The Vegetation of New Mexico

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DISTRIBUTION OF VEGETATIVE ZONES IN NEW MEXICO
THE VEGETATION OF NEW MEXICO

NEW MEXICO is the fourth largest state in the union; it has a total of 121,666 square miles and within its confines are tremendous variations in topography and physiography. Thus the elevation ranges from 2,850 feet at the point where the Pecos River crosses the southern border of the state into Texas, to 13,160 feet atop Wheeler Peak in the Sangre de Cristo Range. The state has no natural boundaries. Roughly and basically it consists of a high arched plateau, the axis of the arch being near the middle and running north to south. This plateau is about 7,000 feet above sea level at its highest point on the northern boundary line and drops to an average of about 3,500 feet at its southern end. Rising from the plateau are numerous mountain ranges of two well-defined types — first, great high mountain masses that consist of numerous associated ridges more or less densely covered with forests and woodland; second, narrow, rocky, more or less isolated, desert mountains or ridges that support only a scattering of trees, if indeed any at all, and a scanty covering of shrubs, undershrubs, forbs, and grasses. Almost all the main ranges have a north-south axis. Among these are seemingly level plains that are independent of each other, at various altitudes, the Estancia Valley and the San Augustine Plains being typical examples. On the eastern side of the state the mountains and mesas gradually subside into that wide expanse known as the Llano Estacado or Staked Plains.

Many of the physiographic features of the state, both of sculpture and deposition, are the result of wind action. Some of the

1 Delivered as the third annual research lecture at the University of New Mexico, April 15, 1956.
2 A forb is an herbaceous plant that is neither a grass nor a sedge.
interesting and characteristic features are the extensive white gypsum sands lying west of Alamogordo in the Tularosa Basin, the broad expanses of quartz sand dunes such as those seen from Orogrande south to the Texas line, and the Mescalero Sands and other sand dune areas in the eastern part of the state. The large lava flows, owing to their hardness and consequent resistance to erosion, have done much to modify the relief features.

The river valleys are narrow and are frequently confined entirely to the river channels or cut their way by means of box canyons through mountains and mesas. The two largest rivers, the Rio Grande and the Rio Pecos, run entirely or almost the length of the state from north to south. The San Juan, San Francisco, and Gila rivers flow westward into Arizona, whereas the rivers of the northeastern part of the state, such as the Cimarron and Canadian, flow eastward out of the state. The rivers have few permanent tributaries in relation to the size of their drainage areas.

The climate of New Mexico is as variable as its topography. The temperature ranges from a maximum of about 110°F in the southern part of the state to the highest mountain peaks in the northern part of the state where there is rarely a frostless night during the year, and where snowbanks remain, in protected places, throughout the summer. Likewise, precipitation varies greatly, ranging from about 8 inches in the lower Rio Grande Valley to 45 inches in the high mountain country east of Costilla at the northern border of the state.

The seasonal influence of precipitation is important in relation to vegetation. Although total annual precipitation does much to determine the types of vegetative cover in a given area, the time of year in which such precipitation occurs is of almost equal influence. Thus the amount of precipitation that falls within the period April 1 to September 30 varies from 75 per cent in the northeastern sector of the state to 58 per cent in the western part of Grant County.
As one goes from south to north in the state, the annual mean temperature drop is 1.5° to 2° F. for each degree of latitude; and for each degree of latitude there is a lag of four days in the spring emergence of vegetable and animal life.

Then, too, for every rise of 1,000 feet in elevation there is a decrease of 3.3° F. in mean annual temperature, and this produces a lag of 10 days in seasonal biological advance for each rise of 1,000 feet elevation. The greatest length of the state from south to north is 369 miles and this latitudinal influence on temperature is equivalent to approximately 1,400 feet rise in elevation.

As might well be expected, the marked variations in elevation, physiography, topography, drainage, temperature, precipitation, and evaporation, as well as soil conditions, are responsible for the pronounced diversity in the vegetation of the state. Nevertheless, this vegetation is so uniform in distribution as to take the expression of definite zones or bands, and these are correlated with the factors mentioned.

