or heavy regeneration of *Abies lasiocarpa* but mature sizes sometimes less common than *Picea*. Very sparse shrubs and herbs in the understory. Mosses and lichens dominate.

Geography.—Sangre de Cristo and San Juan Mountains, Pinaleno Mountains, San Francisco Peaks.

[4] *Unpublished manuscript.*

Topography.—Dry, high elevation sites. Ridges, upper slopes, southerly exposures, and saddles from 10,000-11,500 feet elevation (3,000-3,500 m).

Soils.—Excessively drained, often lithic and skeletal profiles.

Ecotones and related habitats.—In northern New Mexico, ecotones occur with *Picea/Vaccinium/Polemonium* and *Abies/Vaccinium* HT's and with dry meadows. In the San Francisco Peaks, the *Picea engelmannii/Geum rossii* HT occurs on wetter sites of the same or higher elevations, and the *Abies lasiocarpa/Lathyrus arizonicus* HT is found at lower elevations. In the Pinaleno Mountains are ecotones with *Abies/Vaccinium, Picea engelmannii/Carex foenea,* and dry meadow habitats.

The *Picea engelmannii/Moss* HT is probably related to the *Abies lasiocarpa-Picea engelmannii/Moss* and *Abies-Picea/Vaccinium/Moss* types of Colorado as classified by Steen and Dix.

Discussion.—Considerable geographic variation is found within this HT. In northern New Mexico, *Vaccinium caespitosum* is a rather diagnostic species of the sparse understory and may be common in cobbly meadow openings and aspen fringes which border the coniferous type. Cryptogamic cover is highly variable, depending upon litter accumulation, soil stoniness, and other factors. Perhaps the most reliable habitat indicator is the sparsity of understory vascular plant cover, including only meager representation of *Vaccinium scoparium* (ranging from a trace to 19% cover in our plots). In the Pinaleno Mountains, the sparsity of understory cover is again the best criterion of this habitat. This flora may include trace amounts of *Muhlenbergia montana, Carex hoodii, Potentilla subviscosa, Vaccinium myrtillus,* and *Erigeron formossissimus.* In some stands *Picea engelmannii* may be considerably more important than *Abies lasiocarpa.* In the San Francisco Peaks, the cover of cryptogams is mostly greater than total cover of herbs and shrubs (fig. 2), but local patches of *Lathyrus arizonicus* may exist in small openings. *Ribes montigenum* and *R. pinetorum* are usually present but infrequent. Both *Picea* and *Abies* are climax species, at least in our plots.

Site quality for Engelmann spruce is usually very poor to poor. Five trees between 100 and 165 years old were 50-60 feet (15-18 m) tall; three 130-160-year-old trees were 70-75 feet (21-23 m) tall. More favorable microsites, however, may have trees 90-100 feet (27-30 m) tall at about 140 years of age.

The principal seral tree is *Populus tremuloides,* but all plots occurred in stands which displayed only sporadic distribution of mature aspen stems. It is also likely that both *Picea* and *Abies lasiocarpa* are their own seral predecessors on these lithic, skeletal soils. Neither *Pseudotsuga menziesii* or *Pinus strobiformis* are important seral species, although a few individuals are sometimes found on high ridges (in New Mexico and the Pinaleno Mountains of Arizona.)

Figure 2.—*Picea engelmannii/Moss* HT, San Francisco Peaks. Sparse understory vascular plant vegetation at high elevations (here 3,160 m) is characteristic of the type. The meter stick banded into five 2-dm segments is used for scale.

The warm, dry sites of this habitat may also be favored bedding and shelter areas (from storms) for game. There were abundant signs of elk, for example, in several plots in the Sangre de Cristo Mountains. The presence of numerous large browsing animals may contribute to the lack of understory vegetation, since many of these plants are important browse.

Abies lasiocarpa Series

3. *Abies lasiocarpa/Vaccinium scoparium* HT

Diagnostic vegetation.—Usually moderate to heavy regeneration of both *Picea engelmannii* and *Abies lasiocarpa. Pseudotsuga menziesii* regeneration absent or minor, but mature trees sometimes common. Cover of species of *Vaccinium,* the understory dominant, ranged from 3% to 95% (mean 60%). In northern New Mexico, *Vaccinium scoparium* is important; in southwestern New Mexico and Arizona, *V. myrtillus* is the only *Vaccinium.* Herbs are mostly of few species with low canopy coverage, considerably less than *Vaccinium.*

Geography.—Sangre de Cristo and San Juan Mountains, Mogollon Mountains, Pinaleno Mountains, and Mount Baldy (Arizona).

Topography.—Gentle to steep, smooth to dissected mountain and canyon sideslopes, upland slopes and ridges, narrow to broad valley bottoms at elevations of 9,800 -11,200 feet (2,400-3,400 m). All exposures, but south-facing slopes are mostly burned and in aspen or other seral stages.

Soils.—In northern New Mexico, soils may or may not exhibit weak spodic horizons, and sometimes show a well-developed, thick paleo-A2 horizon.[5] Soil map-

[5] Similar soils have been described in Colorado by Moir (1969) and Johnson and Cline (1965). The latter call profiles with thick eluvial horizon as Gray Wooded. Also see Madole (1969).

ping units include Angostura, Nambe, Latir, Jarosa, and Mallette Cobbly loams, Granite and rhyolite rock land, Greenie Loam. Elsewhere soils have not been described.

Ecotones and related habitats.—On upper slopes, the *Abies lasiocarpa/Vaccinium scoparium* HT is bounded by the *Picea engelmannii/Vaccinium scoparium/Polemonium delicatum* HT or on dry sites by the *Picea engelmannii/Moss* HT. On lower slopes, there may be ecotones with the *Abies lasiocarpa/Vaccinium scoparium–Linnaea borealis* HT or with the *Abies lasiocarpa/Erigeron superbus* HT. This latter may also adjoin the *Abies lasiocarpa/Vaccinium scoparium* HT on benches, minor drainage areas, or wherever variations in soil moisture and drainage or snowpack conditions cause shifts from one HT to the other.

Our *Abies lasiocarpa/Vaccinium scoparium* HT can be readily identified with other *Abies/Vaccinium* types of western North America, particularly in the Rocky Mountain Cordillera (Langenheim 1962, Oosting and Reed 1952, McLean 1970, Daubenmire and Daubenmire 1968). The *Abies lasiocarpa/Vaccinium scoparium* HT of Utah (Pfister 1972) appears to be nearly identical with ours. The mountains of southern Colorado probably contain extensive areas of the *Abies lasiocarpa/Vaccinium scoparium* HT.

There is a close relationship between our *Abies/Vaccinium scoparium* and *Abies/Erigeron superbus* HT's. It is uncertain just what environmental factors produce shifts from *Vaccinium* dominated to herb dominated understories. Possibly the latter occupy sites that are warmer, but well watered and well drained. One plot in the San Juan Mountains (Chicoma Peak) is an example of intergrading between these two habitat types. Here, both *Erigeron superbus* and low, evergreen shrubs (*Vaccinium myrtillus* and *Pachistima myrsinites*) are codominant.

Discussion.—As Langenheim (1962) pointed out, this habitat type has a high floristic homogeneity based upon an apparent repetitive pattern, not only of the dominant understory species, but also among many subdominant and minor plants. Shrubs of high constancy include *Ribes montigenum, Lonicera involucrata,* and in southern geographic areas *Lonicera utahensis.* Commonly encountered herbs include *Pedicularis racemosa (P. angustissima* in the Mogollon Mountains), *Epilobium angustifolium, Fragaria virginiana* var. *glauca, Haplopappus parryi, Erigeron superbus*, and *Bromus ciliatus* (fig. 3). However, the range of environmental variation within this habitat type can be seen as understory differences in comparatively wet and comparatively dry sites. The former, along streamsides or lower slopes, may exhibit (sometimes with high cover values) such species as *Trautvetteria grandis, Senecio sanguisorboides, S. bigelovii* or *Mertensia fransicana* and may have a rich complement of shrub and herb species. Dry upper slopes and ridges can be floristically impoverished (fewer than 10 species) and have cover values well below the mean.

Figure 3.—*Abies lasiocarpa/Vaccinium scoparium* HT, Mogollon Mountains. Broad high ridges (elevation here is 3,130 m) in this area may contain *Pedicularis angustissima* as an understory dominant.

Although *Picea engelmannii* and *Abies lasiocarpa* seem to occur as co-climax species in most of our plots, there is a very wide range of site quality ranging generally from moderate to poor. The growth potential for trees is better predicted by physical site features (exposure, position in the landscape) than by understory vegetation. There is little evidence to support the suggestion by some workers that *Abies lasiocarpa* would eventually replace *Picea engelmannii* in the absence of fire. Although young regeneration of *Abies* may be significantly greater than *Picea* in many plots, the latter survives better and often exhibits greater abundance of older regeneration.

Logging and fires are the principal causes of succession. Large areas of commercial forest land occur within this HT. Natural regeneration after clearing may be highly variable. In the vicinity of Cerro Vista (Penasco Ranger District, Carson National Forest), extensive herb meadows dominated by species of *Carex* have become established after clearing, and there is very little sign of natural restocking by conifers. Elsewhere, however, either or both *Picea engelmannii* and *Abies lasiocarpa* become reestablished, and occasional *Pseudotsuga menziesii* can be found. On some sites, particularly the warmer, south-facing slopes of the Sangre de Cristo Mountains, *Pinus aristata* is a major seral species. Other pine species, however, demonstrate little or no success as seral species within this habitat type. The most prevalent seral tree, especially after fire, is *Populus tremuloides.* Aspen, either as pure stands or with mixtures of conifers, is the most common seral species of this habitat type. Fire intensities are extremely variable and probably determine the proportion of aspen and conifers (Jones 1974). The composition of the stand at the time of fire is also a determinant.

The composition of understory vegetation and rates of coniferous succession under aspen dominated canopies are highly variable. Dominant herbs can include *Lathyrus arizonicus, Stellaria jamesiana, Geranium* *richardsonii, Bromus ciliatus,* species of *Castilleja, Fragaria vesca, Carex foenea,* or *Pseudocymopteris montanus.* The presence of *Vaccinium scoparium* or *V. myrtillus* is often a reliable clue, despite herb dominance, to the *Abies/Vaccinium scoparium* HT.

4. Abies lasiocarpa/Vaccinium scoparium-Linnaea borealis HT

Diagnostic vegetation.—Moderate to heavy regeneration by either or both *Picea engelmannii* and *Abies lasiocarpa. Pseudotsuga menziesii* and *Abies concolor* are both seral, and regeneration of the species may be light to heavy. *Pseudotsuga menziesii* is mostly dominant and sometimes codominant with *Picea engelmannii* in the canopy overstory. A low shrub layer is codominated by *Vaccinium scoparium* and *Linnaea borealis. Pachistima myrsinities* may also be codominant in this layer. A rich assortment of herbaceous species is found. Species of high constancy include *Aguilegia elegantula, Clematis pseudoalpina, Erigeron superbus, Fragaria virginiana* var. *glauca, Haplopappus parryi, Oryzopsis asperifolia, Bromus ciliatus,* and *Pyrola asarifolia.*

Geography.—Sangre de Cristo Mountains.

Topography.—Lower, north-facing canyon slopes, benches, and alluvial terraces between 8,800-9,800 feet (2,700-3,000 m) elevation.

Soil mapping units.—The mapping units include Jaroso-Encebado-Mascarenas complex, Mallette-Granite-Stony Land complex, Mallette Cobbly Loam, Mallette-Rhyolite-Granite Stony Land complex, and Shale and Sandstone Stony Land Complex.

Ecotones and related habitats.—At higher elevation or midslopes, this HT adjoins *Abies/Vaccinium scoparium* or *Abies/Erigeron superbus* HT's. At lower elevations of similar topography, there may be an ecotone with *Picea pungens-Pseudotsuga* HT, *Linnaea borealis* phase. Along adjoining streamsides is usually found the *Picea pungens/Poa pratensis* HT.

The *Abies lasiocarpa/Vaccinium scoparium-Linnaea borealis* HT is clearly most closely related to the *Abies/Vaccinium scoparium* HT but is found on lower, wetter slopes. The principal distinctions from the *Abies/Vaccinium scoparium* HT include greater regeneration densities of *Pseudotsuga* and *Abies concolor,* marked dominance of *Linnaea,* in the understory and the richer complement of herbaceous species. There is also a similarity between the *Abies/Vaccinium-Linnaea* HT and the *Abies/Erigeron superbus* HT as suggested by the expression of a tall shrub stratum (*Acer glabrum, Amelanchier alnifolia, Salix scouleriana*).

Habitats related to the *Abies/Vaccinium-Linnaea* HT are also found on similar topograpy in other geographic areas. In the Mogollon Mountains, the *Abies/Rubus parviflorus* HT is analogous. In Colorado, Steen and Dix[6] classify an *Abies lasiocarpa-Picea engelmannii/Vaccinium-Linnaea borealis* type on north-facing mesic slopes.

Discussion.—Successional stages of this habitat are generally similar to the *Abies/Vaccinium scoparium* HT. In both, aspen is the most common seral dominant. However, *Pseudotsuga menziesii, Abies concolor,* and occasional *Picea pungens* are also important seral and late seral trees. This habitat has a widespread history of disturbance by fire and logging. Virtually all plots exhibited generous proportions of *Pseudotsuga menziesii* and *Populus tremuloides.* But the generally moderate and heavy regeneration densities of *Abies lasiocarpa* and *Picea engelmannii* are evidence of the climax status of these shade tolerant species.

Douglas fir is the most important commercial tree of this habitat. Nevertheless, the site quality is poor: four trees at 80 years breast height age averaged only 57 feet (17 m) in height (range 49-66 feet); a fifth, at 89 years old was only 63 feet (19 m) tall. Growth rates for Engelmann spruce appear similar, but our data are very limited.

5. Abies lasiocarpa/Rubus parviflorus HT

Diagnostic vegetation.—Both *Abies lasiocarpa* and *Picea engelmannii* are climax dominants with moderate to heavy regeneration of *Abies* and light to moderate regeneration of *Picea. Pseudotsuga menziesii* is a major seral species. *Rubus parviflorus* is a conspicuous dominant of a well developed shrub layer. There is also a good coverage by herbaceous species, including *Geranium richardsonii, Haplopappus parryi, Ligusticum porteri, Erigeron superbus,* or *Senecio cardamine.*

We recognize two phases of this HT. The first is characterized by the low shrub *Vaccinium myrtillus* being codominant with *Rubus parviflorus.* The second is characterized by the consistent occurrence of *Acer glabrum* in the tall shrub stratum, and absence of *Vaccinium myrtillus* in the low shrub stratum. In the *Vaccinium myrtillus* phase, *Abies concolor* is minor or accidental, whereas in the *Acer glabrum* phase, *Abies concolor* is a major seral species.

Geography.—Mogollon Mountains.

Topography.—Moderate and steep, well watered mid- and lower slopes, and benches from 8,500-10,300 feet (2,600-3,100 m) elevation. Exposures are north, west and east.

Soils.—One plot of our *Acer glabrum* phase of this HT is mapped as Corner Stony Loam; however, most soils of this basaltic and rhyolitic area along Whitewater Creek and Whitewater Baldy have not been described.

Ecotones and related habitats.—The *Abies lasiocarpa/Rubus parviflorus* HT, *Vaccinium myrtillus* phase ecotones with the *Abies lasiocarpa/Vaccinium scoparium* HT occurs on cooler sites with deeper snowpack. This phase may be analogous to the *Abies lasiocarpa/Vaccinium scoparium-Linnaea borealis* HT of rather similar

[6] *Unpublished manuscript.*

wet locations in the Sangre de Cristo Mountains. At lower elevations (warmer, drier sites) the phase ecotones with the *Acer glabrum* phase of this HT. Habitats on adjacent, drier sites include the *Pinus strobiformis/Festuca arizonica* HT (on opposite south-facing slopes) and extensive *Populus tremuloides* seral communities (with understory dominated by *Muhlenbergia virescens* in some stands) of unknown HT.

Plot 326 has generous regeneration of *Abies concolor* and rather sparse cover (2%) of *Rubus parviflorus*. This plot is probably an integrade to the *Abies concolor-Pseudotsuga menziesii/Acer glabrum* HT.

Discussion.—This habitat type is clearly at the lower boundary of the spruce-fir zone on wet sites. Although climatic data are not available, the profusion and richness of the understory flora (21-27 species) suggests that this HT is very well watered, with minimal growing season water stresses. This is an outstanding wildlife habitat by virtue of its wealth of forage and browse species. The plots are all in the vicinity of Whitewater Baldy in the heart of the Mogollon Mountains. Summer precipitation in this area may possibly be higher than normal for mountains of New Mexico and Arizona.

Site quality for spruce and subalpine fir appears moderate to good. *Picea engelmannii* specimens were 65 and 73 feet (29 and 22 m) at respective breast height ages of 55 and 59 years. *Abies lasiocarpa* at 126 years of age (two specimens) ranged from 80 to 100 feet (24-30 m). Site quality was moderate for Douglas fir, attaining about 100 feet (30 m) at about 110 years of age.

Plots for the *Vaccinium myrtillus* phase were seral. Plot 323 was dominated by large old-growth (about 235 years old) *Pseudotsuga menziesii,* with young and advanced regeneration of mostly *Abies lasiocarpa.* Plot 328 was a young pole stand of both spruce and subalpine fir. *Picea engelmannii, Abies lasiocarpa, Pseudotsuga menziesii,* and *Populus tremuloides* are all seral species, with the last forming pure canopy in some areas (such as just below plot 328). Plot 327 is typical of young burned forest along lower, north-facing slopes of Whitewater Creek. There is heavy stocking of young regeneration of both *Pseudotsuga menziesii* and *Abies lasiocarpa,* as well as moderate stocking of young regeneration by *Picea engelmannii.* Despite the young age of this stand, the ground vegetation characteristics of the habitat are well developed. *Vaccinium myrtillus* and *Rubus parviflorus* had 60% and 50% cover, respectively, and herbaceous cover, principally *Senecio cardamine, Geranium richardsonii,* and *Valeriana acutiloba,* totaled about 20%.

The three plots of the *Acer glabrum* phase were also all seral, dominated by *Pseudotsuga menziesii* of approximately 325 years old. Numerous aspen saplings (mostly 4-6 inches d.b.h., or 10-15 cm) also characterized two of the plots. Primeval wildfires were probably mostly light, burning irregularly in patchy distribution within this, and related, wet habitats (Jones 1974).

6. *Abies lasiocarpa/Erigeron superbus* HT

Diagnostic vegetation.—*Picea engelmannii* with light or moderate regeneration, or less commonly, absent or with heavy regeneration. *Abies lasiocarpa* with moderate to heavy regeneration, occasionally only light regeneration. *Pseudotsuga menziesii* and *Abies concolor* may also show light or moderate regeneration densities, but their combined density is usually less than *Picea engelmannii* and *Abies lasiocarpa* together. Species of *Vaccinium* are usually absent, but with cover not over 15% when present. The understory is characteristically herbaceous. Dominants include *Erigeron superbus, Haplopappus parryi, Geranium richardsonii, Bromus ciliatus,* or *Lathyrus arizonicus.* Species of high constancy also include *Viola canadensis, Osmorhiza obtusa, Fragaria virginiana,* and *Artemisia franseriodes.*

Geography.—Widespread. Sangre de Cristo and San Juan Mountains, Mogollon Mountains, Escudilla Mountain, White Mountains (Arizona), and San Francisco Peaks.

Topography.—Gentle to moderate slopes (4%-30%) of rolling uplands or canyon mid- and upper-slopes; moderate to steep (30%-70%) canyon sideslopes; gentle lower canyon slopes and benches; occasionally along streamsides. In Arizona at elevations from 9,000-9,900 feet (2,700-3,000 m); in New Mexico from 9,200-10,900 feet (2,800-3,300 m). All exposures.

Soils.—Numerous soil types are found in this HT. Parent materials range from basalts (Sponseller silt loam in Arizona) to granitics and sedimentaries. Mapping units in northern New Mexico include Angostura, Maes, and Latir Cobbly Loams and Jarosa-Encebado-Mascarenas Complex. In other areas, the soils are not mapped or described.

Ecotones and related habitats.—The principal ecotone at higher elevation or cooler sites is *Abies/Vaccinium scoparium* HT. Warmer sites or lower elevations contain a wide variety of mixed conifer forest habitats, depending on geographic location and site and soil conditions.

There appear to be no related habitats in Utah or Colorado. Pfister (1972) describes an *Abies lasiocarpa/Berberis repens* HT at low elevations bordering mixed conifer forests in Utah, but it has little similarity to our *Abies lasiocarpa/Erigeron superbus* HT. There is nothing similar in the spruce-fir region of Colorado as classified by Steen and Dix.[7]

Discussion.—Although this habitat is found on a diversity of sites, it generally appears on comparatively warm (for the spruce-fir region) and mesic sites, with deep, well drained soils. The herb dominated understory is characteristic of the habitat (fig. 4), but much variation in composition can be found. At wetter extremes, *Senecio sanguisorboides, S. triangularis, Smilacina*

[7] *Unpublished manuscript.*

stellata, and *Ligusticum porteri* may be conspicuous codominants. Such habitats, usually restricted to streamside terraces in northern New Mexico, are rather strikingly similar to the *Abies/Senecio sanguisorboides* HT of the Sacramento Mountains in southern New Mexico. It is also floristically related to a wetter variation of the *Abies/Erigeron superbus* HT. On drier upper slopes, the cover of forbs may be reduced well below the mean for the habitat type, and more xerophytic grasses such as *Festuca arizonica* and *Muhlenbergia montana* may appear as minor components of the herb layer. The modal sites are typically dominated by *Erigeron superbus* and lack herb species of the wetter or drier extremes.

Both *Picea engelmannii* and *Abies lasiocarpa* are considered to be potential climax species of this habitat. Our examination of the stand structure of 35 sites indicated the following successional trends:

Indicated climax	Number of sites
Picea engelmannii	4
Abies lasiocarpa	7
Picea + Abies	24

Abies has greater density of seedlings and young regeneration, but greater mortality and lower longevity than *Picea*. *Picea* may have rather episodic reproduction in certain sites.

Site quality for *Picea engelmannii* is moderate. Trees can attain heights of 95-100 feet (29-30 m) at breast height age of 100 years.

The most important seral trees are *Pseudotsuga menziesii* and *Populus tremuloides*. *Abies concolor* is mostly a minor seral tree as is *Picea pungens*. Several plots showed evidence of *Pinus strobiformis* and *P. ponderosa* being early seral trees, possibly after hot fires which might have created forest openings. Hot fires can also create seral communities dominated purely by aspen (Jones 1974). Plots 16 and 17 are paired on either side of a fire line on similar sites in the Sangre de Cristo Mountains. *Pseudotsuga menziesii* dominates plot 16; *Populus tremuloides* dominates plot 17.

The herb dominated vegetation under aspen consists of *Vicia americana, Geranium richardsonii, Achillea lanulosa, Fragaria virginiana, Bromus richardsonii,* and *Viola canadensis* (each in excess of 10% cover); but vegetation under Douglas-fir consisted only of *Erigeron superbus* and *Haplopappus parryi* (in excess of 10% cover), and species such as *Artemisia franseriodes* and *Pachistima myrsinites* not found in the paired aspen plot. Vegetation composition under aspen or Douglas-fir seral stages of this HT can differ considerably.

7. *Abies lasiocarpa/Juniperus communis* HT

Diagnostic vegetation.—Both *Picea engelmannii* and *Abies lasiocarpa* dominate the forest regeneration.

Figure 4.—*Abies lasiocarpa/Erigeron superbus* HT, Mogollon Mountains. Common forbs in this stand are *Erigeron superbus, Geranium richardsonii,* and *Smilacina stellata.*

Pseudotsuga menziesii and *Abies concolor* are seral, but of sparse regeneration in stands dominated by spruce or subalpine fir. Understory shrubs and herbs are sparse. The most constant species are *Juniperus communis* and *Pyrola secunda.* Herbaceous cover is usually less than 1%.

Geography.—North Kaibab Plateau and mountains of northern New Mexico.

Topography.—Mostly gentle north- or east-facing draws and upland slopes on the North Kaibab Plateau between 8,700-9,200 feet (2,600-2,800 m) elevation. Hot, dry slopes about 10,500 feet (3,200 m) in the Sangre de Cristo Mountains.

Soils.—Generally undescribed. The plot in the Sangre de Cristos on Mallette-Granite-Rhyolite Stony Land soil mapping unit.

Ecotones and related habitats.—The major ecotone of this HT is the *Abies concolor-Pseudotsuga menziesii* HT, *Berberis repens* phase on ridges and west-facing slopes of the North Kaibab Plateau and the Sangre de Cristo Mountains; however, the *Picea pungens/Carex foenea* HT is commonly found on lower slopes and adjoining parks. This HT is related to the *Abies lasiocarpa/Berberis repens* HT in Utah, especially the modal phase described by Pfister (1972). Plots in the North Kaibab Plateau, however, lack *Pachistima myrsinites* and other species of the *Berberis repens* union described by Pfister. The geographic isolation of plots at North Kaibab is probably a leading cause of floristic impoverishment (Merkel 1954).

Discussion.—The sparcity of the understory and the relatively low elevations suggest this to be one of the driest habitats within the spruce-fir region of Arizona and New Mexico (see also the *Picea engelmannii/Acer glabrum* HT at southernmost outliers of the spruce-fir region). The *Abies lasiocarpa/Juniperus communis* HT shares this feature of sparse understory with the *Picea engelmannii/Moss* HT of higher elevations in other mountain areas of Arizona and New Mexico.

Plot 64, at 10,500 feet (3,200 m) on a south-facing slope of the Sangre de Cristo Mountains, provides a link between those two comparatively dry habitats. This plot is included with those of the North Kaibab Plateau because the diagnostic vegetation features are those of the *Abies lasiocarpa/Juniperus communis* HT of that region. Unfortunately most intermediate and high elevation, south-facing slopes visited in northern New Mexico were in young, aspen-dominated stages of succession. Therefore, there are very few samples of mature forests on these hot, dry slopes within the spruce-fir types. Many aspen stands are probably representative of the *Abies lasiocarpa/Vaccinium scoparium* HT, but since aspen is also a seral feature of the *Abies lasiocarpa/Juniperus communis* HT, a broader geographical range of this latter HT might be expected on south-facing mid- and upper-slopes at intermediate to high elevations in mountains of northern New Mexico.

Examination of stand structure of the seven North Kaibab plots suggests both *Picea* and *Abies* as major coclimax trees in five stands, and *Abies* (with *Picea* minor) in two stands. Site quality for *Picea engelmannii* is moderate; heights from 80 to 95 feet (24-29 m) are attained at 100 years of age, and heights of 100 feet (30 m) or so from 106-140 years of age. Most of the plots suffered defoliation by spruce budworms in 1974.

This HT is limited in acreage on commercial forest lands of the North Kaibab Plateau. Its extent within the North Rim portion of the adjoining Grand Canyon National Park is uncertain. Since most visitors in this area are destined for the Park, this HT in the Kaibab National Forest has little recreational usage except for hunters.

8. *Abies lasiocarpa/Senecio sanguisorboides* HT

Diagnostic vegetation.—*Abies lasiocarpa* is in all sizes and classes, with moderate to heavy restocking of young and advanced regeneration. *Picea engelmannii* has light to moderate regeneration densities. Crown dominance is often by *Abies lasiocarpa,* but sometimes, *Picea* is codominant. No *Abies concolor; Pseudotsuga menziesii* is seral only at low elevations. The shrub layer is dominated by either or both *Ribes wolfii* (average cover 18%) and *R. montigenum* (average cover 3%). A rich, well expressed herbaceous layer is dominated by *Senecio sanguisorboides* (average cover 10%). Other common species are *Ligusticum porteri, Osmorhiza depauperata, Actaea arguta, Bromus ciliatus, Trisetum montanum, Festuca sororia, Pseudocymopteris montana,* and *Erigeron superbus.*

Geography.—Sacramento Mountains in vicinity of Sierra Blanca Peak.

Topography.—All slopes and exposures above 10,000 feet (3,000 m).

Soil.—Soils have mostly developed from Three Rivers stock of intrusive monzonite and granite. They are primarily coarse-loamy, pachic cryoborolls. Profiles are deep, well drained, and have A1-A3-C mineral horizon sequences. Cobbles may be very compact in the profile below about 30-40 cm.

Dye and Moir (1977) sampled the uppermost mineral horizon (A11) in stands along a successional sequence ranging from young burns (dominated by shrubs) to climax. In their A11 horizons, they found a general increase of extractable phosphorus and basic cations along this successional sequence, with the most nutrient-rich soils in old-growth stand types. This trend inversely reflected understory canopy coverage, for the most luxuriant growth was found in the shrub thickets where extractable nutrients were lowest.

Ecotones and related habitats.—Ecotones occur with tundra along high, windswept ridges (Moir and Smith 1970), and with meadows dominated by *Festuca thurberi* (Moir 1967). At lower elevations, mixed conifer forest is mostly of the *Abies concolor-Pseudotsuga menziesii/Acer glabrum* HT, *Holodiscus dumosus* phase.

There appear to be no related habitats in the central and northern Rocky Mountains (Dye and Moir 1977). Herb-dominated habitats lacking *Vaccinium* occur along streamsides in northern New Mexico's Sangre de Cristo Mountains at high elevations. We interpret these as variations of the *Abies lasiocarpa/Vaccinium scoparium* and *Picea engelmannii/Vaccinium scoparium/Polemonium delicatum* HT's.

There is high floristic similarity of understory vegetation with other herb dominated spruce-fir habitat types, namely the *Abies lasiocarpa/Erigeron superbus, Abies lasiocarpa/Rubus parviflorus* and *Picea pungens-Picea engelmannii/Senecio cardamine* HT's. These are all either of low elevation or southern geographical distribution and may have certain common climatic features such as long, warm (in comparison to other spruce-fir HT's) growing seasons and good soil water supply during the growth season.

Discussion.—There may be two phases of this habitat type, although they are not definitely separated here. The typical phase occurs on most sites and lacks *Pseudotsuga* as a seral tree. Fires severe enough to create large forest openings (often along upper slopes and ridges) result in shrub dominated communities. Thickets are dominated by *Ribes montigenum* and *R. wolfii.* Gradually both *Picea engelmannii* and *Abies lasiocarpa* reinvade. Aspen is often absent. On warmer sites and lower elevations, a *Pseudotsuga menziesii* phase of this habitat type may be present. Fires may bring about seral communities suggestive of the *Abies concolor-Pseudotsuga menziesii/Acer glabrum* HT, *Holodiscus dumosus* phase. *Ribes* have low coverage values, and *Populus tremuloides* seral communities may also be found at some locations. We are reluctant to separate these phases as distinct because of the overall homogeneity of vegetation in mature forests and the very limited distribution of these spruce-fir forests in the Sierra Blanca area (Dye and Moir 1977). Instead, we regard the *Pseudotsuga* phase as a warmer, drier variation of this HT.

This habitat at low and intermediate elevations is of high site quality for *Abies lasiocarpa* var. *arizonica*. Robust, long-lived ecotypes and the tallest known specimens occur here (fig. 5). Larger specimens are often older than 275 years. Such longevity may explain the higher density of mature *Abies* in this type than in most other spruce-fir habitat types in Arizona and New Mexico. Examination of stand structure of six mature stands indicates the major climax species in four stands is *Abies lasiocarpa* var. *arizonica,* and both *Abies* and *Picea engelmannii* in two.

The spruce-fir forest in the vicinity of Sierra Blanca Peak is extensively used for skiing, and numerous paths have been cut for lift-lines and downhill runs. These paths and related access and maintenance roads have seriously chopped this very limited forest by creating numerous edge effects, but effects on water yield and quality are not documented. Snow depths vary from year to year, and during years of low snowfall, snow-making machines may be used to provide a satisfactory base for the runs. The *Abies lasiocarpa/Senecio sanguisorboides* HT is the principal watershed for the towns of Ruidoso and Capitan.

Dye and Moir (1977) studied the relationship of this HT to adjoining *Festuca thurberi* meadows. There is no evidence that many of these meadows are fire-initiated precursors of spruce-fir forest. Seral communities of the *Abies lasiocarpa/Senecio sanguisorboides* HT typically show a wealth of plant species, most of which are entirely absent from *Festuca thurberi* meadows (Moir 1967). Tree invasion under present climatic conditions is mostly lacking, except possibly in old sheep camps. However, a few small aspen stands have understories of *Festuca* and associated meadow species. These sites mostly border more mature coniferous forest and are seral forest communities of the *Abies lasiocarpa/Senecio sanguisorboides* HT. Conceivably, these seral border communities originated by grass fires pushing into adjoining forests. The greatest extent of *Festuca thurberi* meadows appears to be an edaphic climax on soils more finely textured than forest soils (Moir 1967). The meadows may have originated during drier or warmer postglacial climates as forests generally retreated upward in elevation and steppic vegetation expanded.

Figure 5.—*Abies lasiocarpa/Senecio sanguisorboides* HT, Sacramento Mountains. The shrubs, *Ribes wolfii* and *R. montigenum*, are common in the understory. The large tree at the right is *Abies lasiocarpa* var. *arizonica*. (Photo courtesy A.J. Dye)

DESCRIPTION OF MIXED CONIFER HABITAT TYPES

Picea pungens Series

9. *Picea pungens-Picea engelmannii/Senecio cardamine* HT

Diagnostic vegetation.—*Picea engelmannii* usually in all size classes with light or moderate densities of regeneration and *Picea pungens* characteristically present. A low shrub layer is sparse and inconspicuous with *Lonicera utahensis* and *Rubus parviflorus* the most constant species. The herbaceous layer is well developed and diverse. Patches of *Senecio cardamine* are often conspicuous. Other common plants are *Pteridium aquilinum, Helenium hoopsii, Viola canadensis, Senecio wootoni, Geranium richardsonii, Fragaria virginiana, Bromus ciliatus,* and *Carex* spp.

We recognize two phases—the *Abies lasiocarpa* phase when this species has light to moderate regeneration, and the *Abies concolor* phase when this species has light to moderate regeneration with *Abies lasiocarpa* sparse or absent. Young *Picea pungens* and *Pinus strobiformis* are absent or sparse in the *Abies lasiocarpa* phase, but both have light densities in the *Abies concolor* phase. *Pseudotsuga menziesii* occurs in most size classes in both phases. *Pinus ponderosa* is an infrequent seral tree in both phases.

Geography.—Hannagan and Thomas Creek drainages of the White Mountains, Arizona.

Topography.—Gentle upland slopes and drainages, 8,800-9,200 feet (2,700-2,800 m), fingering down intermittent streamsides and lower northerly slopes to about 8,800 feet (2,700 m). The *Abies lasiocarpa* phase is usually not found on south-facing exposures, otherwise no consistent microsite differences occur between these phases.

Soils.—Sponseller Loam and various textural phases.

Ecotones and related habitat types.—Lower elevations have *Abies concolor-Pseudotsuga menziesii/Quercus gambelii* and *Abies concolor-Pseudotsuga menziesii* HT's as ecotones. Plot 10 on very stony, rocky upper side slopes is an old growth *Pinus strobiformis* forest with moderate stocking of young *Abies concolor* and *Pseudotsuga menziesii* and a herbaceous understory (including 4% cover of *Senecio cardamine;* the plot could not be classified.

These habitats are mostly closely related to the *Abies lasiocarpa/Rubus parviflorus* HT of the Mogollon Mountain. The *Abies lasiocarpa/Erigeron superbus* HT is also related, but the sparse cover of *Erigeron superbus* suggests that both phases occupy somewhat drier sites. All these habitats at lower elevations of the spruce-fir forests are within a family of HT's characterized by herbaceous understories (see the *Picea pungens-Picea englemannii/Erigeron superbus* HT).

Discussion.—This habitat type forms mosaics on undulant upland topography of the Hannagan and Thomas Creek drainages. Our study of tree structure from plots of both phases suggests the following climax status (C = climax co-dominant, c = minor climax, S = seral co-dominant, s = minor seral species, a = absent):

Species	Climax status	Percent of plots in phase *A. lasiocarpa*	*A. concolor*
Picea engelmannii	C	44	57
	c	56	15
	a	0	15
Abies lasiocarpa	C	78	0
	c	22	36
	a	0	64
Picea pungens	C	11	21
	c	33	71
	a	56	8
Abies concolor	C	0	36
	c	0	21
	S	22	8
	s	33	21
	a	45	0
Pseudotsuga menziesii	C	0	64
	c	0	14
	S	100	22
Pinus strobiformis	S	0	50
	s	44	29
	a	56	21
Pinus ponderosa	s	44	36
	a	56	64

Picea engelmannii, Picea pungens, and *Abies lasiocarpa* all have major or minor climax status in this *Picea/Senecio cardamine* HT, *Abies lasiocarpa* phase, and *Pseudotsuga menziesii, Abies lasiocarpa* and the pines are always seral. But all conifer species, except the pines, exhibit at least some climax potential in the *Picea/Senecio cardamine* HT, *Abies concolor* phase—a remarkable phenomenon that we have never experienced in coniferous forest of North America.

Site quality for *Picea engelmannii* is excellent. Site index at base age of 100 years breast height is about 110, but some specimens may reach 120 feet (37 m) or more at 100 years. Similarly, both *Pseudotsuga menziesii* and *Picea pungens* have good growth potential in this habitat; annual height increments averaged about 1 foot (25 cm). These habitats are important commercial forests. Timber volume from species such as *Picea engelmannii, Pseudotsuga menziesii,* and *Pinus ponderosa* is high in many old growth stands which contain larger trees often

240-260 years old at breast height. Gentle terrain is favorable to many logging operations and reforestation.

The major seral species after fire is *Populus tremuloides,* but many conifers of the late seral or climax vegetation may also become quickly established after fire. We consider this habitat type to be very near the boundary between spruce-fir and mixed conifer forests.

10. *Picea pungens-Picea engelmannii/ Erigeron superbus* HT

Diagnostic vegetation.—*Pseudotsuga menziesii* occurs in all sizes, and in four of five plots, is the leading regeneration species. Both *Picea pungens* and *Picea engelmanii* are major or minor co-climax species and have light or moderate regeneration densities. A well developed assemblage of herb species is present, with dominants including *Erigeron superbus, Carex foenea, Fragaria virginiana,* and *Lathyrus arizonicus.* Grasses are sometimes important: *Festuca arizonica* (up to 20% cover), *Muhlenbergia virescens, Poa pratensis,* and *Bromus ciliatus.*

Geography.—White Mountains, generally in the vicinity of Big Lake.

Topography.—Gentle slopes and plateau summits and ridges mostly around 9,000 feet (2,740 m) elevation; but on Burro Mountain it occurs at 9,800 feet (3,000 m); on all exposures.

Soils.—Mostly Sponseller gravelly silt loam.

Ecotones and related habitats.—These forests may adjoin grassy meadows dominated by *Festuca arizonica.* The most common nearby forest habitat is the *Picea pungens/Carex foenea* HT. This habitat is also related to the *Picea engelmannii/Senecio cardamine* HT of mountains just to the east. The tree structures are similar in both habitats; both have herbaceous understories, and occupy sites of similar landform and soils.

Discussion.—Most plots consisted of old-growth trees (larger trees 250-300 years old at breast height), forming semi-open canopies (overstory cover from 10% to about 35%) of *Pseudotsuga menziesii* and *Pinus ponderosa.* Partial overstory cutting took place in stands sampled by plots 80 and 81, but tree removal was light and seemed to have little effect on the present understory species composition. The other plots are within unlogged stands. Cattle are grazed in this HT, but the influence upon composition of the herbaceous understory could not be assessed.

Examination of the tree structures in the five plots located in this HT suggests the following climax status of the conifers (C = major climax, c = minor climax, S = major seral, s = minor seral, a = accidental or absent):

Species	Climax status	No. plots
Picea engelmannii	C	1
	c	4
Abies lasiocarpa	c	1
	a	4
Picea pungens	C	3
	c	2
Abies concolor	c or s	1
	a	4
Pseudotsuga menziesii	C	4
	c	1
Pinus strobiformis	S or s	5
Pinus ponderosa	S or s	3
	a	2

This habitat, like the *Picea pungens-Picea engelmannii/Senecio cardamine* HT, has at least four major or minor co-climax species. However, *Abies lasiocarpa* is very minor, and the climax status of *Abies concolor* is uncertain.

Fire scars at bases of some of the larger trees indicated ground fires. Fires in dry seasons may have been carried along a herbaceous cover, and some of these may have originated as range fires in dry parklands bordering these stands. *Populus tremuloides* is the major tree of the fire sere, but the 200-300-year-old pines in plots, as well as *Pseudotsuga menziesii* of about the same age, also may have become established, mostly in forest openings.

Site quality is moderate to good for both *Picea* species and moderate for *Pseudotsuga menziesii.* Individual tree selection is a suitable harvesting method, since these stands are mostly within a major recreation area (Big Lake) and have scenic value. Much of the timber volume is from the 200-300-year age classes, but shorter rotations of Douglas fir and shade tolerant spruce seem feasible.

11. *Picea pungens/Poa pratensis* HT

Diagnostic vegetation.—*Picea pungens* in all sizes and dominant in regeneration. Species of *Salix* and *Alnus* in a tall shrub stratum; other species of this stratum may include *Amelanchier alnifolia, Prunus virginiana,* and *Acer glabrum.* Extremely rich and diverse herbaceous vegetation (34-49 species in the plots). Dominants include *Poa pratensis* (3%-70% cover), *Fragaria* spp., *Erigeron superbus, Geranium richardsonii, Equisetum* spp., *Viola nephrophylla, Schizachne purpurascens,* and *Heracleum lanatum.*

Geography.—Sangre de Cristo, San Juan, Sacramento, Mogollon, and San Mateo Mountains.

Topography.—Streamsides and well watered tributary draws, the plots between 8,000-9,100 feet (2,440-2,750 m) elevation.

Soils.—Mostly deep alluvial soils with black, mollic epipedon.

Ecotones and related habitats.—This HT strings for miles along alluvial terraces of major drainages. At higher elevations, it merges with *Abies lasiocarpa/Vaccinium scoparium* HT, and at lower elevations, with *Pseudotsuga-Pinus ponderosa* streamside habitats, outside the scope of this study. *Populus augustifolia* may occur as codominant in some of these streamside habitats near lower distributional limits of *Picea pungens.*

Closely related habitats exist in canyon drainages at mid-elevations in southern Colorado and along the Front Range as far north as Left Hand Canyon near Boulder. We know of no related habitat in Arizona, although the *Picea pungens/Carex foenea* HT is, perhaps, the closest analogue. Alluvial terraces of major mountain drainage systems probably are just not that common in Arizona at elevations generally between 8,000-9,000 feet (2,440-2,740 m).

The habitat types of adjoining canyon sideslopes are numerous and varied, depending upon geographic range and elevation. Over much of the elevational and geographic range of the blue spruce streamsides, are adjacent sideslopes within the range of mixed conifer forest habitats described in this paper. At lower elevations, however, south-facing slopes may exhibit forest types of the *Pinus ponderosa* region (such as *Pinus ponderosa* and *Juniperus scopulorum* or *Pinus edulis* mixtures) while opposite slopes are classifiable as mixed conifer habitats. At upper elevations are north-facing slopes of habitat types classified as spruce-fir types in this paper, while south-facing slopes are again within the mixed conifer forest region.

Discussion.—This habitat type is possibly the most intensively utilized of all forests in Arizona and New Mexico. The number of recreational forest campgrounds along rivers and streams exceeds that of any other HT. Recreational fishing is also heavy. Many stands have been logged at least once. The habitat is very important as summer pasturage for livestock, because the best forage and watering areas are on the gentle slopes with low erosion potential.

For these reasons, it has been almost impossible to find stands with minimum human disturbance. Nearly all stands displayed signs of moderate to extensive impacts from some combination of camping, fishing, logging, or grazing.

The value of this HT is enhanced, because *Picea pungens* is a valuable horticultural species. Thus, the habitat is a valued gene pool for this species. But many other species of plants are also more or less confined to this habitat. Among these are *Cypripedium calceolus,* a rare species. Other species of botanical interest within this HT include *Habenaria hyperborea* and *H. saccata, Viola nephrophylla, Carex capillaris, Schizachne purpurascens,* and *Dodecatheon ellisiae.*

Site quality for *Picea pungens* is high (average annual growth exceeding 1 foot (30 cm)) or sometimes moderate (under 1 foot per year). Grazing quality for cattle and horses is high. The abundance of *Poa pratensis* in plot 130 may reflect a history of livestock grazing. Experience from other grazed locations within this HT suggests that *Poa pratensis,* a hardy and grazing-tolerant grass, increases, while palatable forbs such as *Heracleum lanatum* or *Mertensia franciscana* decline. Many pastures along streamsides throughout New Mexico are dominated by *Poa pratensis* within this habitat, although plots 26 and 121, which were lightly grazed by livestock, had only about 3%-4% cover.

Browse plants are important for domestic and wildlife in this habitat. In addition to the dominants listed above, *Cornus stolonifera, Rubus parviflorus, Lonicera involucrata* (at higher elevations), *Pachistima myrsinites, Symphoricarpos oreophilus,* several species of *Ribes,* and *Sherperdia canadensis* also are found. This browse assemblage might also be simplified or reduced in cover under intensive livestock grazing.

Aspen is the principal tree of the fire sere. Fires are probably less frequent in this habitat than in adjoining sideslopes or hotter, drier environments, but we have no evidence. However, *Populus tremuloides* was present in all plots, and often forms rather pure copses along the streamsides. Other seral species are *Pinus ponderosa, Pseudotsuga menziesii,* and *Abies concolor.*

12. *Picea pungens/Carex foenea* HT

Diagnostic vegetation.—*Picea pungens* in all size classes and of moderate to heavy regeneration densities. A well developed, herbaceous understory is dominated by graminoid species (*Carex foenea*) and grasses (*Muhlenbergia montana, Festuca arizonica,* and *Bromus ciliatus*).

We recognize two phases: the *Pseudotsuga menziesii* phase which has a strong codominance of Douglas fir including good regeneration, and the *Pinus ponderosa* phase which has Douglas fir poorly represented, especially in regeneration. The *Pseudotsuga menziesii* phase has *Carex foenea* as a strong herbaceous dominant with grasses not as important. The *Pinus ponderosa* phase has *Muhlenbergia montana* and other grasses as dominant in the understory, but *Carex foenea* is often minor. *Festuca arizonica* may be codominant in either phase, or is often absent. Important forbs include *Fragaria virginiana, Antennaria* spp., *Achillea lanulosa, Lathyrus arizonicus,* and species of *Erigeron.*

Geography.—White Mountains, North Kaibab Plateau, and possible outliers in the Mogollon Mountains.

Topography.—Gentle lower slopes and drainages, streamsides, and forest borders of grassy parks. Elevations as low as 8,300 feet (2,500 m) along drainages, but mostly 8,600-9,100 feet (2,620-2,770 m), and all exposures for the *Pinus ponderosa* phase and to 9,400 feet (2,860 m) for the *Pseudotsuga menziesii* phase. Some plots of the *Pseudotsuga menziesii* phase are also on moderate to steep sideslopes.

Soils.—Sponseller gravelly silt loam (White Mountains), and deep valley fills and alluviums derived from limestone (Kaibab Plateau), along with some Sprucedale Cobbly soils.

Ecotones and related habitats.—The most conspicuous ecotone is the grassy parkland of lower elevations. Forest ecotones include the *Abies lasiocarpa/Juniperous communis* and the *Abies lasiocarpa/Erigeron superbus* HT's on cooler, wetter sites, and the *Abies concolor-Pseudotsuga menziesii/Acer glabrum* HT, *Berberis repens* phase, and the *Abies concolor/Festuca arizonica* HT on drier sites. We know of no closely related habitats of other geographic areas. The *Picea pungens/Poa pratensis* HT of streamsides in New Mexico are usually on alluvial soils along permanent streams and rivers, whereas drainages in Arizona are more commonly intermittent within the *Picea pungens/Carex foenea* HT.

Discussion.—This is a major forest habitat of central and northern Arizona. The codominance of *Picea pungens* and *Pinus ponderosa,* often with heavy mixture of *Populus tremuloides,* are striking features of the pine phase of this HT. This habitat appears to be the optimum environment in Arizona for *Picea pungens,* which we regard as the climatic climax tree. This HT has very high scenic quality, and is visible from roads throughout valleys and parklands. The high proportion of aspen and the juxtaposition of forests and parklands contributes to this scenic appeal. Most stands of this habitat type visited are within summer grazing allotments.

Many stands in this habitat type are in areas of cold air drainage or frost pockets. At frost pockets (along margins of De Motte Park, for example), both *Picea englemannii* and *Abies lasiocarpa* occur sporadically, and on gentle, north-facing slopes, stands intergrade into spruce-fir habitat types. Warm, south-facing slopes may feature open, savanna-like *Pinus ponderosa* forest with light regeneration of *Picea pungens* and *Pinus ponderosa* (drier variants of our *Pinus ponderosa* phase of this HT). Xeric herbs of such warm microsites include *Chrysopsis villosa* var *foliosa, Hymenoxys subintegra, Festuca arizonica, Erigeron flagellaris,* and *E. formosissimus.* This herb assortment is highly similar to that of *Abies concolor/Festuca arizonica* HT. The chief distinctions between the two HT's at the warmer margins of the *Picea pungens/Carex foenea* HT are the regeneration of *Picea pungens* and the lack of any strong suggestion that *Abies concolor* is climax.

The shifts from *Carex foenea* to grasses in the two phases are quite distinctive. The reason for this differentiation of dominance relationships is uncertain. The influences of livestock, the frequency and characteristics of fires, and the duration of coniferous dominance between fire intervals are all possible causes. Our experience in other forest habitats hints that *Carex foenea* and other rhizomatous sedges are more

Figure 6.—*Picea pungens/Carex foenea* HT, *Pinus ponderosa* phase, North Kaibab Plateau. Note saplings of *Picea pungens,* mature *Pinus ponderosa,* and understory turf of *Carex foenea.*

tolerant of shaded coniferous microenvironments than the *Festuca arizonica* and the associated grasses (Moir 1966).

Fires play a major role in the dynamics of vegetation in this HT. Abundance of both *Populus tremuloides* and *Pinus ponderosa* in stands throughout this HT indicates that fires must have occurred frequently and at many locations within the past 100 years. The fires may commonly be surface fires. All the larger pines of plot 354, for instance, were fire-scarred at the ground (fig. 6). An occasional *Picea pungens* was spared as fire pursued its erratic course where fuel accumulations permitted. Specimens of *Picea pungens* in plot 371 were 230 years old at breast height. But fires may also crown during dry years or where high fuel loads or dense canopies allow. Fire created forest openings, regardless of size, may create herb dominance for a few years (Moir 1966), but rapidly growing aspen suckers soon result in tree dominance again. At certain sites along gentle drainages, a heavy cover of *Picea pungens* may be quickly established under aspen after fire.

Selective cutting has taken place at several locations adjoining or within plots. Trees harvested are mostly old-growth, overstory *Pinus ponderosa* or occasionally *Pseudotsuga menziesii. Pinus ponderosa* is the most important commercial tree of this HT, but its growth is poor to moderate. Site index is generally 70-80 (at 100 years). For *Picea pungens,* site quality of this HT is good to moderate.

13. *Picea pungens-Pseudotsuga menziesii* HT

Diagnostic vegetation.—The most conspicuous feature of this HT is the codominance of both *Picea pungens* and *Pseudotsuga menziesii* as climax species on valley sideslopes (rather than alluvial terraces or valley bottoms). *Abies concolor* is usually accidental, but may be minor seral in some plots. We are uncertain of its successional status in this HT.

We recognize four phases of this HT differing primarily in the following understory vegetative characteristics:

a) *Arctostaphylos uva-ursi* phase—Conspicuous abundance of both tall and low shrubs in the understory. Tall shrubs include *Amelanchier alnifolia* and *Salix scouleriana.* Low, evergreen shrubs include *Arctostaphylos uva-ursi* (20%-25% cover in two plots), *Pachistima myrsinites, Berberis repens* (4%-8% cover), and *Juniperus communis.* Low, deciduous shrubs are represented by *Rosa woodsii, Symphoricarpos oreophilus,* and *Rubus parviflorus.* Herbaceous cover was 15% and 44% in plots. Herbs present include *Oryzopsis asperifolia, Geranium* spp., *Lithospermum multiflorum, Achillea lanulosa, Pedicularis canadensis, Fragaria virginiana,* and *Poa pratensis.*

b) *Valeriana acutiloba* phase—A tall shrub layer may be represented by *Quercus gambelii, Acer glabrum,* or *Amelanchier alnifolia,* but it is typically rather sparse. Low shrubs include *Rosa* spp., *Lonicera arizonica, Juniperus communis,* and *Jamesia americana.* However, no shrub species exhibited sufficient constancy or dominance to be regarded as diagnostic. The herb cover is well expressed, with *Valeriana acutiloba, Bromus ciliatus, Fragaria vesca, Poa fendleriana, Aquilegia* spp., and *Cystopteris fragilis* characteristically present (fig. 7).

c) *Linnaea borealis* phase—The low evergreen shrub layer is very conspicuous, with *Linnaea borealis* 30%-60% cover. *Pachistima myrsinites, Juniperus communis,* and *Vaccinium myrtillus* may also be common.

d) *Juniperus communis* phase—Characterized by a very sparce understory cover, with only *Juniperus communis* reaching 1%-2% cover.

Geography.—The *Arctostaphylos uva-ursi,* the *Linnaea borealis,* and *Juniperus communis* phases occur in the Sangre de Cristo Mountains, with the latter extending into the San Juans. The *Valeriana acutiloba* phase occurs in the Sacramento, Mogollon, and White Mountains, Arizona.

Topography.—The *Valeriana acutiloba* and the *Linnaea borealis* phases occupy lower slopes of northerly aspect at 7,800-8,100 feet (2,380-2,470 m) and 8,700-8,900 feet (2,650-2,700 m) elevation respectively. The *Arctostaphylos uva-ursi* phase occurs on benches or lower slopes of east and south aspect at about 9,100 feet (2,760 m). The *Juniperus communis* phase is found on drier, upper slopes and ridges at 9,100 and 9,500 feet (2,770 and 2,900 m).

Soils.—Plots of the *Arctostaphylos uva-ursi* phase occur on the Jaroso-Encebado-Mascarenas Complex, and the Granite and Rhyolite Rockland mapping units. The *Valeriana acutiloba* phase plots along Gilita Creek were identified as the Rocker-Rockland Complex, and those in the Beaver Creek drainage as the Sprucedale very stony loam. Plots of the *Linnaea borealis* phase are mapped as the Jaroso-Encebado-Mascarenas Complex. The plot of the *Juniperus communis* phase along the Red River is mapped as Mallette-Granite and Rhyolite Stony Land.

Figure 7.—***Picea pungens-Pseudotsuga menziesii* HT, Mogollon Mountains. A rich herb flora on these steep, lower slopes (elevation 2,430 m) along Gilita Creek includes *Poa fendleriana, Bromus ciliatus, Valeriana acutiloba,* and *Geranium richardsonii.***

Ecotones and related habitats.—The adjoining streamsides of all four phases are the *Picea pungens/Poa pratensis* HT. The upper ecotones of the *Arctostaphylos uva-ursi* phase include the *Abies lasiocarpa/Erigeron superbus* HT on north-facing slopes and the *Abies concolor–Pseudotsuga menziesii/Quercus gambelii* HT on south-facing slopes. This phase does not appear to have related habitats in other geographic regions. The *Valeriana acutiloba* phase in the White and Sacramento Mountains often adjoins grassy, streamside meadows. This phase seems to be related to the *Abies concolor-Pseudotsuga menziesii/Acer glabrum* HT, but occupies somewhat warmer sites (or possibly within cold air drainage convection) at lower elevations. The *Linnaea borealis* phase has an upper ecotone on north-facing slopes with the *Abies lasiocarpa/Vaccinium scoparium-Linnaea borealis* HT. The *Juniperus communis* phase plot along Deer Trail Creek is situated on a minor ridge paralleling the creek and is fringed by *Populus tremuloides* at the edge of the grassy meadows along the creek. Stands adjoining the plot of this phase on the

Red River appear to be mostly of the *Abies concolor-Pseudotsuga menziesii* HT, *Berberis repens* phase.

Discussion.—This HT and its various phases are generally at the drier environmental extreme for *Picea pungens*. Soils are usually colluvial rather than alluvial. Site indexes for both *Picea pungens* and *Pseudotsuga menziesii* are poor or very poor. For example, in the *Arctostaphylos uvi-ursi* phase, specimens of *Picea pungens* at 64, 84, and 96 years of age at breast height were respectively only 50, 59, and 74 feet (15, 18, and 22.5 m) tall. Similar poor growth was measured for *Picea pungens* in the *Juniperus communis* phase. Slightly better growth for both *Picea pungens* and *Pseudotsuga menziesii* may take place in the *Valeriana acutiloba* phase (site index at 100 years around 70 to 80).

Since this is a forest HT of lower canyon slopes, it has a high scenic quality, with high visibility along roads and streams. It provides good habitat for wildlife, but sparse understories in some stands permit less use by livestock than the adjoining *Picea pungens/Poa pratensis* HT of streamsides.

Selection cutting and fires are the most common disturbances. Seral species are *Populus tremuloides, Quercus gambelii,* and *Pinus strobiformis*. *Abies concolor* may be co-climax or late seral with *Picea pungens* and *Pseudotsuga menziesii* in our *Arctostaphylos uvi-ursi* phase.

Abies concolor Series

14. *Abies concolor-Pseudotsuga menziesii/Acer glabrum* HT

Diagnostic vegetation.—Either or both *Abies concolor* and *Pseudotsuga menziesii* dominate the forest regeneration of this habitat. *Pinus ponderosa* is accidental or minor, since neither regeneration nor mature trees are important in climax stands. The tall shrub layer is characteristic and consists of *Acer glabrum, Acer grandidentatum,* and *Amelanchier alnifolia*. *Quercus gambelii* and *Salix scouleriana* may be important in narrow canyons or streamsides, but *Acer* is always present.

We distinguish two phases based on the low shrub layer. The *Berberis repens* phase features this shrub as well as *Pachistima myrsinites*. The *Holodiscus dumosus* phase lacks *Berberis*. Other low shrubs characteristic of both phases may include *Symphoricarpus oreophilus, Jamesia americana,* and *Rosa woodsii*. There is often an excellent cover of herbs, with *Bromus ciliatus, Artemisia franserioides, Clematis pseudoalpina, Haplopappus parryi,* and *Lathyrus arizonicus* common.

Geography.—The *Berberis repens* phase occurs mostly in the Mountains of northern New Mexico, with an outlier in the White Mountains of Arizona. The *Holodiscus dumosus* phase occurs in the Sacramento, Mogollon, Chiricahua, and Pinaleno Mountains.

Topography.—The *Berberis repens* phase in northern New Mexico is found on east, south, or west-facing canyon sideslopes at elevations from 8,900-9,600 feet (2,700-2,900 m). It extends down streamsides to 7,700 feet (2,300 m). In the San Juan Mountains, it occurs on gentle north-facing mesa tops at 9,200-9,400 feet (2,800-2,900 m). It occurs on knolls in the White Mountains. The *Holodiscus dumosus* phase in southern New Mexico and adjacent Arizona is found on moderate to steep canyon sideslopes of east, and northwest exposures generally between 7,900 and 9,500 feet (2,400-2,900 m) in elevation. It also extends along streamsides down to about 6,800 feet (2,100 m). When found on south-facing slopes, this phase occurs on deep, well drained soils at higher elevations between 9,400 and 10,000 feet (2,900-3,000 m).

Soils.—Our plots of the *Berberis repens* phase occur on the following soil mapping units: Maes and Jarosa Cobbly Loams, Jarosa-Encebado-Mascarenas Complex, Granite and Rhyolite Stony Land, Jarosa-Encebado-Shale and Sandstone Stony Land, and Mallette-Granite and Rhyolite Stony Land Complexes. Our plots of the *Holodiscus dumosus* phase are on undescribed soils.

Ecotones and related habitats.—Cooler, wetter sites have spruce-fir forest HT's according to geographic area; warmer, drier sites commonly feature the *Abies concolor-Pseudotsuga menziesii/Quercus gambelii* HT or the *Abies concolor-Pseudotsuga menziesii* HT with a sparse understory. The two phases of this HT are clearly related, but neither appear to be similar to other habitats in this geographic region.

Discussion.—This is a major HT of cool, moist canyons and uplands of much of New Mexico and bordering mountains in Arizona. It is among the coolest, wettest of mixed conifer forest habitats and usually subtends spruce-fir forest. Either *Picea engelmannii* or *Abies lasiocarpa* may be found as regeneration or occasional mature trees in some stands, but they are minor and almost always are under severe competition from dense regeneration and canopy dominance of *Abies concolor* and *Pseudotsuga menziesii*.

Examination of plot data reveals the following:

Indicated climax	Number of plots by phase	
	Berberis	*Holodiscus*
Abies concolor	6	6
Pseudotsuga menziesii	7	0
Abies + Pseudotsuga	13	9

Most plots have both species as co-climax. However, even in those plots where either species alone was indicated climax, the other species was present in lesser amounts as young or advanced regeneration. Thus, we regard *Abies concolor* and *Pseudotsuga menziesii* as climax species of equal importance in this HT.

Site quality for *Pseudotsuga* is poor in the *Berberis repens* phase. Heights at age 100 (bh) averaged about 75 feet (23 m). However, growth may be somewhat better in the *Holodiscus dumosus* phase. Heights of 55-year-old trees were 60-70 feet (18-21 m). In general, these trees are about 10 feet (3 m) taller than trees of comparable age in the other phase.

Populus tremuloides is the most important seral tree after fires, but *Pseudotsuga menziesii* can also be seral after fire on certain sites or after certain fires where *Populus* is not stimulated. Fires in these wet mixed conifer habitats are probably mostly light, erratic, and infrequent. *Pinus ponderosa,* possibly an indicator of more intensive fires in this HT, is only infrequently encountered. Localized "hot spots" may account for the patchiness or irregular structure—a cluster of aspen stems, mixed aspen and conifers, an infrequent ponderosa pine, open canopy of large old Douglas fir, or sapling thickets of mixed Douglas fir and aspen—all on the same slope (Jones 1974). Other disturbance factors encountered which contribute to the irregular forest structure include windthrow of large specimens of Douglas fir, and selective logging of mature trees.

Successional relationships within the *Holodiscus dumosus* phase have been studied by Hanks (1966) in the Sacramento Mountains. The principal cause initiating sucession was fire. Burns occured in 1963, 1950, 1945, 1939, and around 1886. Vegetation is primarily dominated by herbaceous species for a few years after heavy burns. *Quercus gambelii* and *Robinia neomexicana* follow this herb stage the second or third year after fire and persist—often attaining tree size—until coniferous dominance gradually ensues. Other important shrubs of this sere are *Acer glabrum, Holodiscus dumosus,* and *Ptelea angustifolia.* The final coniferous stage of succession on the north and east exposures is marked by establishment of *Pinus strobiformis, Abies concolor,* or *Pseudotsuga menziesii.* Hanks found *Pinus ponderosa* to be an infrequent species of the coniferous stage. *Pinus strobiformis* occurred as young or advanced regeneration in 80% of our plots of this HT phase, with regeneration densities ranging from 4 to 36 stems per ha. *Populus tremuloides* is also seral in some sites, either with, or to the exclusion of, *Quercus gambelii.* Aspen may be less important as a seral species in this phase than it is within the *Berberis repens* phase of northern New Mexico.

There is considerable environmental variation within this HT. Wetter streamside vegetation contains rich species assemblages. For example, plot 169 along Gallina Creek on the Espanola Ranger District has 62 understory species, many of which are apparently restricted to the wettest sites within the *Berberis repens* phase; among these species are *Melica porteri, Glyceria striata, Ranunculus* spp,. *Aquilegia chrysantha.* and *Trautvetteria grandis.* Mesic species included within the *Holodiscus dumosus* phase of this HT are *Potentilla thurberi, Rudbeckia laciniata, Aquilegia chrysantha,* and *Cardamine cordifolia.* Drier mid- and upper-slope sites have fewer understory species and usually a rather sparse herbaceous cover. However, the well developed shrub layer is diagnostic of this HT across this environmental range from wetter to drier sites.

This HT has an outlier occurring on a basaltic knoll in the White Mountain of Arizona. Its tall and low shrub strata are conspicuous, and tree regeneration of both *Abies concolor* and *Pseudotsuga menziesii* is dense. A scattering of *Picea pungens* and *Pinus strobiformis* of various sizes from young regeneration to mature individuals are found. Both *Picea Pungens* and *Populus tremuloides* skirt this knoll at the border of grassy meadows.

15. *Abies concolor-Pseudotsuga menziesii/ Quercus gambelii* HT

Diagnostic vegetation.—Either or both *Abies concolor* and *Pseudotsuga menziesii* dominate forest regeneration, usually with moderate to heavy densities. Either or both *Pinus strobiformis* and *P. ponderosa* are common seral trees. The understory tree or shrub vegetation is dominated by *Quercus gambelii,* with *Robinia neomexicana* often subdominant; species of *Acer* are absent.

We identify three phases of this habitat type. The typical *Quercus gambelii* phase has such characteristic graminoid species as *Bromus ciliatus, Poa fendleriana, Carex rossii,* and occassionally rhizomatous species of *Carex.* The *Muhlenbergia virescens* phase may have up to 60% cover by this bunchgrass. Other grasses may include *Stipa pringlei, Sitanion hystrix,* and minor amounts of *Festuca arizonica, Poa fendleriana, P. interior,* and *Koeleria cristata.* Forbs occasionally important include *Pteridium aquilinum, Thermopsis pinetorum,* and *Vicia pulchella.* The *Festuca arizonica* phase is diagnostic when dominance or codominance by this grass is apparent. *Muhlenbergia montana* and *Poa fendleriana* may also be common. Typical forbs include *Geranium caespitosum, Erigeron platyphyllus,* and *Artemisia ludoviciana.*

Geography.—Widespread in New Mexico and Arizona: Bill Williams Mountain, Sierra Ancha Mountains (Pase and Johnson 1968), Mogollon Plateau, White Mountains, Chiricahua Mountains (mostly in canyon bottoms), Mogollon Mountains, Sacramento Mountains (Hanks and Dick-Peddie 1974), Capitan Mountains, San Juan Mountains, Sangre de Cristo Mountains, and probably in most minor mountain ranges of New Mexico where elevations of major peaks exceed about 9,000 feet (2,740 m).

Topography.—All plots are between 7,700 and 9,500 feet (2,340-2,900 m) mostly on moderate to steep canyon sideslopes and generally on west, south, and east exposures (see the *Abies concolor-Pseudotsuga menziesii/Acer glabrum* HT for a habitat description of opposite canyon slopes). On the Mogollon Plateau the plots range from 7,400-7,900 feet (2,250-2,400 m) on gentle to steep sideslopes of north-flowing drainages. In minor mountain areas, this HT is often found in wet canyon drainages above about 7,400 feet (2,250 m) elevation.

Soils.—The soils of this HT are highly variable with respect to parent material, stoniness, and depth. Plots are commonly on soils of mollisolic and entisolic classifications developed from coarse talus colluviums of rough broken land, stony land complexes, and rock outcrop complexes.

Ecotones and related habitats.—Because of the widespread geographic distribution of this HT, ecotones occur with a great variety of habitats. Generally wetter or cooler sites have the *Acer concolor-Pseudotsuga menziesii/Acer glabrum* HT or various "forb-rich" understory HT's; while drier or warmer sites may exhibit stands of the *Abies concolor-Pseudotsuga menziesii* (sparse understory) HT or stands of the *Abies concolor/Festuca arizonica* and related HT's with grass dominated understories. A major ecotone is with grass dominated open meadows.

This HT extends into Colorado along the Sangre de Cristo and Front Range to about Colorado Springs and along the San Juan Mountains into southwestern Colorado. The oakbrush types described by Brown (1958) in west-central Colorado are drier habitats well outside the mixed conifer forest zone.

Discussion.—This is one of the most important mixed conifer HT's in the Southwest by virtue of its widespread occurrence and utilization. Most of the areas visited are commercial forest lands, and most are within livestock grazing allotments. In addition, the oaks and related understory plants provide many habitat requirements of food and shelter for deer and other wildlife.

The 54 plots within the typical phase of this HT reflect the widespread distribution of this type. In terms of environmental gradients within the mixed conifer zone, this phase probably occupies moderate regimes of both temperature and moisture. The *Muhlenbergia virescens* and *Festuca arizonica* phases of this HT were found in the mountains of southern Arizona and New Mexico and thus probably represent the drier fringe of mixed conifer forests. Forest stands of these phases intergrade to the *Quercus gambelii* phases of the *Pinus ponderosa/Muhlenbergia virescens* and the *Pinus ponderosa/Festuca arizonica* HT's of Hanks et al. (1977). Although there is no definite explanation for the relative dominance between grasses and oaks in these phases, but edaphic variability, especially in soil rooting volume and stoniness, may be partly the cause.

Considerable variation in both tree and understory characteristics is found throughout this HT. Our study of the tree structure in the typical phase indicates that most plots have both *Abies concolor* and *Pseudotsuga menziesii* sharing climax status as codominants:

Indicated climax	No. of plots
Abies concolor	16
Pseudotsuga menziesii	7
Abies + Pseudotsuga	26

Quercus gambelii may occur as understory trees—specimens up to 50 feet (15 m) and 14-15 inches (35-40 cm) d.b.h. are common on the Mogollon Plateau—or as low shrubby patches. The cover of herbaceous vegetation varies from sparse to moderate (about 40% of the plots had herb cover under 10%; about 30% of the plots had herb cover between 10%-20%; and the remaining 30% of the plots had herb cover exceeding 20%). Graminoid species are the most constant (*Poa fendleriana* up to 8% cover; *Bromus ciliatus* up to 5%; and *Carex rossii* to 15%). Forbs present in over half the plots included *Lathyrus arizonica, Pseudocymopteris montanus,* and *Thalictrum fendleri.*

Fires occur rather frequently within this HT (Hanks and Dick-Peddie 1974). After hot fires, a stage of forb succession may last a year or so before new oak sprouts assume dominance (Hanks 1966). The oak stage of the sere is most persistent—the oak dominating until conifers again come in and overtop the oaks. Important seral conifers are *Pinus ponderosa* and *P. strobiformis.* However, both *Pseudotsuga menziesii* and *Abies concolor* can also establish themselves within the oak thickets. Recurring fires kill seedling conifers, and even light surface burns may cause high mortality among *Abies* and *Pseudotsuga.* Open, park-like savannas with scattered groves of oak result (Cooper 1961, Hanks and Dick-Peddie 1974, Weaver 1967).

On most sites, natural succession into the final coniferous stages may proceed very slowly, but the oakbrush stage of this sere is never climax in this HT as indicated in some of the Timber Management Plans (Hanks 1966). On some sites, natural regeneration of conifers may proceed rapidly. Factors influencing regeneration rates include: the proximity of good seed sources, favorable microclimates for seedling survival, the nature of the fire initiating succession, the degree of oak competition, and seedling mortality from mammals (Jones 1974).

The most important commercial tree in this HT is *Pinus ponderosa,* a seral species. Site quality for *Pinus ponderosa* ranges from poor (site index about 65) to good (site index about 90), with most plots exhibiting moderate growth potential. Site quality for *Pseudotsuga menziesii* is poor to moderate, with the fastest growing specimens mostly between 75-100 feet (23-30 m) at age 100 (bh). The potential for livestock grazing in the typical phase is generally poor, since herbage production is often low, and the canyon terrain is often steep and poorly watered for livestock needs. However, the wildlife value is good, since many shrubs and herbs of this phase are favorable browse and forage.

16. *Abies concolor-Pseudotsuga menziesii* HT (Sparse understory)

Diagnostic vegetation.—Either or both *Abies concolor* and *Pseudotsuga menziesii* in all size classes and moderate or heavy stocking of young and advanced regeneration. Crown dominance by *Abies, Pseudotsuga, Pinus strobiformis,* and *P. ponderosa* in closed canopy. The understory has very sparse shrub and herbaceous cover, mostly less than 1%, but occassionally as high as 15%.

Plots of this habitat type were sorted into two geographic phases. The *Berberis repens* phase has understory with low evergreen shrubs such as *Berberis repens* (trace to 7% cover), *Juniperus communis* (trace to 15% cover), or *Pachistima myrsinites* (up to 2% cover). These shrubs are absent from nearly all stands of the *Robinia neomexicana* phase, where instead, deciduous shrubs *(Robinia neomexicana, Symphoricarpos oreophilus, Salix scouleriana,* and *Quercus gambelii)* are usually of at least sporadic occurrence.

Geography.—Widespread; the *Berberis repens* phase was sampled on the North Kaibab Plateau, White Mountains, San Juan, and Sangre de Cristo Mountains; the *Robinia neomexicana* phase was sampled in the Sacramento, Pinaleno, Chiricahua, Mogollon, and White Mountains.

Topography.—This habitat type occupies cool, dry sites. In northern New Mexico, stands of the *Berberis repens* phase occurred on generally steep slopes of various aspects between 9,200-10,500 feet (2,800-3,200 m) elevation. In southern parts of the State and southern Arizona, stands of the *Robinia neomexicana* phase were found on moderate to steep, north- to east-facing slopes mostly between 8,050-9,200 feet (2,450-2,800 m) elevation. However, stands also occurred on south- or west-facing slopes (and sometimes on high ridgetops) at higher elevations (8,700-9,300 feet, or 2,650-2,830 m).

In central and northern Arizona, forests of the *Berberis repens* phase were sampled on undulant, gentle to moderately sloping uplands between 8,600-9,000 feet (2,620-2,740 m).

Soils.—Sponseller Loam (White Mountains), Corner Stony Loam and Whitetail Stony Sandy Loam (Mogollon Mountains), mostly stony soils of rough broken land and stony land mapping complexes in northern New Mexico, including Granite and Rhyolite Stony Land, Mallette-Granite-Rhyolite Stony Land, and Jaroso-Encebado-Mascarenas Complex.

Ecotones and related habitats.—Ecotones include *Abies concolor-Pseudotsuga menziesii/Quercus gambelii* HT, *Picea pungens/Carex foenea* HT (North Kaibab Plateau), and *Pseudotsuga menziesii/Quercus hypoleucoides* HT (Chiricahua Mountains). At the cooler, wetter border of this habitat type are forests of spruce-fir habitat types, depending upon the geographic area. We are unaware of related habitats in other western states.

Discussion.—The definition of this habitat type was difficult. There were very few consistent understory characteristics to conceptualize the habitat. Many herbs and shrubs of the mixed conifer region occur but these exhibit low constance and seldom

Figure 8.—*Abies concolor-Pseudotsuga menziesii* HT at 2,740 m elevation on the North Kaibab Plateau. The sparse understory is typical of this habitat type.

have more than a trace of cover. In a few plots, *Quercus gambelii* or *Robinia neomexicana* suggested affinity to herb-sparse variations of the *Abies concolor-Pseudotsuga menziesii/Quercus gambelii* HT. We were concerned that some stands where sparse understories were found might be shade phases of other HT's under closed conifer canopies or local areas of intensive or prolonged wildlife browsing. Plots in the Chiricahua Mountains helped resolve these difficulties. The four plots all occurred on cool slopes of the highest peaks on sites that could not be assigned to any other habitat type that was clearly recognized in those mountains. The stands were all undisturbed by man, with largest trees between 95-140 years old at breast height. This distinctive forest habitat in the Chiricahua Mountains was initially defined as the *Abies concolor-Pseudotsuga menziesii-Pinus strobiformis* sparse shrub and herb habitat. Similar forests in the Pinaleno Mountains were identified later, providing a sufficient nucleus of plot types of this HT to identify similar plots from other geographic locations. Distinctive features of stands in this HT in late seral succession are closed canopies of mixed conifers and generally sparse understories (fig. 8).

The environment of this HT is cool and relatively dry. In the Chiricahua Mountains, a pronounced drought occurs from May to early July, but the high elevation and northerly exposures may ease drought effects. Both seasonal soil water deficits and shading may combine to limit herb growth (small openings in the Chiricahua Mountains are dominated by *Bromus ciliatus, Helenium hoopsii,* and other herbs), while deer populations may limit shrub development.

Site quality is good in the Chiricahua Mountains. Measured specimens of *Pseudotsuga* were about 115 feet (35 m) in height at 100 years of age (bh). A 95-year-old specimen of *Abies concolor* near Rustlers Park was 119 feet tall (36 m). Unfortunately this high site quality is seldom found on commercial forest lands of other locations. In the White Mountains, Pinaleno, and

Sacramento Ranges, site quality for *Pseudotsuga menziesii* in our stands was generally moderate (site index about 80 at base age of 100 years). Observations on *Pinus ponderosa* were too few for estimating growth potential.

Neither *Populus tremuloides* nor *Quercus gambelii* are important seral trees after fire. We suggest that severe fires might bring about herb dominated clearings where conifers rapidly reestablish. Both *Pinus ponderosa* and *P. strobiformis* are important seral trees, and the latter persists well into the closed canopy stage. But *Abies concolor* and *Pseudotsuga menziesii* may also be seral, depending on seed sources and environmental conditions following disturbance. Fire behavior in these habitats may be erratic and unpredictable, with highly variable burn conditions from year to year.

In the Mogollon Mountains *Chimaphila umbellata* and *Pyrola picta* are constant, low evergreen herbs of this HT. The minor occurrence of *Picea engelmannii* or *Abies lasiocarpa* in most of our plots suggests environmental similarity to the cooler spruce-fir forests. Other rather distinctive features include the infrequent occurrence of such mesic forbs as *Viola canadensis, Senecio cardamine, Smilacina racemosa,* and *Clematis pseudoalpina.* In addition, trees or suckers of *Populus tremuloides* occurred in five plots; this is not usually a seral species of the HT in southern New Mexico and Arizona. For these reasons we suggest that the Mogollon Mountains present a somewhat distinctive microclimate on mid-elevation north-facing slopes compared to adjoining, smaller mountain areas (Chiricahua, Pinaleno Mountains, Black Range) where stands of this HT are also found.

Plots in the North Kaibab Plateau were all within commercial forest land. Timber volume is mainly *Abies concolor* with lesser amounts of *Pseudotsuga* and *Pinus ponderosa.* Heights at 100 years of age (bh) for dominant *Abies* specimens are mostly 75-85 feet (23-26 m) with occasional trees to 95 feet (29 m). Periodic defoliation by budworms and infections of *Arceuthobium campylopodum* var. *abietinum* reduce growth rate in this HT. Measurements on six specimens of *Pinus ponderosa* between 102-157 years of age (bh) were from 77-92 feet (23-28 m).

Dominant vegetation of clearcut openings near plot 361 consisted of *Chenopodium album* and *Epilobium angustifolium.* Other common or abundant species were *Berberis repens, Ribes cereum, Rubus strigosus,* species of *Carex, Poa fendleriana,* and *Penstemon barbatus.* Such clearings provide major food resources for deer.

In the Sangre de Cristo Mountains, this habitat is found on the boundary of mixed conifer forests on dry south and west aspects with cobbly, coarse-textured soils. Unlike other habitat types with sparse herbaceous understories, here *Abies concolor* may be absent or of minor climax status.

Although many stands in the Sangre de Cristo Mountains are within commercial forest lands, the site quality for both *Pseudotsuga menziesii* and *Pinus ponderosa* is poor. Site index at base age of 100 years is about 60 for *Pseudotsuga menziesii.* Mostly visual estimates for pine suggest a similar slow growth rate and site index of 50-60.

Tree species of a fire sere include *Populus tremuloides* and *Pinus ponderosa.* Species of sporadic or minor importance include *Pinus aristata, P. strobiformis,* and *Quercus gambelii.*

The warm slopes of this HT appear to be of considerable value to wildlife. The steep slopes are often laced with game trails, and many of the shrub species are heavily browsed.

Although herbaceous vegetation is poorly developed under conifers, the nearby openings may exhibit good cover of grasses such as *Koeleria cristata, Muhlenbergia montana,* and *Poa fendleriana.* Possible explanations are discussed in the section on *Pseudotsuga menziesii-Pinus strobiformis/Muhlenbergia virescens* HT below and in Moir (1966).

17. *Abies concolor/Acer grandidentatum* HT

Diagnostic vegetation.—*Abies concolor* dominates regeneration; *Pseudotsuga menziesii* is minor. *Acer grandidentatum* is a strong dominant (70-90% cover) of the understory.

Geography.—Plots are on the Mogollon Plateau (Chevelon Ranger District). The habitat occurs locally in drainages along the Mogollon Rim and in the Pinaleno Mountains, and Santa Catalina Mountains (Whittaker and Niering 1965).

Topography.—Gentle northerly drainages of the Mogollon Plateau at 7,500-7,900 feet (2,300-2,400 m), and well watered intermittent drainages of steeper canyons to about 7,000 feet (2,100 m).

Soils.—Undescribed.

Ecotones and related habitats.—Plots all adjoin stands of the *Abies concolor-Pseudotsuga menziesii/Quercus gambelii* HT. The habitat is related to streamside variants of the *Abies concolor-Pseudotsuga menziesii/Acer glabrum* HT, *Holodiscus dumosus* phase. It is also similar in floristic composition to the *Abies concolor/Carex foenea* HT along gentle drainages at higher elevations, above 9,000 feet (2,700 m), in the Pinaleno Mountains, although this habitat lacks *Acer grandidentatum.*

Discussion.—This is a comparatively minor HT in Arizona, which is found mostly as a topographic climax along gentle drainages at comparatively low elevations. Dominance of the understory by *Acer grandidentatum* is the most characteristic feature of the HT, but the understory is also well developed with such herb species as *Carex foenea* (7%-30% cover), *Thalictrum fendleri* (trace to 40%), *Aquilegia chrysantha,* and others. The location of stands along gentle concave drainages or canyon bottoms is a consistent feature of the HT.

Seral conifers such as *Pseudotsuga menziesii* (common) or *Pinus ponderosa* (infrequent) have mostly been logged in this habitat. Other seral trees are *Populus tremuloides* and *Quercus gambelii* (the former reaching 120 feet (36 m) in sheltered canyon bottoms such as upper See Canyon on the Tonto Rim). Logging probably accelerates growth and development of *Acer grandidentatum* as a result of increased light in the understory. Some specimens of *Acer* in our plots were about 40 feet (12 m) tall. Strong dominance by *Acer* in logged plots does not seem to retard conifer establishment; young regeneration by *Abies concolor* ranged from 26-360 stems/ha and *Pseudotsuga menziesii* from 2-40 stems/ha.

In the Santa Catalina Mountains, Whittaker and Niering (1965) record the presence of *Acer grandidentatum* in ravines and draws at about 8,000 feet (2,500 m) elevation. They describe within their Montane Fir Forest Zone the dominance of *Pseudotsuga* and *Abies concolor* with *Acer grandidentatum* in ravines and on lower slopes between 7,000-8,000 feet (2,200-2,500 m). These forests most likely can be assigned to the *Abies concolor/Acer grandidentatum* HT.

18. *Abies concolor/Festuca arizonica* HT

Diagnostic vegetation.—Usually moderate to heavy stocking of young *Abies concolor* (densities of young regeneration vary from 22-330 stems/ha; young plus advanced regeneration vary from 44-400 stems/ha); light to moderate stocking of young *Pseudotsuga*. *Pinus ponderosa* is an important seral species, and may exhibit scattered regeneration in mature stands.

Shrubs are minor and unimportant. A well developed herbaceous vegetation is particularly conspicuous in openings. Dominants include combinations of the following bunchgrasses: *Festuca arizonica, Muhlenbergia montana,* and *M. virescens*. Other grasses usually present include *Poa fendleriana, Koeleria cristata, Sitanion hystrix,* and *Stipa pringlei*. Forbs commonly associated with the grasses include *Lithospermum multiflorum, Antennaria* spp., *Lathyrus arizonicus, Thalictrum fendleri, Achillea lanulosa,* and *Erigeron* spp.

Geography.—San Francisco Peaks, Mogollon Plateau, White Mountains, and San Juan Mountains.

Topography.—Ridges and gentle slopes or moderate to steep east, south, or west-facing canyon slopes. Elevations from 7,000-9,400 feet (2,130-2,860 m).

Soils.—Generally unmapped and undescribed. Parent materials include basalt and sandstones. Soils on plot 85 were mapped as Sponseller Silt Loam. A roadcut near plot 301 exhibited a shallow, cobbly A1 over sandstone bedrock.

Ecotones and related habitats.—The *Abies concolor/Festuca arizonica* HT intergrades into *Picea pungens/Carex foenea* HT and *Abies concolor-Pseudotsuga menziesii, Berberis repens* phase. Along hotter, drier gradients this HT merges into the *Pinus ponderosa/Festuca arizonica* HT and related habitat types of the ponderosa pine region (Hanks et al. 1977).

This HT is related to *Abies concolor-Pseudotsuga menziesii/Elymus triticoides* HT, *Abies concolor-Pseudotsuga menziesii/Poa fendleriana* HT, and *Abies concolor-Pseudotsuga menziesii/Quercus gambelii* HT, *Muhlenbergia virescens* phase. These HT's all exhibit strong regeneration by *Abies concolor* and grass dominated herbaceous understories. They probably occur within seasonally dry climates near the warmest temperature range of mixed conifer forest.

Discussion.—*Festuca arizonica* ranged from 3%-40% cover, species of *Muhlenbergia* were found from trace amounts to 20% cover. Grasses and associated herbs are best expressed in openings and often have very sparse cover in dense pole stands or under closed conifer canopies. The value of this HT for seasonal livestock grazing is very good, and several plots are within grazing allotments.

The patchy distribution of conifer regeneration commonly seen in this HT can be attributed, at least in part, to the erratic course of wildfires. Fire was a common thinning agent. Dormant shoots of the herbaceous layer could carry a surface fire into thickets of regeneration. If coniferous debris is heavy within these thickets, the fire might crown and consume the entire thicket; otherwise only the smaller trees might be killed, depending upon fire intensity (Weaver 1967, Cooper 1961a, 1961b). Seedlings and poles of *Abies concolor* are particularly sensitive to fire. However, fires are mostly beneficial to herbs, especially during herb dormancy. The fire-created openings produce more favorable conditions of light, nutrient supply (especially nitrogen), and other requirements for enhanced herbaceous growth (Moir 1966).

Pinus ponderosa and *Pseudotsuga menziesii* are important commercial species of this habitat. Gentle terrain and multistoried, patchy canopy distribution encourages selective cutting at many sites. The primary silvicultural problem may be restocking with ponderosa pine, especially in some of the larger herbaceous openings. This problem has been addressed in numerous papers by G. A. Pearson (Axelton 1967). Pearson was concerned mostly with drier pine sites, and it must be kept in mind that this HT is still within the mixed conifer forest zone and at the mesic end of natural ponderosa pine regeneration. Our plots exhibit light to moderate stocking of pine regeneration, but this is usually swamped by competition from *Abies* and *Pseudotsuga*. Cutting and thinning techniques can be used to encourage the young pines.

Site quality appears moderate for *Pinus ponderosa* and poor for *Pseudotsuga menziesii*. The pines are about 70-80 feet (21-24 m) at 100 years of age (bh). Our height and age measurements for six Douglas fir specimens are variable, but fall within the growth range of *Pseudotsuga* for the *Abies concolor-Pseudotsuga menziesii/Acer glabrum* HT.

Although *Pinus ponderosa* is the most important seral tree, the plots occasionally exhibit a scattering of stems and suckers of *Populus tremuloides* or *Quercus gambelii*. These are considered minor seral species of this habitat type.

Pseudotsuga menziesii Series

19. *Pseudotsuga menziesii-Pinus strobiformis/ Muhlenbergia virescens* HT

Diagnostic vegetation.—*Pinus ponderosa* in all sizes, with moderate stockings of young and advanced regeneration. *Pinus strobiformis* is usually of moderate regeneration density. *Pseudotsuga menziesii* is often in dense sapling (0-4 inches d.b.h.) thickets. *Abies concolor* is infrequent or absent. Shrubs are minor. The well developed herbaceous layer is dominated by *Muhlenbergia virescens* (fig. 9).

Geography.—Chiricahua, Mogollon, Pinaleno, and Santa Catalina Mountains (Whittaker and Niering 1965).

Topography.—Ridges and dry mid- to upper-slopes between 7,600-9,200 feet (2,300-2,800 m) elevation. The slopes vary from gentle to steep and are of southerly, west, or less common east-facing aspects.

Ecotones and related habitats.—This HT has many similar features to the *Pinus ponderosa/Muhlenbergia virescens* HT described in the White Mountains by Hanks et al. (1977). The principal distinction concerns the high regeneration potential of *Pseudotsuga menziesii* in plots of the *Pseudotsuga menziesii-Pinus strobiformis/Muhlenbergia virescens* HT. The wettest plots in the *Pinus ponderosa/Muhlenbergia virescens* HT also contain *Abies concolor* in very minor amount, and clearly there is gradation between the two habitat types.

The *Pseudotsuga menziesii-Pinus strobiformis/Muhlenbergia virescens* HT is ecologically similar to other HTs where caespitose grasses are dominant or codominant with shrubs in the understory such as HTs 15 and 18 (table 2). Ecological processes such as fire, seasonal drought, and influences of grazing animals may play similar roles in these conifer-bunchgrass ecosystems, although their intensity and frequency may vary from habitat to habitat (Pearson 1950, Moir 1966, Weaver 1967, Cooper 1960).

Ecotones can occur between *Pseudotsuga menziesii-Pinus strobiformis/Muhlenbergia virescens* and *Pseudotsuga menziesii/Quercus hypoleucoides* HT's on wetter slopes. Hot, drier slopes sometimes exhibit ecotone to Pine-oak woodland (Whittaker and Niering 1965). Adjacent north-facing slopes and lower slopes or canyon bottoms may be within the *Abies concolor-Pseudotsuga menziesii* (sparse understory) or *Abies concolor-Pseudotsuga menziesii/Quercus gambelii* HT's.

Figure 9.—*Pseudotsuga menziesii-Pinus strobiformis/ Muhlenbergia virescens* HT, Mogollon Mountains. The meter stick is near a specimen of *Pinus ponderosa* with fire scarred base. The dominant grass is *Muhlenbergia virescens*.

Discussion.—This is the hottest and driest of mixed conifer forests in the above mountain ranges. *Abies concolor* with low regeneration potential occurred in only 45% of the plots. But thickets of other mixed conifers (mostly *Pseudotsuga)* may have total stem densities as high as 5,700/ha (14,000/acre). Such regeneration is usually in patchy mosaics.

There is a pronounced inverse relationship between coniferous densities and cover of herbaceous vegetation. Mechanisms of herb suppression under conifer thickets probably include shading, soil nitrogen depletion, growth suppressing effects of terpenes and other coniferous biochemicals of the forest floor, altered soil water supply at sites of increasing tree dominance, and interactive effects (Moir 1966, Whittaker and Feeny 1971).

Fire appears to be a critical factor for determining the spatial and cover relationship between trees and herbs. The frequency of surface fires before about 50 years ago is evidenced by fire scars at the bases of most larger *Pinus ponderosa* and *P. strobiformis* in all plots (fig. 9). Charcoal is a common material of surface organic horizons. Decades of fire suppression are resulting in heavy fuel load accumulation and extensive suppression of understory grasses.

The effect on water yield of converting open, grass-dominated, savanna-like ecosystems to closed coniferous forests is possibly very substantial (Swank and Douglas 1974), but little data are available for Southwestern mountain watersheds.

Although the grazing potential of this HT is good where conifer thickets are not extensive, the high ridges and upper slopes may lack reliable water sources for domestic livestock, and access may be difficult in remote areas.

SPRUCE-FIR FORESTS: OTHER HABITAT TYPES

There are a variety of other habitat types of spruce-fir forests in Arizona and New Mexico. These are all of restricted geographic distribution, although each may be important within its particular location.

The *Picea engelmannii/Geum rossii* HT and the *Abies lasiocarpa/Lathyrus arizonicus* HT both occur in the San Francisco Peaks. The former is near timberline and is characterized by absence or accidental status of *Abies lasiocarpa* and by presence in the understory of numerous species of high elevation or tundra affinity, including *Geum rossii, Festuca brachyphylla, Polemonium delicatum,* and dwarfed ecotypes of *Aquilegia chrysantha* and *Mertensia franciscana.* The latter subtends the spruce-fir zone at its lowest elevation. Plots were on westerly slopes at 9,700-9,800 feet (2,900-3,000 m). *Picea engelmannii* was only occasional; the dominant tree overstory consisted of admixtures of *Abies lasiocarpa* and *Populus tremuloides.* Understory is very herbaceous. Abundant species included *Lathyrus arizonicus, Smilacena stellata, Geranium richardsonii, Pteridium aquilinum,* and *Bromus ciliatus.*

The *Picea engelmannii/Elymus triticoides* HT is restricted to the Capitan Mountains at uppermost elevations. *Pseudotsuga menziesii* is codominant; *Abies lasiocarpa* varies from absent to codominant. A shrubby understory varying from 2% to 23% cover consists of *Acer glabrum, Holodiscus dumosus, Jamesia americana,* and *Ribes* spp. Soils are very cobbly, and understory vegetation appears to be related to the buildup of soils, commencing from raw talus. On best developed soils *Elymus triticoides* may have up to about 20% cover.

The *Picea engelmannii/Carex foenea* HT is found in the Pinaleno Mountains on upper slopes and ridges around 10,200 feet (3,100 m) elevation. Soils are cobbly and skeletal, with best expression of *Carex foenea* (up to 70% cover) on finer textured microsites. Clearings after logging are dominated by *Carex* and grasses; aspen is absent. Regeneration by spruce in these meadows may be difficult because of dry site conditions and possible seedling mortality through solarization (Ronco 1970).

The *Abies lasiocarpa/Vaccinium myrtillus* HT is found at Bear Canyon, Mogollon Plateau. Spruce is absent. This disjunct outlier of *Abies lasiocarpa* at 7,750 feet (2,400 m) elevation is most related to *Abies lasiocarpa/Rubus parviflorus* HT of the Mogollon Mountains. Both contain rich herb and shrub understories. Refugium species at Bear Canyon include *Vaccinium myrtillus, Disporum trachycarpum, Calamagrostis canadensis, Polemonium flavum, Lonicera involucrata,* and *Stellaria jamesiana.*

Disjunct outliers of *Picea engelmannii* are also found in the Chiricahua Mountains and in Hubbell and Sacramento Canyons of the Sacramento Mountains. These were assigned to the *Picea engelmannii/Acer glabrum* HT. *Pseudotsuga menziesii* is the most important codominant tree. *Acer glabrum* is usually present in the understory. Herb cover from 5% to 17% in plots included, as most constant species, *Bromus ciliatus, Viola canadensis, Smilacina stellata,* and *Ligusticum porteri.* The HT is of interest primarily because of the presence of Engelmann spruce at low elevations (8,900-9,200 feet, or 2,700-2,800 m) at its southern limits in North America (lat. 31°52'N. in the Chiricahua Mountains).

MIXED CONIFER FORESTS: OTHER HABITAT TYPES

A number of habitat types of mixed conifer forests are either of limited geographic range in Arizona and New Mexico or more widespread, but of insufficient sample frequency to construct reasonably complete habitat type tables.

The *Abies concolor-Pseudotsuga menziesii/Erigeron superbus* HT was sampled in the San Juan Mountains and Mogollon Plateau. Both *Abies concolor* and *Pseudotsuga menziesii* dominate the tree regeneration, and the understory is richly herbaceous with such species as *Erigeron superbus, Lathyrus arizonicus, Fragaria virginiana, Thermopsis pinetorum,* and *Carex foenea.* The habitat appears to be closely related to the *Abies concolor-Pseudotsuga menziesii/Acer glabrum* HT, differing primarily by the absence of *Acer glabrum.*

The *Abies concolor/Carex foenea* HT is restricted to the Pinaleno Mountains in our sample, but may possibly occur elsewhere in Arizona. *Abies concolor* dominates forest regeneration, and *Carex foenea* has 80% cover in a single plot on a gentle south-facing minor concave drainage at 9,100 feet (2,760 m) elevation.

The *Abies concolor/Robinia neomexicana* HT in the White Mountains in the vicinity of Juan Garcia Mountain and upper Pulcifer Creek appears to be an edaphic type on deep volcanic ash soils. The diagnostic habitat characteristic is dominance (30%-60% cover) by *Robinia neomexicana* in the understory. Herbaceous cover is also good. Much of the forest is logged, although site quality for species of *Pseudotsuga* and *Pinus ponderosa* is poor.

The *Abies concolor-Pseudotsuga menziesii/Lathyrus arizonica* HT occurs in the San Francisco Peaks. Either or both *Abies* and *Pseudotsuga* dominate forest regeneration. *Berberis repens* has cover up to about 4%, and *Lathyrus arizonicus* with cover up to 20% dominates the herb layer.

Abies concolor-Pseudotsuga menziesii/Elymus triticoides HT is a special HT in the Capitan Mountains where it fringes the *Picea engelmannii/Elymus triticoides* HT. Soils are rubble pavements and lithic, skeletal profiles with thin mollic epipedon over cobbles. This HT is within the group of mixed conifer habitats characterized by grass-dominated understories (such as habitat types 12, 15, and 18).

The *Abies concolor-Pseudotsuga menziesii/Poa fendleriana* HT was sampled at 8,600-8,900 feet (2,600-2,700 m) in the Bear Creek drainages of the White Mountains. Soils are probably of the Sprucedale Series. The habitat type is characterized by moderate regeneration of both *Abies* and *Pseudotsuga,* and the herbaceous understory dominated by *Poa fendleriana* (15-20% cover). A long list of forb species are important constituents of the herb layer, including *Fragaria vesca, Senecio wootoni, Achillea lanulosa, Geranium richardsonii,* and species of *Erigeron.*

The *Pseudotsuga menziesii/Festuca arizonica* HT may be more common and widespread than our limited sample suggests. Plots occurred in northern New Mexico and the San Francisco Peaks. Stands are comparatively open with light regeneration of *Pseudotsuga menziesii. Abies concolor* is rare; *Pinus strobiformis* may be common. Characteristically, the understory is grassy, with dominance by *Festuca arizonica.* Other herbs include *Muhlenbergia montana, Erigeron subtrinervis, Koeleria cristata,* and *Fragaria vesca.* Plots were all on moderate to steep, southerly facing slopes between 9,600-10,200 feet (2,900-3,100 m). Soils were skeletal-cobbly at all sites, and shallow to underlying bedrock.

The *Pseudotsuga menziesii/Physocarpus monogynus* HT is closely related to *Picea pungens-Pseudotsuga menziesii* HT. It was sampled only once on very poor site with thin, cobbly solum at Rio Chiquito in the Sangre de Cristo Mountains at 8,900 feet (2,680 m). The conspicuous, low shrub layer was dominated by *Physocarpus monogynus* and *Symphoricarpos oreophilus. Pseudotsuga menziesii* is the dominant tree but has poor growth. *Abies concolor* and *Picea pungens* are rare or accidental.

The *Pseudotsuga menziesii/Quercus hypoleucoides* HT is found in Basin and Range Mountains of southern Arizona (Whittaker and Niering 1965) and southwestern New Mexico. *Abies concolor* has minor regeneration potential at the upper elevational edge of this HT, namely around 7,400-7,700 feet (2,250-2,340 m) elevation on northerly or east-facing slopes or draws. The principal climax species, however, is *Pseudotsuga menziesii.* The habitat type is best characterized by abundance of such Madrean species as *Quercus hypoleucoides, Q. rugosa,* and *Yucca schottii.* In the Chiricahua Mountains, the robust grass, *Muhlenbergia longiligula,* is the ground dominant, achieving cover around 25% or more. Other grasses include *Panicum bulbosum, Bromus ciliatus,* and *Agropyron arizonicum.*

The *Pinus strobiformis/Festuca arizonica* HT is rather open forest of windy sites and lithic-skeletal soils. The all-aged pine and grassy understory are diagnostic. *Pseudotsuga menziesii* occurs as scattered regeneration and a few old trees. Principal grasses are *Festuca arizonica* and *Muhlenbergia montana.* The type is closely related to the *Pseudotsuga menziesii-Pinus strobiformis* HT and may be more common in Arizona and New Mexico than our single sample at San Francisco Peaks suggests.

SUMMARY AND CONCLUSIONS

This study presented a habitat type classification of spruce-fir and mixed conifer forests in Arizona and New Mexico, based on field measurements in 415 forest plots.

The classification yielded 8 habitat types in the spruce-fir region and 11 habitat types in the mixed conifer region. In addition, 6 other spruce-fir and 10 other mixed conifer forest habitat types in Arizona and New Mexico were tentatively defined. Most of these 16 other habitat types are of restricted geographical occurrence in Arizona or New Mexico, or are special forest types related to unusual soils, isolated geographic outliers, or restricted topographic occurrences. However, it is possible that some of these may be more extensive or important, and are merely undersampled.

High elevation forests in Arizona and New Mexico are discontinuous by virtue of the varied physiographic regions and discontinuous mountain ranges. In addition, the major routes of migration and evolution of forest floras and communities have been from the north along the Rocky Mountain and Cascade-Sierra Nevada Cordilleras. For these reasons, the high elevation coniferous forests at their southern North American limits in Arizona and New Mexico usually exhibit varying degrees of floristic and ecologic distinctiveness in each of the mountain ranges.

Each habitat type encompasses a relatively narrow range of environmental conditions. We also believe that the biological potential and management opportunities are more uniform and better defined within each habitat type than between habitat types.

Principal seral trees are *Populus tremuloides, Pinus strobiformis, P. ponderosa,* and *Quercus gambelii. Pinus contorta,* a major seral species of mixed conifer and spruce-fir forests of the central and northern Rocky Mountains (Moir 1969), does not occur in Arizona or New Mexico. All other trees of our study can be variously seral or climax depending upon habitat type (appendix table A1). In the drier HT's, where fire frequencies allow species such as *Pinus ponderosa* or *P. strobiformis,* which are normally seral, they can be regarded as fire climax, and *Pseudotsuga menziesii* and *Abies concolor,* otherwise climax, may be minor or absent.

To help identify these habitat types in the field, keys have been prepared (see appendix). The keys are applicable to mature forest stands only, and cannot be used in seral types such as aspen. Two further limitations on the applicability of these keys should be noted:

The keys work best for modal plots of our habitat types. Environmental variants or integrades to other habitat types may not key out;

The keys do not purport to exhaust the habitat types of a region.

We expect refinements and modifications of both our habitat type classification and the descriptive keys as additional data are acquired. This study has been based mostly upon extensive reconnaissance survey throughout high elevation forests of Arizona and New Mexico.

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APPENDIX

Plant List—Spruce-fir and Mixed Conifer Forests, Arizona and New Mexico[1]

I. Trees

Abies concolor (Gord. & Glend.) Hoopes
A. lasiocarpa (Hook.) Nutt.
A. lasiocarpa var. *arizonica* (Merriam) Lemmon
Picea engelmannii Parryi
P. pungens Engelm.
Pinus aristata Engelm.
P. engelmannii Carr
P. ponderosa Laws.
P. ponderosa var. *arizonica* (Engelm.) Shaw
P. strobiformis Engelm.
Populus angustifolia James
P. tremuloides Michx.
Pseudotsuga menziesii (Mirbel) Franco
Quercus gambelii Nutt.
Q. hypoleucoides A. Camus
Q. rugosa Nee
Robinia neomexicana Gray

II. Understory Trees or Shrubs

Acer glabrum Torr.
A. grandidentatum Nutt.
A. negundo L.
Alnus oblongifolia Torr.
A. tenuifolia Nutt
Amelanchier alnifolia Nugg. (4,115,210)
Arctostaphylos uva-ursi (L.) Spreng
Berberis repens Lindl.
Brickellia grandiflora (Hook.) Nutt. (407)
Ceanothus fendleri Gray
Chimaphila umbellata (L.) Nutt. (323)
Chrysothamnus parryi var. *nevadensis* (Gray) Kittell (365)
Cornus stolonifera Michx. (183)
Gaultheria humifusa (Gray) Rydb. (217)
Holodiscus dumosus (Nutt.) Heller (267)
Jamesia americana T. & G. (147)
Juniperus communis L.
J. deppeana Steud.
J. scopulorum Sarg.
Linnea borealis L. (116)
Lonicera arizonica Rehder (35, 298)
L. involucrata (Rich.) Banks (208)
L. utahensis Wats. (32,166)
Pachistima myrsinites (Pursh) Raf. (16)
Philadelphus microphyllus Gray
Physocarpus monogynus (Torr.) Coult. (124)
Populus tremuloides Michx.
Potentilla fruticosa L.
Prunus emarginata (Doug.) Walp. (19,332)
P. virginiana L.
Quercus arizonica Sarg.
Q. gambelii Nutt.
Q. hypoleucoides A. Camus
Q. rugosa Nee
Rhamnus betulaefolia Greene (268)
Robinia neomexicana Gray
Rosa arizonica Rydb (252)
R. fendleri Crepin
R. woodsii Lindl. (126)
Ribes cereum Dougl. (186)
R. coloradense Cov.
R. inerme Rydb. (240)
R. montigenum McClatchie (92, 128)
R. pinetorum Greene (30,266)
R. wolfii Rothrock (125,263)
Rubus neomexicanus Gray
R. parviflorus Nutt. (253)
R. strigosus Michx. (264)
Sambucus glauca Nutt
S. racemosa L.
Salix spp.
S. scouleriana Barratt (113,169)
Saxifraga bronchialis L.
Shepherdia canadensis (L.) Nutt.
Sorbus dumosa Greene
Symphoricarpos oreophilus Gray (136)
Vaccinium caespitosum Michx.
V. myrtillus L. (165)
V. scoparium Leib. (88)

III. Graminoids

Agropyron arizonicum (Gray) Petrak (395)
A. trachycaulum (Link) Malte (95,329)
Agrostis alba L. (299)
A. scabra Willd. (239,353)
Andropogon scoparius Michx.
Blepharoneuron tricholepsis (Torr.) Nash (66-14,66-15)
Bromus anomalus Rupr. (357,414,160)
B. ciliatus L. (98,158,228,322,368,383,398,399)
B. frondosus (Shear) Wood. & Stand. (241)
Calamagrostis canadensis (Michx.) Beauv.
C. inexpansa Gray (167)

[1] *Collection number in parentheses; hyphenated numbers are specimens from the Sacramento Mountains, New Mexico, deposited at University of Colorado, and University of Wyoming herbaria; all other numbers are deposited at the USDA Forest Service Herbarium, Fort Collins, Colo., with duplicates for some numbers at New Mexico State University herbarium, Las Cruces, N. Mex.*

Carex spp. (260,417,418)
C. bella Bailey (231,300)
C. brevipes W. Boott (26)
C. capillaris L. (108)
C. foenea Willd. (25,37,143,66-8)
C. geophila Mack. (338)
C. hoodii Boott (402)
C. microptera Mack. (192)
C. occidentalis Bailey (6,292,352)
C. rossii Boott (251,258,262,269)
Danthonia intermedia Vasey (236,304)
Deschampsia caespitosa (L.) Beauv.
Elymus glaucus Buckl. (179)
E. triticoides Buckl. (265)
Festuca arizonica Vasey (67-13)
F. brachyphylla Schultes (325)
F. ovina L. (351)
F. sororia Piper (175,334,399)
F. thurberi Vasey (67-6)
Glyceria striata (Lam.) Hitchc. (271)
Juncus drummondii E. May (218)
Koeleria cristata (L.) Pers. (90)
Luzula parviflora (Ehrh.) Desv. (122,129,187,405)
L. spicata (L.) DC (216)
Melica porteri Scribn. (235)
Muhlenbergia longiligula Hitchc. (376,412)
M. montana (Nutt.) Hitchc. (349,394)
M. virescens (HBK) Kunth. (18,282,284)
Oryzopsis asperifolia Michx.
O. micrantha (Trin. & Rupr.) Thurb. (238)
Panicum bulbosum H.B.K. (413)
Phleum pratense L.
Poa fendleriana (Steud.) Vasey (14)
P. interior Rydb. (110)
P. occidentalis Vasey (257)
P. pratensis L. (146)
P. reflexa Vasey & Schrib. (193,200,231)
Schizachne purpurascens (Torr.) Swall. (117,303)
Scirpus microcarpa Pers. (272)
Sitanion hystrix (Nutt.) J.G. Sm (161)
Stipa columbiana Macoun
S. pringlei Scribn.
Stipa viridula Trin. (342)
Trisetum montanum Vasey (159,227,247,321,66-44)
Trisetum spicatum (L.) Richt. (328)

IV. Perennial Forbs

Achillea lanulosa Nutt.
Aconitum columbianum Nutt. (188)
Actaea arguta Nutt.
Agastache pallidiflora (Heller) Rydb. (66-47)
Agoseris glauca (Pursh) D. Dietr. (362)
Allium cernuum Roth. (67-2)
A. geyeri Wats. (67-1)
A. gooddingii Ownbey (275)
Anaphalis margaritacea (L.) Gray (66-37)
Angelica grayii C. & R. (202)
Antennaria aprica Greene (1)
Apocynum androsaemifolium L.
Aquilegia caerulea James
A. chrysantha Gray (326)
A. elegantula Greene (121,256)
A. triternata Pays. (3,150)
Arabis spp. (66-11)
Arenaria confusa Rydb. (308,310,361)
A. fendleri Gray (67-14)
A. macrophylla Hook. (222)
Arnica cordifolia Hook. (205)
A. latifolia Bong. (204)
Artemisia dracunculoides Pursh
A. franserioides Greene (224,66-43)
A. frigida Willd.
A. ludoviciana Nutt. spp. *mexicana* (Willd.) Keck (66-27)
A. scopulorum Gray
Aster adenolepsis Blake (359)
Astragalus humistratus Gray (341,358)
A. subcinereus Gray (350)
Brickellia grandiflora (Hook.) Nutt. (250,391)
Cacalia decomposita Gray (378)
Calochortus spp.
Caltha leptosepala DC
Calypso bulbosa (L.) Oakes (29)
Campanula rotundifolia L.
Cardamine cordifolia Gray (120,190)
Castilleja confusa Greene (270,289,363)
C. miniata Hook. (81,123)
C. patriotica Fern. (379)
C. wootonii Standl. (66-13,66-53,67-9)
Cheilanthes fendleri Hook. (415)
Chrysopsis villosa var. *foliosa* (Nutt.) D.C. Eat. (360)
Circium arizonicum (Gray) Petrak (366,389)
C. pallidum Woot. & Standl. (181,66-21,67-4)
Clematis ligusticifolia Nutt.
C. pseudoalpina (Kuntze) A. Nels. (15, 145)
Commelina dianthifolia Delile (386)
Corallorhiza maculata Raf. (105)
C. striata Lindl.
C. trifida Chat.
Corydalis aurea Willd.
Cynoglossum offininale L.
Cypripedium calceolus L.
Cystopteris fragilis (L.) Bernh. (229)
Dodecatheon ellisiae Standl.
Draba aurea Vahl. (313)
D. helleriana Greene (111,173,195,196,219,221,233,66-2)
Disporum trachycarpum (Wats.) B. & H. (33)
Epilobium adenocaulon Hausskn. (273)
E. angustifolium L.
Erigeron spp. (401)
Erigeron coulteri Porter (201)
E. flagellaris Gray (97)
E. formosissimus Greene (343,364,397,286,184)
E. lobatus A. Nels. (372)
E. melanocephalus Nels. (215)

E. neomexicanus Gray (248,372,335)
E. peregrinus (Pursh) Greene
E. platyphyllus Greene (261,293,317,337,66-46)
E. rusbyi Gray (385,411)
E. speciosus (Lindl.) DC var. *macranthus* (Nutt.) Cronq. (318,66-31)
E. speciosus (Lindl.) DC var. *speciosus* (176)
E. subtrinervis Rydb. (96,213)
E. superbus Rydb. (101,163,220,226,286,314,67-8)
Eriogonum racemosum Nutt. (331,348)
E. jamesii Benth (85)
Erysimum asperum (Nutt.) DC (89)
Eupatorium herbaceum (Gray) Greene (416)
Fragaria vesca var. *bracteata* (Heller) Davis (23)
Fragaria virginiana var. *glauca* Wats. (= F. ovalis (Lehm.) Rydb.) (22)
Frasera speciosa Doubl.
Galium asperrimum Gray (382)
G. boreale L. (180)
G. triflorum Michx. (149,225,307)
Gaultheria humifusa (Gray) Rydb. (217)
Gentiana amarilla L. (211,66-48)
G. microcalyx Lemmon (419)
Geranium caespitosum James (99,278)
G. richardsonii Fisch. & Trautv. (107,134,157,311,373)
Geum rossii (R.Sr.) Ser. (330)
Gilia aggregata (Pursh) Sprengel
G. macombii Torr. (367)
Goodyera oblongifolia Raf. (296)
G. repens (L.) R.Br.
Habenaria hyperborea (L.) R.Br. (245)
H. saccata Greene (83)
H. viridis var. *bracteata* (Muhl.) Gray (82)
Haplopappus parryi Gray *(Oreochrysum parryi* Rydb.) (148,223,66-52)
Hedeoma hyssopifolium Gray (291,400)
Helenium hoopesii Gray (66-6)
Helianthella parryi Gray (214)
H. quinquenervis (Hook.) Gray (66-9)
Heracleum lanatum Michx.
Heuchera spp.
Hieracium fendleri Schutz-Bip. (164,173,316,409)
H. gracile Hook. (194)
Houstonia wrightii Gray (281)
Hydrophyllum fendleri (Gray) Heller (135)
Hymenopappus radiatus Rose
H. mexicanus Gray (306)
Hymenoxys subintegra Cockl. (344)
Iris missouriensis Nutt.
Lathyrus spp. (133)
Lathyrus arizonicus Britt. (9,20,21)
L. graminifolius (Wats.) White (380)
Ligusticum porteri C. & R. (191,207)
Linanthrastrum nuttallii (Gray) Ewan (297)
Linnaea borealis L. (116)
Listera cordata (L.) R.Br. (84)
Lotus rigidus (Benth.) Greene (346)
L. wrightii (Gray) Greene (283)
Lupinus argenteus Nutt. (340)
L. sierrae-blancae Woot. & Standl. (66-7)
Lithospermum multiflorum Torr. (132,155,324)
Malaxix corymbosa (Wats.) Kuntze
M. soulei L.O.Williams (246)
Macromeria viridiflora DC
Mertensia franciscana Heller (131,140,141,171,259,327)
Moneses uniflora (L.) Gray (104)
Monarda menthaefolia Graham (279)
Oenothera hookeri T. & G. (319)
Oreoxis alpina (Gray) C. & R.
Osmorhiza depauperata Phil. (127,144,67-15)
Oxalis metacalfei (Small) Kunth (312)
Oxybaphus comatus (Small) Weatherby (375,392,66-50)
Oxypolis fendleri (Gray) Heller (232)
Pedicularis angustissima Greene (309)
P. canadensis L. (142)
P. centranthera Gray (294,302)
P. grayii A. Nels. (285)
P. parryi Gray (162)
P. racemosa Dougl. (168)
Penstemon barbatus (Cav.) Roth. (277)
P. virgatus Gray (305)
P. virgatus ssp. *arizonicus* (Gray) Keck (153)
P. whippleanus Gray (318)
Perideridia gairdneri (H. & A. Math.) (301)
Phacelia heterophylla Pursh
Phaseolus parvulus Greene (371)
Physaria australis (Payson) Rollins
Podistera eastwoodii (C. & R.) Math. & Const. (234)
Polemonium pulcherrimum var. *delicatum* (Rydb.) Cronq. (203) (= *P. delicatum* Rydb.)
P. foliosissimum Gray (182)
P. flavum Greene
Polygonum bistortoides Pursh
Potentilla concinna Richards (10)
P. diversifolia Lehm. (206)
P. hippiana Lehm. (287)
P. pennsylvanica L. (66-24)
P. gracilis var. *pulcherrima* (94,66-26,255) (= *P. pulcherrima* Lehm.)
P. thurberi Gray (393)
P. subviscosa Greene (404)
Prunella vulgaris L.
Primula ellisiae Pollard & Cockll.
P. parryi Gray
Pteridium aquilinum (L.) Kuhn.
Pseudocymopteris montanus (Gray) C. & R. (138,67-10)
Pterospora andromedea Nutt.
Pyrola asarifolia Michx. (212)
P. picta Smith (310)
P. secunda L. (= *Ramishia secunda* (L.) Garke) (102,67-17)
P. uniflora L. (= *Moneses uniflora* (L.) Gray) (104)
P. virens Schweigg (5,103,114)
Ranunculus hydrocharoides Gray (274)
R. subsagittatus (Gray) Greene (31)
Rudbeckia hirta L.
R. laciniata L. (174)

Salvia arizonica Gray (406)
S. davidsonii Greenm.
Sedum spp.
S. amplectens Gray (197)
Senecio atratus Greene
S. bigelovii Gray (230,66-33)
S. cardamine Greene (11,244)
S. cymbalarioides Nutt. (100,109,112,185)
S. eremophilus Richards (408,66-20)
S. fendleri Gray (93)
S. Macdougalii Heller
S. neomexicanus Gray (24,152,170)
S. sanguisorboides Rydb. (189,66-1)
S. triangularis Hook.
S. wootoni Greene (27)
Sibbaldia procumbens L.
Sidalcea neomexicana Gray (276,288)
Silene laciniata Cav. (66-41)
S. scouleri Hook (345,396)
Smilacina racemosa (L.) Desf. (7)
S. stellata (L.) Desf. (12)
Solidago altissima L. (336)
S. spathulata var. *neomexicana* (Gray) Cronq. (209,243)
S. wrightii Gray (384)
Stellaria jamesiana Torr. (130)
Stevia serrata Cav. (369,388,410)
Streptopus amplexifolium (L.) DC
Taraxacum spp. (cf. T. officinale Weber) (34)
Thalictrum fendleri Engelm. (66-45)
Thelypodium integrifolium (Nutt.) Endl. (290,335)
Thermopsis pinetorum Greene
Thlaspi fendleri Gray (28)
Townsendia formosa Greene (156)
Tragopogon dubius Scop.
Trautvetteria grandis Nutt.
Trifolium spp.
T. dasyphyllum T. & G. (198)
Urtica spp.
Valeriana acutiloba Rydb.
V. edulis Nutt.
Verbena macdougalii Heller (66-21)
Veronica wormskjoldii R. & S. (199)
Vicia americana Muhl. var. *americana* (137)
V. pulchella H.B.K. (249,370)
Viola adunca J.E. Sm. (118,119)
V. canadensis L. (17)
V. nephrophylla Greene (13,106)
Zygadenus elegans Pursh (295,333)
Z. virescens (HBK) Macbr. (315)

V. Annuals

Androsace septentrionalis L. (36)
Bidens lemmonii Gray (377)
Cerastium arvense L. (254)
Chenopodium incisum Poir (s.n.)
Conyza schiedeana (Less.) Cronq. (403)
Halenia recurva (J.E. Sm.) Allen (242)
Muhlenbergia wolfii (Vasey) Rydb. (66-35)
Verbesina longifolia Gray (390)

Key to Forest Habitat Types by National Forest Area and Geographic Location

Apache and Sitgreaves Forests (White Mountains, Mogollon Plateau)

1. PIEN or ABLA climax (regeneration clearly not accidental)........................ 2
1. PIEN and ABLA regeneration absent or accidental 6
2. *Vaccinium myrtillus* common 3
2. *Vaccinium myrtillus* absent or rare 4
3. PIEN absent; Chevelon Ranger District .... ABLA/VAMY HT
3. PIEN present; Mount Baldy .... ABLA/VASC HT
4. ABLA regeneration light to moderate .... PIPU-PIEN/SECA HT, ABLA Phase
4. ABLA regeneration absent or rare 5
5. Patches of SECA present .... PIPU/PIEN/SECA HT, ABCO Phase
5. Patches of SECA absent 6
6. PIPU present and clearly not accidental 7
6. PIPU absent or accidental 11
7. PSME the leading codominant tree; regeneration by PIEN and PIPO usually sparse or absent 8
7. PIEN or PIPO leading codominants; PSME regeneration minor 10
8. CAFO common (3%-10%) .... PIPO/CAFO HT, PSME Phase
8. CAFO cover less than 1% or absent 9
9. JUCO or *Lonicera arizonica* common .... PIPO-PSME HT, VAAC Phase
9. POFE common ..... ABCO-PSME/POFE HT
10. PIEN regeneration absent or light .... PIPU/CAFO HT, PIPO Phase
10. PIEN regeneration common; ERSU usually common .... PIPU-PIEN/ERSU HT
11. Tall shrubs (or low deciduous trees) present 12
11. Tall shrubs absent or very infrequent 18
12. Species of *Acer* present 13
12. *Acer* absent 14
13. *Acer grandidentatum* dominant .... ABCO/ACGR HT
13. *A. grandidentatum* absent or minor ...... ABCO-PSME/ACGL HT, BERE Phase
14. Forest of deep ash soils; RONE dominant .... ABCO/RONE HT
14. RONE sparse, minor or absent; soils otherwise 15
15. QUGA dominant; MUVI absent or infrequent .... ABCO-PSME/QUGA HT
15. QUGA cover less than about 5%, or if more then MUVI dominant in herbaceous layer 16
16. ERSU common .... ABCO-PSME/ERSU HT
16. ERSU absent or uncommon; POFE or MUVI common 17
17. MUVI common ..... ABCO-PSME/QUGA HT, MUVI Phase
17. POFE cover over 10% .... ABCO-PSME/POFE HT
18. Understory cover sparse; bunch-grasses uncommon .... ABCO-PSME HT
18. Grass cover well developed (MUVI, MUMO, FEAR) 19
19. MUVI dominant .... PSME-PIST/MUVI HT
19. FEAR or MUMO dominant .... ABCO-FEAR HT

Coronado National Forest (Chirichua, Pinaleno, Santa Catalina Mountains)

1. PIEN or ABLA climax (regeneration clearly not accidental)............................ 2
1. Regeneration of PIEN and ABLA absent or accidental 5
2. VAMY or CAFO common 3
2. Both VAMY and CAFO uncommon, rare or absent 4
3. VAMY common .... ABLA/VASC HT
3. CAFO common .... PIEN/CAFO HT
4. ACGL absent .... PIEN/Moss HT
4. ACGL present .... PIEN/ACGL HT
5. Species of *Acer* absent 6
5. *Acer* absent 7
6. *Acer grandidentatum* present or dominant .... ABCO/ACGR HT
6. *A. grandidentatum* absent or rare ..... ABCO-PSME/ACGL HT, HODU Phase
7. QUGA present, usually common 8
7. QUGA absent or minor 9
8. MUVI absent or minor .... ABCO-PSME/QUGA HT
8. MUVI common ..... ABCO-PSME/QUGA HT, MUVI Phase
9. Evergreen oaks common .... PSME/QUHY HT
9. Evergreen oaks absent or infrequent 10
10. Herbs very sparse; CAFO and MUVI clearly not dominant .... ABCO-PSME HT
10. CAFO or MUVI dominate herb layer (except where sometimes suppressed under conifer thickets) 11
11. CAFO dominant; MUVI absent or uncommon 12
11. MUVI dominant .... PSME-PIST/MUVI HT

12. ABCO regeneration common . . . . ABCO/CAFO HT
12. ABCO regeneration absent or minor . . . . PSME/CAFO HT

Lincoln National Forest (Sacramento and Capitan Mountains)

1. PIEN or ABLA climax (regeneration clearly not accidental) 2
1. PIEN and ABLA regeneration absent or accidental 4

2. *Senecio sanguisorboides* and either or both *Ribes wolfii* and *R. montigenum* dominants of the understory . . . . ABLA/SESA HT
2. The above species minor or absent 3

3. Low elevation forests, Sacramento Mts.; no ABLA . . . . PIEN/ACGL HT
3. High elevation forests, Capitan Mts. . . . . PIEN/ELTR HT

4. PIPU present 5
4. PIPU absent 6

5. Forests of alluvial soils of valleys . . . . PIPU/POPR HT
5. Forests of canyon sideslopes . . . . PIPU-PSME HT, VAAC Phase

6. QUGA or species of *Acer* common 7
6. *Acer* absent; QUGA with less than 5% cover, but if greater then both PSME and ABCO with only minor regeneration 10

7. *Acer* species present; PIPO uncommon . . . . ABCO-PSME/ACGL HT, HODU Phase
7. *Acer* absent; PIPO a common seral tree 8

8. Combinations of MUMO, FEAR, MUVI, or *Stipa pringlei* important understory grasses (but sometimes suppressed under conifer thickets) 9
8. Above combination of grasses minor; POFE, BRCI, or caespitose sedges (*Carex* spp.) may be common . . . . ABCO-PSME/QUGA HT, QUGA Phase

9. ABCO or PSME regeneration usually of light or moderate density . . . . ABCO-PSME/QUGA HT, FEAR Phase
9. ABCO and PSME regeneration absent or rare 11

10. ELTR common; Capitan Mountains . . . . ABCO-PSME/ELTR HT
10. ELTR absent or rare 11

11. Very little shrub or herb cover under mature stands . . . . ABCO-PSME HT
11. Understory grasses with at least 2% cover . . . . ABCO-PSME/QUGA HT, FEAR Phase

Carson and Santa Fe National Forests (San Juan, Sangre de Cristo Mountains, San Pedro, Jamez Mountains)

1. PIEN or ABLA climax (regeneration clearly not accidental) 2
1. Regeneration by PIEN and ABLA absent or accidental 9
2. PSME not even seral, or only minor (see also 5,8) 3
2. PSME seral, common in understory 4
3. Forests near timberline; *Polemonium delicatum* or *Senecio amplectens* common . . . . PIEN/VASC/PODE HT
3. Forests at timberline or below, often on dry ridges or upper slopes; understory vascular flora rather sparse . . . . PIEN/Moss HT
4. *Vaccinium* dominant 5
4. *Vaccinium* minor or absent 6
5. LIBO dominant or codminant . . . . ABLA/VASC/LIBO HT
5. LIBO minor or absent . . . . . ABLA/VASC HT

6. LIBO dominant or codminant; PIPU common . . . . PIPU-PSME HT, LIBO Phase
6. LIBO absent 7

7. Moderate or heavy cover by understory forbs 8
7. Sparse cover of understory forbs . . . . ABLA/JUCO HT

8. ERSU dominant or at least common . . . . ABLA/ERSU HT
8. SESA, *Cardamine cordifolia* or *Oxypolis fendleri* common; forests of creeks or drainages . . . . ABLA/SESA HT

9. PIPU climax or co-climax 10
9. PIPU absent or minor 13

10. Forests of streamsides, alluvial terraces, or benches 11
10. Forests of canyon sideslopes 12

11. *Poa pratensis* common; ABCO and PSME minor . . . . PIPU/POPR HT
11. ABCO or PSME apparently co-climax; POPR infrequent . . . . PIPU-PSME HT, ARUV Phase
12. LIBO common; forests of mesic lower or midslopes . . . . . PIPU-PSME HT, LIBO Phase
12. LIBO absent; forests of dry mid or upper slopes . . . . PIPU-PSME HT, JUCO Phase
13. Mesic forbs (ERSU, HAPA, VICA, ARFR, LAAR) common; tall shrubs (ACGL, SASC, QUGA) present or absent 14
13. Mesic forbs infrequent; tall shrubs usually absent, but low shrubs (BERE, PHMO, SYOR, *Ribes cereum*) may be common 16
14. Both ACGL and QUGA absent or rare; CAFO common . . . . ABCO-PSME/ERSU HT

14. Either ACGL or QUGA present, or if absent then CAFO also absent or minor (cover less than 10%) 15
15. ACGL present . . . . ABCO-PSME/ACGL HT, BERE Phase
15. ACGL absent . . . . . ABCO-PSME/QUGA HT
16. FEAR and MUMO absent or rare 17
16. FEAR or MUMO common 18
17. PHMO common . . . . PSME/PHMO HT
17. PHMO minor at best; BERE, SYOR, or JUCO present . . . . . . ABCO-PSME HT, BERE Phase
18. Regeneration of ABCO moderate or heavy . . . . ABCO/FEAR HT
18. Regeneration of ABCO absent or sparse . . . . PSME/FEAR HT

Coconino and Kaibab National Forests (Kaibab Plateau, San Francisco Peaks, Bill Williams Mountain)

1. PIEN and ABLA climax (regeneration clearly not accidental) 2
1. Regeneration by PIEN and ABLA absent or accidental 6
2. Forests near timberline, *Geum rossii* or other tundra species present . . . . PIEN/GERO HT
2. Forests either well below timberline or *Geum rossii* absent 3
3. Herbaceous cover usually over 10% 4
3. Herbaceous cover usually sparse, less than 10% 5
4. ERSU common; PIEN common to occasional . . . . ABLA/ERSU HT
4. ERSU absent or rare; LAAR common; PIEN uncommon . . . . ABLA/LAAR HT
5. Forests below 10,000 ft elevation; JUCO or BERE present, but understory herbaceous cover usually sparse . . . . ABLA/JUCO HT
5. Forests over 10,000 ft elevation; BERE absent . . . . PIEN/Moss HT
6. PIPU climax or co-climax 7
6. PIPU minor or absent 8
7. PIPO regeneration common, or if uncommon then MUMO or FEAR common; ERSU usually absent . . . . PIPU/CAFO HT, PIPO Phase
7. PIPO regeneration minor; MUMO and FEAR uncommon; ERSU usually present . . . . PIPU/CAFO HT, PSME Phase
8. FEAR or MUMO common 9
8. FEAR and MUMO absent or uncommon 10
9. Regeneration of ABCO common . . . . ABCO/FEAR HT
9. Regeneration of ABCO absent or minor . . . . PSME/FEAR HT
10. QUGA common . . . . ABCO-PSME/QUGA HT
10. QUGA absent 11
11. CAFO less than 5% cover, if more then JUCO present 12
11. CAFO cover over 5% and JUCO usually absent . . . . ABCO/CAFO HT
12. LAAR absent or under 1% cover . . . . ABCO-PSME HT, BERE Phase
12. LAAR cover exceeds 10% . . . . ABCO-PSME/LAAR HT

Gila National Forest (Mogollon Mountains)

1. PIEN or ABLA climax (see also 8) 2
1. PIEN and ABLA regeneration absent or accidental 6
2. *Vaccinium myrtillus* dominant or codominant in understory 3
2. *Vaccinium myrtillus* minor or absent 4
3. Mature PSME absent or infrequent; RUPA absent or cover less than about 5% . . . . ABLA/VASC HT
3. Mature PSME common; RUPA cover 7% or more . . . . ABLA/RUPA HT, VAMY Phase
4. PIEN common to absent, low elevation forests with ACGL and numerous herbs in the understory . . . . ABLA/RUPA HT, ACGL Phase
4. PIEN common; mostly high elevation forests 5
5. *Pedicularis angustissima* dominant . . . . ABLA/VASC HT
5. *P. angustissima* uncommon; ERSU and GERI common . . . . ABLA/ERSU HT
6. PIPU climax or co-climax 7
6. PIPU absent or accidental 8
7. Forests of streamside alluvium . . . . PIPU/POPR HT
7. Forests of colluvial sideslopes . . . . PSME-PIPU HT, VAAC Phase
8. Sparse understory cover: RONE *Chimaphila umbellata* usually with about 1% cover . . . . ABCO-PSME HT, RONE Phase
8. Understory herb or shrub strata well-developed 9
9. ACGL present . . . . ABCO-PSME/ACGL HT, HODU Phase
9. ACGL absent 10
10. QUGA or QUHY present 11
10. Oaks absent or rare 14
11. ABCO with at least light regeneration 12
11. ABCO regeneration absent or rare 13
12. MUVI, FEAR, MUMO or some combination dominates the herb layer 15

12. The above grasses uncommon or absent . . . . ABCO-PSME/QUGA HT

13. QUHY present . . . . PSME/QUHY HT
13. QUHY absent 15

14. CAFO dominant . . . . PSME/CAFO HT
14. MUVI dominant . . . . PSME-PIST/MUVI HT

15. FEAR or MUMO common . . . . ABCO-PSME/QUGA HT, FEAR Phase
15. FEAR and MUMO rare or absent 16
16. MUVI common . . . . ABCO-PSME/QUGA HT, MUVI Phase
16. MUVI uncommon . . . . ABCO-PSME/QUGA HT, QUGA Phase

Table A-1.—Dynamic status of the trees within spruce-fir and mixed conifer forest habitat types, Arizona and New Mexico. Dynamic status has been summarized and interpreted from the plot tables as C = major climax, c = minor climax, S = major seral, s = minor seral, cs = minor climax or seral (data not clear). Accidental or rare occurrences in random size classes are omitted

	Species									
	PIEN	ABLA	PSME	ABCO	PIPU	PIST	PIPO	POTR	PIAR	QUGA
Spruce-Fir Forest Habitat Types										
1. PIEN/VASC/PODE HT [1]	C	c						s	s	
2. PIEN/Moss HT	C	C						s	s	
3. ABLA/VASC HT	C	C	s					S	s	
4. ABLA/VASC/LIBO HT	C	C	S	s	s			S		
5. ABLA/RUPA HT, VAMY Phase	C	C	S	s				S		
, AGCL Phase	c	C	S	S				S		
6. ABLA/ERSU HT	C	C	S	s	s	s		S		
7. ABLA/JUCO HT	C	C	S	S				S		
8. ABLA/SESA HT	C	C	s					S		
Mixed Conifer Forest Habitat Types										
9. PIPU-PIEN/SECA HT, -ABLA Phase	C	C	S	s	c	s	s	S		
, -ABCO Phase	C	c	C	C	C	s	s	S		
10. PIPU-PIEN/ERSU HT	C	c	C	cs	C	s	s	S		
11. PIPU/POPR HT			s	s	C		s	S		
12. PIPU/CAFO HT, PSME Phase			C	c	C	s	s	S		
, PIPO Phase			c		C		SC[2]	S		
13. PIPU-PSME HT, ARUV Phase			C	C	C	s	s	S		
, VAAC Phsae			C	cs	C	s				s
, LIBO Phase	c		C	s	C			S		
, JUCO Phase			C	c	C	s	s	s		
14. ABCO-PSME/ACGL HT, BERE Phase			C	C		s		S		s
, HODU Phase			C	C		s		s		S
15. ABCO-PSME/QUGA HT, Typical Phase			C	C		S	S	s		S
, MUVI Phase			C	C		S	S	s		S
, FEAR Phase			C	C		c	c			S
16. ABCO-PSME HT, BERE Phase			C	C		s	S	s	s	s
, RONE Phase	c		C	C		S	S	s		
17. ABCO/ACGR HT			c	C		s	s	S		s
18. ABCO/FEAR HT			C	C		s	S	s		s
19. PSME-PIST/MUVI HT			C	c		SC	SC[2]			

[1]See table 2 for full species names of these HT abbreviations.
[2]Seral or fire climax depending on fire frequency.

Table A-2.—Spruce-fir forest habitat types. Summary of 66 species (listed by life form) importance values (square root of mean density or cover times frequency)

	Habitat Type[1]							
Trees	1	2	3	4	5	6	7	8
Picea engelmannii								
Young regeneration[2]	62	68	79	51	36	54	40	44
Advanced regeneration	51	61	56	37	28	33	35	28
Mature	40	32	29	11	10	22	22	20
Abies lasiocarpa								
Young regeneration	61	79	104	95	66	83	65	94
Advanced regeneration	26	41	47	29	40	35	38	35
Mature	19	18	18	0	15	12	16	32
Populus tremuloides								
Regeneration	0	0	0	5	4	5	1	0
Mature	0	1	3	25	35	15	28	1
Abies concolor								
Young regeneration	0	0	0	36	29	6	13	0
Advanced regeneration	0	0	1	14	10	4	6	0
Mature	0	0	0	1	2	2	1	0
Pseudotsuga menziesii								
Young regeneration	0	1	2	56	30	22	11	0
Advanced regeneration	0	0	4	29	16	14	15	0
Mature	0	2	7	31	24	18	7	4
Picea pungens								
Young regeneration	0	0	0	3	0	4	0	0
Advanced regeneration	0	0	0	6	0	3	0	0
Mature	0	0	0	2	0	3	0	0
Pinus strobiformis								
Young regeneration	0	0	0	7	2	3	0	0
Advanced regeneration	0	0	1	0	2	2	0	0
Mature	0	0	0	0	0	2	0	0
Pinus ponderosa								
Young regeneration	0	0	0	0	0	0	0	0
Advanced regeneration	0	0	0	0	2	1	1	0
Mature	0	0	0	0	0	1	0	0
Quercus gambelii								
Regeneration	0	0	0	0	0	0	0	0
Mature	0	0	0	0	0	0	0	0
Robinia neomexicana								
Regeneration	0	0	0	0	0	0	0	0
Mature	0	0	0	0	0	0	0	0
Pinus aristata								
Mature	0	0	0	0	0	0	0	0
Quercus hypoleucoides								
Mature	0	0	0	0	0	0	0	0
Tall shrubs								
Acer glabrum	0	0	0	6	23	2	1	4
Acer grandidentatum	0	0	0	0	0	0	0	0
Amelanchier alnifolia	0	0	0	3	0	0	0	0
Prunus virginiana	0	0	0	0	0	0	0	0
Quercus gambelii	0	0	0	0	0	0	0	0
Robinia neomexicana	0	0	0	0	6	0	0	0
Salix scouleriana	0	0	0	10	13	2	0	0
Low deciduous shrubs								
Holodiscus dumosus	0	0	0	0	4	0	0	0
Jamesia americana	0	0	0	0	0	2	0	0
Lonicera arizonica	0	0	0	0	0	0	0	0
L. involucrata	0	0	2	3	0	2	0	9
L. utahensis	0	0	3	0	8	2	0	0
Physocarpus monogynus	0	0	0	0	6	0	0	0
Ribes montigenum	4	0	2	0	0	4	0	18
Rosa spp.	0	0	1	12	0	4	2	0
Rubus parviflorus	0	0	2	12	43	6	0	7
Symphoricarpos oreophilus	0	0	1	3	2	3	1	0
Low evergreen shrubs								
Berberis repens	0	0	1	7	0	2	5	0
Juniperus communis	0	2	3	3	0	5	20	0
Linnaea borealis	0	0	2	55	0	1	0	0
Pachistima myrsinites	0	2	6	29	0	8	0	0
Pyrola secunda	2	2	4	6	4	5	2	1
Vaccinium spp.	73	17	75	65	35	7	0	0

Table A-2.—Continued

Trees	Habitat Type[1] 1	2	3	4	5	6	7	8
Forbs								
Achillea lanulosa	1	0	0	0	0	6	0	1
Antennaria aprica	0	0	0	0	0	0	0	0
Aquilegia elegantula	0	0	1	5	0	2	0	1
Artemisia franserioides	0	0	2	14	7	10	1	4
Clematis pseudoalpina	0	0	1	4	0	1	0	0
Epilobium angustifolium	0	1	2	2	6	3	1	7
Erigeron spp.	0	0	0	0	0	0	0	0
E. superbus	1	5	8	15	18	43	1	19
Fragaria vesca var. *bracteata*	0	0	0	0	11	2	0	0
F. virginiana var. *glauca*	4	4	6	11	4	17	1	2
Galium boreale	0	0	0	1	0	1	0	0
Geranium richardsonii	0	0	3	3	28	16	0	3
Goodyera oblongifolia	0	0	1	2	1	1	1	0
Haplopappus parryi	3	2	13	18	13	16	0	19
Helenium hoopesii	0	0	0	0	0	3	0	0
Lathyrus arizonicus	1	5	3	19	2	18	0	0
Ligusticum porteri	2	0	1	1	6	2	0	7
Mertensia franciscana	4	0	1	2	0	6	0	2
Osmorhiza depauperata	3	1	2	0	2	6	0	14
Pedicularis spp.	8	0	6	0	0	0	0	0
Polemonium pulcherrimum var. *delicatum*	23	0	0	0	0	0	0	2
Pseudocymopteris montanus	1	1	3	0	3	6	1	12
Pteridium aquilinum	0	0	0	0	4	3	0	0
Senecio neomexicanus	0	0	0	3	0	0	0	0
S. cardamine	0	0	0	0	9	0	0	0
S. sanguisorboides	5	0	0	0	0	1	0	32
S. wootoni	0	0	0	0	0	5	0	0
Smilacina racemosa	0	0	0	0	1	1	0	0
S. stellata	0	0	0	0	2	9	0	0
Solidago spp.	0	0	0	0	0	0	0	0
Thalictrum fendleri	0	0	0	0	1	2	0	0
Thermopsis pinetorum	0	0	0	3	4	0	0	0
Valeriana acutiloba	0	0	0	0	3	0	0	0
Vicia americana	0	0	0	2	0	4	0	0
Viola canadensis	0	0	1	7	2	11	0	7
Graminoids								
Bromus ciliatus	1	1	5	9	10	17	4	12
Carex foenea	0	0	0	0	0	6	2	3
Carex rossii	1	3	1	2	0	4	2	0
Elymus glaucus	0	0	0	0	0	1	0	0
Festuca arizonica	0	0	0	0	0	1	0	0
Koeleria cristata	0	0	0	0	0	0	0	0
Luzula parviflora	9	0	1	0	0	0	0	13
Muhlenbergia montana	0	0	0	0	0	0	0	0
M. virescens	0	0	0	0	0	0	0	0
Poa fendleriana	0	0	0	0	0	0	0	0
P. pratensis	0	0	0	0	0	2	0	0
Sitanion hystrix	0	0	0	0	0	0	0	0
Trisetum montanum	0	0	1	3	1	3	0	12

[1]*Habitat types are numbered as follows:*

1. *Picea engelmannii/Vaccinium scoparium/Polemonium delicatum* HT
2. *Picea engelmannii*/Moss HT
3. *Abies lariocarpa/Vaccinium scoparium* HT
4. *Abies lasiocarpa/Vaccinium scoparium/Linnaea borealis* HT
5. *Abies lasiocarpa/Rubus parviflorus* HT
6. *Abies lasiocarpa/Erigeron superbus* HT
7. *Abies lasiocarpa/Juniperous communis* HT
8. *Abies lasiocarpa/Senecio sanguisorboides* HT

[2]*Young regeneration = trees less than 2" d.b.h. Advanced regeneration = trees 2-10" d.b.h. Mature = trees larger than 10" d.b.h.*

Table A-3.—Mixed conifer forest habitat types. Summary of 66 species (listed by life form) importance values (square root of mean density or cover times frequency)

	Habitat type[1]										
Trees	9	10	11	12	13	14	15	16	17	18	19
Picea engelmannii											
Young regeneration	36	32	5	6	12	2	0	5	0	0	0
Advanced regeneration	25	25	9	2	5	1	0	4	0	0	0
Mature	16	10	0	0	1	0	0	0	0	0	0
Abies lasiocarpa											
Young regeneration	30	11	6	6	4	1	0	4	0	0	0
Advanced regeneration	9	2	5	2	1	1	0	2	0	0	0
Mature	7	2	0	1	0	0	0	1	0	0	0
Populus tremuloides											
Regeneration	0	7	11	13	5	6	1	3	6	6	0
Mature	9	17	22	27	8	13	5	9	20	15	0
Abies concolor											
Young regeneration	38	8	15	20	29	62	59	55	94	82	5
Advanced regeneration	13	2	12	1	19	33	29	33	32	49	3
Mature	5	0	0	1	3	17	11	15	19	14	1
Pseudotsuga menziesii											
Young regeneration	39	54	24	23	54	42	43	49	30	43	82
Advanced regeneration	20	30	14	12	42	28	28	34	7	27	30
Mature	20	19	9	7	29	24	14	24	13	7	10
Picea pungens											
Young regeneration	14	38	52	59	39	4	2	2	0	0	0
Advanced regeneration	12	36	52	29	31	2	1	0	0	2	0
Mature	6	8	31	17	12	1	0	1	0	0	0
Pinus strobiformis											
Young regeneration	14	11	0	8	11	13	18	15	15	4	36
Advanced regeneration	13	6	0	3	3	7	12	11	6	5	16
Mature	3	2	0	0	3	3	7	5	2	1	7
Pinus ponderosa											
Young regeneration	1	0	0	21	0	1	10	8	2	23	44
Advanced regeneration	2	0	0	11	1	1	16	7	0	21	36
Mature	3	9	0	15	3	1	13	10	0	16	27
Quercus gambelii											
Regeneration	0	0	0	0	6	2	9	0	0	0	0
Mature	0	0	0	0	2	5	24	0	5	2	0
Robinia neomexicana											
Regeneration	0	0	0	0	0	0	0	0	0	0	0
Mature	0	0	0	0	0	0	0	0	5	0	0
Pinus aristata											
Mature	0	0	0	0	0	0	0	1	0	0	0
Quercus hypoleucoides											
Mature	0	0	0	0	0	0	0	0	0	0	0
Tall shrubs											
Acer glabrum	0	0	18	0	3	25	0	1	0	0	0
Acer grandidentatum	0	0	0	0	0	2	0	0	89	0	0
Amelanchier alnifolia	0	0	9	0	5	6	0	0	0	0	0
Prunus virginiana	0	0	22	0	0	3	2	0	0	0	0
Quercus gambelii	0	0	0	0	5	13	50	1	13	7	0
Robinia neomexicana	1	0	0	1	0	2	10	3	22	0	0
Salix scouleriana	0	1	24	1	0	5	0	1	2	0	0
Low deciduous shrubs											
Holodiscus dumosus	0	0	0	0	1	13	2	1	0	0	2
Jamesia americana	0	0	0	0	3	10	2	1	0	0	0
Lonicera arizonica	2	0	0	0	4	0	6	2	11	0	0
L. involucrata	0	0	15	0	2	0	0	0	0	0	0
L. utahensis	1	0	0	0	0	0	0	0	0	0	0
Physocarpus monogynus	0	0	0	0	0	7	1	1	0	0	0
Ribes montigenum	0	0	0	0	0	0	0	0	0	0	0
Rosa spp.	0	0	33	1	14	7	4	1	0	2	0
Rubus parviflorus	3	0	15	0	5	4	0	0	0	0	0
Symphoricarpos oreophilus	1	0	22	0	4	12	8	5	0	0	0
Low evergreen shrubs											
Berberis repens	0	0	0	0	6	10	4	5	17	1	0
Juniperus communis	0	7	1	9	17	1	1	4	0	0	0
Linnaea borealis	0	0	0	0	13	1	0	0	0	0	0
Pachistima myrsinites	5	0	13	1	13	12	3	1	0	0	0
Pyrola secunda	3	0	1	0	3	1	0	1	0	0	0
Vaccinium spp.	0	0	0	0	10	3	0	1	0	0	0

Table A-3.—Continued

Trees	Habitat type[1] 9	10	11	12	13	14	15	16	17	18	19
Forbs											
Achillea lanulosa	2	7	17	8	9	2	6	0	0	8	4
Antennaria aprica	0	0	0	9	1	0	3	1	0	8	3
Aquilegia elegantula	3	0	3	0	5	3	0	0	0	0	0
Artemisia franserioides	0	3	1	0	8	13	1	1	0	0	0
Clematis pseudoalpina	1	0	1	0	5	7	1	1	0	0	0
Epilobium angustifolium	0	0	0	0	0	0	0	0	1	0	0
Erigeron spp.	0	3	7	7	0	0	3	0	0	11	0
E. superbus	5	33	32	4	16	15	0	1	0	0	0
Fragaria vesca var. *bracteata*	10	5	12	0	13	7	4	2	8	1	1
F. virginiana var. *glauca*	7	23	16	13	11	6	3	2	11	6	0
Galium boreale	0	0	9	0	5	1	1	0	4	0	5
Geranium richardsonii	7	8	17	4	9	4	2	1	10	1	3
Goodyera oblongifolia	1	0	0	0	0	0	0	2	0	0	0
Haplopappus parryi	0	5	1	3	2	10	2	1	0	1	0
Helenium hoopesii	9	1	0	0	0	0	1	0	0	0	0
Lathyrus arizonicus	11	29	10	11	10	13	9	2	10	12	0
Ligusticum porteri	0	0	0	0	0	0	1	1	2	0	0
Mertensia franciscana	1	0	13	0	0	1	0	0	0	0	0
Osmorhiza depauperata	1	0	5	0	0	2	1	0	7	0	0
Pedicularis spp.	0	0	0	0	0	0	1	0	0	0	0
Polemonium pulcherrimum var. *delicatum*	0	0	0	0	0	0	0	0	0	0	0
Pseudocymopteris montanus	1	9	6	3	1	1	4	1	1	8	9
Pteridium aquilinum	12	4	0	0	1	0	4	3	30	0	16
Senecio neomexicanus	0	0	0	4	0	1	2	0	1	4	0
S. cardamine	35	0	0	0	0	0	0	0	0	0	0
S. sanguisorboides	0	0	0	0	0	0	0	0	0	0	0
S. wootoni	11	11	0	7	2	2	2	0	0	8	0
Smilacina racemosa	1	0	0	0	3	2	1	0	5	0	0
S. stellata	1	0	7	2	1	4	1	0	0	0	0
Solidago spp.	4	1	0	0	2	0	3	0	0	0	3
Thalictrum fendleri	7	9	15	2	4	8	6	1	24	5	0
Thermopsis pinetorum	13	0	0	0	0	3	5	1	14	2	4
Valeriana acutiloba	0	0	0	0	8	1	1	0	0	2	0
Vicia americana	1	8	5	3	1	1	1	0	0	6	2
Viola canadensis	10	7	0	1	4	6	5	0	43	0	0
Graminoids											
Bromus ciliatus	12	12	14	6	15	20	9	4	14	3	10
Carex foenea	11	28	13	32	14	2	4	3	46	1	0
Carex rossii	7	5	6	6	9	6	11	6	5	5	0
Elymus glaucus	0	0	0	0	0	0	1	0	0	0	0
Festuca arizonica	0	21	0	15	0	0	3	1	0	35	0
Koeleria cristata	1	6	0	4	4	1	3	4	0	4	6
Luzula parviflora	0	0	0	0	0	0	0	0	0	0	0
Muhlenbergia montana	0	3	0	14	0	0	1	0	0	14	0
M. virescens	1	6	0	3	0	0	9	1	0	7	41
Poa fendleriana	4	0	0	6	15	1	10	3	2	10	0
P. pratensis	0	11	51	0	0	1	0	0	0	0	0
Sitanion hystrix	0	1	0	4	0	0	3	2	0	5	1
Trisetum montanum	3	0	2	0	3	4	0	0	0	0	0

[1]*Habitat types are numbered as follows:*

9. *Picea pungens-Picea engelmannii/Senecio cardamine* HT
10. *Picea pungens-Picea engelmannii/Erigeron superbus* HT
11. *Picea pungens/Poa pratensis* HT
12. *Picea pungens/Carex foenea* HT
13. *Picea pungens-Pseudotsuga menziesii* HT
14. *Abies concolor-Pseudotsuga menziesii/Acer glabrum* HT
15. *Abies concolor-Pseudotsuga menziesii/Quercus gambelii* HT
16. *Abies concolor-Pseudotsuga menziesii* HT
17. *Abies concolor/Acer grandidentatum* HT
18. *Abies concolor/Festuca arizonica* HT
19. *Pseudotsuga menziesii-Pinus strobiformis/Muhlenbergia virescens* HT

Table A-4.—Other (minor) spruce-fir forest habitat types. Summary of 66 species (listed by life form) importance values (square root of mean density or cover times frequency)

Trees	Habitat Type[1]					
	20	21	22	23	24	25
Picea engelmannii						
Young regeneration	85	28	59	68	0	36
Advanced regeneration	75	10	40	42	0	38
Mature	39	9	24	35	0	31
Abies lasiocarpa						
Young regeneration	22	101	8	5	82	0
Advanced regeneration	0	48	17	0	41	0
Mature	0	22	8	0	22	0
Populus tremuloides						
Regeneration	0	0	5	0	0	0
Mature	0	46	9	0	14	18
Abies concolor						
Young regeneration	0	0	0	0	44	15
Advanced regeneration	0	0	0	0	0	8
Mature	0	0	0	0	14	5
Pseudotsuga menziesii						
Young regeneration	0	0	11	0	0	15
Advanced regeneration	0	0	3	0	17	14
Mature	0	0	30	0	14	14
Picea pungens						
Young regeneration	0	0	0	0	0	0
Advanced regeneration	0	0	0	0	0	0
Mature	0	0	0	0	0	0
Pinus strobiformis						
Young regeneration	0	7	6	0	22	5
Advanced regeneration	0	0	5	0	22	0
Mature	0	0	3	0	14	0
Pinus ponderosa						
Young regeneration	0	0	0	0	0	0
Advanced regeneration	0	0	0	0	0	0
Mature	0	0	0	0	0	0
Quercus gambelii						
Regeneration	0	0	0	0	0	0
Mature	0	0	0	0	0	0
Robinia neomexicana						
Regeneration	0	0	0	0	0	0
Mature	0	0	0	0	0	0
Pinus aristata						
Mature	0	0	0	0	0	0
Quercus hypoleucoides						
Mature	0	0	0	0	0	0
Tall shrubs						
Acer glabrum	0	0	9	0	3	15
Acer grandidentatum	0	0	0	0	0	0
Amelanchier alnifolia	0	0	0	0	14	0
Prunus virginiana	0	0	0	0	0	0
Quercus gambelii	0	0	0	0	1	0
Robinia neomexicana	0	0	0	0	0	0
Salix scouleriana	0	0	0	0	0	0
Low deciduous shrubs						
Holodiscus dumosus	0	0	19	0	0	5
Jamesia americana	0	0	14	0	0	3
Lonicera arizonica	0	0	0	0	14	0
L. involucrata	0	0	0	0	1	0
L. utahensis	0	0	0	0	0	0
Physocarpus monogynus	0	0	0	0	0	0
Ribes montigenum	26	0	0	0	0	0
Rosa spp.	0	0	0	0	0	0
Rubus parviflorus	0	0	0	0	0	7
Symphoricarpos oreophilus	0	0	0	0	0	0

Table A-4.—Continued

Trees	Habitat Type[1] 20	21	22	23	24	25
Low evergreen shrubs						
Berberis repens	0	0	0	0	14	0
Juniperus communis	0	0	0	0	0	0
Linnaea borealis	0	0	0	0	0	0
Pachistima myrsinites	0	0	0	0	22	7
Pyrola secunda	1	0	0	0	1	1
Vaccinium myrtillus	0	0	0	0	39	0
Forbs						
Achillea lanulosa	0	0	0	0	0	0
Antennaria aprica	0	0	0	0	1	0
Aquilegia elegantula	0	0	1	0	0	1
Artemisia franserioides	0	0	0	0	0	9
Clematis pseudoalpina	0	0	0	0	0	0
Epilobium angustifolium	1	0	0	0	0	1
Erigeron spp.	0	0	0	0	0	1
E. superbus	0	0	4	0	1	0
Fragaria vesca var. *bracteata*	0	0	5	0	1	1
F. virginiana var. *glauca*	1	0	0	0	3	2
Galium boreale	0	0	0	0	0	1
Geranium richardsonii	0	9	0	1	10	1
Goodyera oblongifolia	0	0	0	0	14	0
Haplopappus parryi	17	0	0	1	0	12
Helenium hoopseii	0	2	0	0	0	0
Lathyrus arizonicus	0	47	0	1	0	7
Ligusticum porteri	0	0	0	0	14	2
Mertensia franciscana	1	5	0	1	0	0
Osmorhiza depauperata	0	0	0	0	3	1
Pedicularis sp.	0	0	0	0	0	0
Polemonium polcherrimum var. *delicatum*	3	0	0	0	0	0
Pseudocymopteris montanus	3	0	0	0	3	1
Pteridium aquilinum	0	7	0	0	3	0
Senecio neomexicanus	0	0	0	0	0	0
S. cardamine	0	0	0	0	0	0
S. sanguisorboides	0	0	0	0	0	7
S. wootoni	0	0	0	2	0	0
Smilacina racemosa	0	0	0	0	32	1
S. stellata	0	21	1	0	0	1
Solidago spp.	0	0	0	0	0	0
Thalictrum fendleri	0	0	0	0	22	0
Thermopsis pinetorum	0	0	0	0	10	0
Valeriana acutiloba	0	0	0	0	0	0
Vicia americana	0	12	0	1	0	0
Viola canadensis	0	0	0	0	20	3
Graminoids						
Bromus ciliatus	0	27	0	3	10	13
Carex foenea	0	7	0	60	39	0
Carex rossii	0	7	1	0	1	0
Elymus triticoides	0	0	29	0	0	0
Festuca arizonica	0	0	0	0	0	0
Koeleria cristata	0	0	0	0	0	0
Luzula parviflora	1	0	0	0	0	0
Muhlenbergia montana	0	0	0	0	0	0
M. virescens	0	0	0	0	0	0
Poa fendleriana	0	0	0	2	1	0
P. pratensis	0	0	0	10	0	0
Sitanion hystrix	0	0	0	0	0	0
Trisetum montanum	1	0	6	0	10	2

[1]*Habitat types are numbered as follows:*

20. *Picea engelmannii/Geum rossii* HT
21. *Abies lasiocarpa/Lathyrus arizonica* HT
22. *Picea engelmannii/Elymus triticoides* HT
23. *Picea engelmannii/Carex foenea* HT
24. *Abies lasiocarpa/Vaccinium myrtillus* HT
25. *Picea engelmannii/Acer glabrum* HT

Table A-5.—Other (minor) mixed conifer habitat types. Summary of 66 species (listed by life form) importance values (square root of mean density or cover times frequency)

Trees	Habitat type[1]									
	26	27	28	29	30	31	32	33	34	35
Picea engelmannii										
Young regeneration	6	3	5	0	0	5	0	0	0	0
Advanced regeneration	6	0	5	9	0	0	0	0	0	0
Mature	0	3	5	0	0	0	0	0	0	0
Abies lasiocarpa										
Young regeneration	0	0	0	0	0	0	0	0	0	0
Advanced regeneration	3	0	0	0	0	0	0	0	0	0
Mature	0	0	0	0	0	0	0	0	0	0
Populus tremuloides										
Regeneration	12	0	9	0	0	0	0	0	0	24
Mature	11	26	25	23	11	0	0	0	0	0
Abies concolor										
Young regeneration	70	70	75	75	46	67	18	17	0	0
Advanced regeneration	32	16	59	23	22	20	15	0	14	0
Mature	21	16	13	12	13	19	6	0	0	0
Pseudotsuga menziesii										
Young regeneration	40	40	16	37	49	50	34	0	13	17
Advanced regeneration	28	24	19	40	21	27	37	44	22	0
Mature	27	10	9	12	15	24	25	33	20	17
Picea pungens										
Young regeneration	0	0	0	0	0	12	0	0	0	0
Advanced regeneration	3	0	0	0	0	5	0	14	0	0
Mature	3	0	0	0	0	0	0	0	0	0
Pinus strobiformis										
Young regeneration	6	21	10	21	21	20	0	0	9	22
Advanced regeneration	5	26	5	0	24	0	0	0	0	17
Mature	0	12	0	0	4	9	0	0	0	28
Pinus ponderosa										
Young regeneration	6	21	10	5	4	0	0	0	9	0
Advanced regeneration	0	9	0	15	0	0	0	0	10	0
Mature	0	16	5	24	0	5	0	0	0	0
Quercus gambelii										
Regeneration	0	0	0	0	0	0	0	0	0	0
Mature	6	0	0	0	4	0	0	0	29	0
Robinia neomexicana										
Regeneration	0	0	5	0	0	0	0	0	0	0
Mature	0	0	16	0	0	0	0	0	0	0
Pinus aristata										
Mature	0	0	0	0	0	0	11	0	0	0
Quercus hypoleucoides										
Mature	0	0	0	0	0	0	0	0	44	0
Tall shrubs										
Acer glabrum	0	9	0	0	0	0	0	0	0	0
Acer grandidentatum	0	0	0	0	0	0	0	0	0	0
Amelanchier alnifolia	5	0	0	0	0	0	0	3	0	0
Prunus emarginata	0	0	0	0	0	0	0	0	0	10
Quercus gambelii	7	0	0	0	9	9	0	1	0	0
Robinia neomexicana	0	0	71	0	0	12	0	0	0	0
Salix scouleriana	3	0	0	0	0	0	0	0	0	0
Low deciduous shrubs										
Holodiscus dumosus	0	0	0	0	9	0	11	0	0	14
Jamesia americana	0	0	0	0	22	0	0	0	0	0
Lonicera arizonica	6	0	11	0	0	0	0	0	0	3
L. involucrata	0	0	0	0	0	0	0	0	0	0
L. utahensis	0	0	0	0	0	0	0	0	0	0
Physocarpus monogynus	0	0	0	0	0	0	0	63	0	0
Ribes montigenum	0	0	0	0	0	0	0	0	0	0
Rosa spp.	5	0	0	0	0	2	7	3	0	10
Rubus parviflorus	5	0	0	0	0	10	0	0	0	0
Symphoricarpos oreophilus	0	0	0	1	0	0	11	32	0	0
Low evergreen shrubs										
Berberis repens	3	0	0	17	0	0	0	0	0	22
Juniperus communis	0	0	0	0	0	0	8	0	0	0
Linnaea borealis	0	0	0	0	0	0	0	0	0	0
Pachistima myrsinites	7	0	0	0	0	5	0	0	0	0
Pyrola secunda	5	0	0	0	0	2	0	0	0	0
Vaccinium spp.	7	0	0	0	0	0	0	0	0	0

Table A-5.—Continued

Trees	Habitat type[1]									
	26	27	28	29	30	31	32	33	34	35
Forbs										
Achillea lanulosa	7	5	0	0	0	10	1	0	0	0
Antennaria aprica	7	0	0	2	0	0	1	0	0	0
Aquilegia elegantula	0	0	0	0	0	0	0	0	0	0
Artenisia franserioides	5	0	0	0	0	1	2	10	0	0
Clematis pseudoalpina	0	0	0	0	0	0	2	3	0	0
Epilobium angustifolium	0	0	0	0	0	0	0	0	0	0
Erigeron spp.	0	3	0	0	0	2	16	17	0	0
E. superbus	48	3	2	2	3	0	5	0	0	0
Fragaria vesca var. *bracteata*	11	1	16	0	0	19	11	3	0	0
F. virginiana var. *glauca*	23	8	7	0	0	7	1	0	0	0
Galium boreale	5	0	0	0	0	0	0	3	0	0
Geranium richardsonii	3	13	1	0	0	2	0	0	0	0
Goodyera oblongifolia	0	0	0	1	0	0	0	0	0	0
Haplopappus parryi	3	0	2	0	0	7	0	0	0	0
Helenium hoopesii	0	3	0	0	0	2	0	0	0	0
Lathyrus arizonicus	53	1	0	42	1	19	0	0	0	0
Ligusticum porteri	9	0	0	0	0	0	0	0	0	0
Mertensia franciscana	0	0	0	0	0	0	0	0	0	0
Osmorhiza depauperata	8	0	0	0	0	0	0	0	0	0
Pedicularis spp.	0	0	0	0	0	0	0	0	0	0
Polemonium pulcherrimum var. *delicatum*	0	0	0	0	0	0	0	0	0	0
Pseudocympoteris montanus	5	5	0	0	0	2	0	0	2	0
Pteridium aquilinum	0	12	11	0	0	5	0	0	0	0
Senecio neomexicanus	0	0	0	0	0	2	9	0	2	0
S. cardamine	0	0	0	0	0	0	0	0	0	0
S. sanguisorboides	0	0	0	0	0	0	0	0	0	0
S. wootoni	0	11	0	0	0	14	0	0	0	0
Smilacina racemosa	0	0	5	0	0	0	0	0	0	0
S. stellata	5	0	0	7	0	0	0	0	0	0
Solidago spp.	0	0	0	0	7	0	0	0	12	3
Thalictrum fendleri	10	2	32	0	0	7	0	10	5	0
Thermopsis pinetorum	27	0	2	0	0	0	6	0	0	0
Valeriana acutiloba	0	0	0	2	0	0	0	0	0	0
Vicia americana	1	5	0	0	0	0	1	3	0	0
Viola canadensis	16	0	2	0	0	2	0	0	0	0
Graminoids										
Bromus ciliatus	13	31	39	10	22	19	0	0	0	14
Carex foenea	38	71	35	0	10	7	0	0	0	0
Carex rossii	2	6	7	2	9	14	8	3	0	3
Elymus triticoides	0	0	0	0	54	0	0	0	0	0
Festuca arizonica	0	3	0	0	3	0	40	0	0	17
Koeleria cristata	0	1	0	2	8	5	9	14	2	0
Luzula parviflora	0	0	0	0	0	0	0	0	0	0
Muhlenbergia montana	0	1	0	0	19	0	7	0	0	22
M. virescens	0	0	0	0	0	2	0	0	0	0
Poa fendleriana	3	2	2	9	1	41	2	1	2	3
P. pratensis	0	14	9	0	1	0	0	0	0	0
Sitanion hystrix	0	1	0	0	1	0	3	0	0	0
Trisetum montanum	8	0	0	0	0	0	0	0	0	0

[1]*Habitat types are numbered as follows:*

26. *Abies concolor-Pseudotsuga menziesii/Erigeron superbus* HT
27. *Abies concolor/Carex foenea* HT
28. *Abies concolor/Robinia neomexicana* HT
29. *Abies concolor-Pseudotsuga menziesii/Lathyrus arizonicus* HT
30. *Abies concolor-Pseudotsuga menziesii/Elymus triticoides* HT
31. *Abies concolor-Pseudotsuga menziesii/Poa fendleriana* HT
32. *Pseudotsuga menziesii/Festuca arizonica* HT
33. *Pseudotsuga menziesii/Physocarpus monogynus* HT
34. *Pseudotsuga menziesii/Quercus hypoleucoides* HT
35. *Pinus strobiformis/Festuca arizonica* HT

Moir, William H., and John A. Ludwig. 1979. A classification of spruce-fir and mixed conifer habitat types of Arizona and New Mexico. USDA For. Serv. Res. Pap. RM-207, 47 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Nineteen major forest habitat types (HT's) are described on the basis of extensive reconnaissance data throughout the major mountain ranges and plateaus of Arizona and New Mexico. Eight of these HT's are within spruce-fir forests where either *Picea engelmannii* or *Abies lasiocarpa* are the climax dominants; the remainder are within mixed conifer forests where *Abies concolor, Picea pungens,* and *Pseudotsuga manziesii* are climax dominants or codominants. Sixteen other HT's are briefly described based on limited data, usually from one geographic location.

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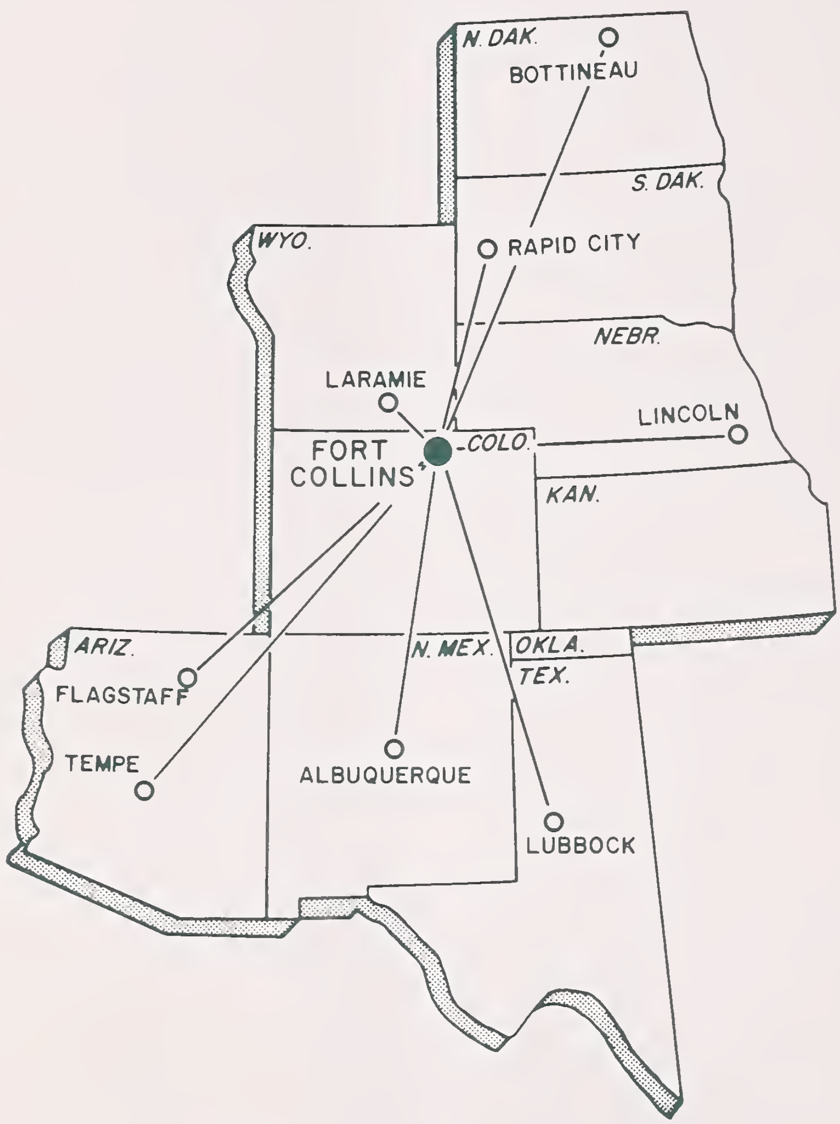
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