An airplane view of New Mexico reveals three great types of vegetative cover: forest, shrub, and grassland. Yet a closer scrutiny of these three discloses that each is composed of strikingly different plant and animal communities. The major types of vegetation, together with their associated animal life, are designated as biomes. A biome is the major category in the classification of communities; the most inclusive recognized aggregation of interdependent living things, both plant and animal, in and with their environment. However, only the plant life of each biome will be discussed here. Biomes are easily recognized on the basis of life form, such as tree, shrub, grass, etc. Thus we have on the North American continent the deciduous forest biome, the coniferous forest biome, the tundra biome, the prairie biome, and the desert shrub biome.

In the interest of clarity it is important to explain another concept, namely the climax. Neither in geology nor in biology is
there any such thing as "the everlasting hills." Vegetation must be viewed not in terms of its present composition, but rather in terms of its historic and biological development. When, historically, a geographic area reaches the point where it is for the first time capable of supporting life of any kind, the first plants to come in usually are lichens. Over the centuries this pioneer vegetation is gradually replaced by successional stages of vegetation that involve increasingly higher forms of plant life until eventually the climax community or association is reached. A climax may be defined as the final or stable type of community, the highest type of vegetation possible in a particular climate. It always consists of the most mesophytic vegetation that an area will support continuously. These units of vast extent and permanence are the product of, and are controlled by, climate. In other words, a climax is the direct expression of the existing climate in an area; climate is the cause, a climax is the effect. A climax has developed over a long period of time in response to the existing climate, but if the climate changes the nature of the climax will change. Vegetation responds to very small, long-time changes in climate that not even instruments may record.

Before the advent of civilized man, nearly the whole area of each climax was occupied by the dominant (controlling, rather than conspicuous) species. Any climax has within its confines numerous but relatively small and scattered portions in which primary succession is taking place, such as in areas of water, dune sand, or rock. Also, it contains local disturbed areas wrought by such things as fire, avalanche, logging, or grazing misuse. In any case these areas are gradually developing toward the climax vegetation. Thus, each climax consists not only of the stable areas that represent its original mass, but also of all contained successional stages regardless of the kind or stage of development.

*Mesophytic vegetation is comprised of plants that grow under medium conditions of atmospheric and soil moisture as contrasted with desert plants and aquatic plants.
Grassland Biome

DESERT GRASSLAND ASSOCIATION. The grassland biome occupies a large part of New Mexico. The biome has two subdivisions, desert plains grassland and mixed grassland or mixed prairie, each of which will be referred to henceforth as an association. Neither this nor any other association found within the state is limited to New Mexico; each extends far beyond the borders of the state in several directions.

The geographic limit of the desert grassland association in New Mexico is controversial, and any delimitation of its borders would not meet with universal approval. Nevertheless, it is important at the outset to define the conception of desert plains grassland in the state as here employed.

It appears mandatory to determine the geographical limits of desert grassland in terms of the limits of its dominant grass species, although, in doing so, the distributional limits of some of its important forbs, half-shrubs, and shrubs must not be ignored. It is widely recognized that the most noteworthy characteristic of this association in New Mexico is the occurrence throughout of the climax dominant, black grama grass (*Bouteloua eriopoda*), and its codominant tobosa grass (*Hilaria mutica*). Thus, only those areas in which black grama or tobosa grass are, or have been, the dominant species will be regarded as desert grassland. Viewed on this basis, the desert grassland association in New Mexico sweeps as a broad, almost unbroken band, except for mountain areas, across the southern part of the state, with long tonguelike extensions northward into the major river valleys and into the Tularosa Basin.

In altitude, the association ranges from 2,850 feet at the point where the Pecos River crosses the state line into Texas to approximately 5,500 feet, although this higher limit varies somewhat in different parts of the state.

Most of us, in traveling over much of this desert grassland area today, would be amazed to hear it referred to as grassland,
since its most striking characteristic, particularly at lower levels, is not the grass cover but the heavy stands of creosote bush (Larrea tridentata), mesquite (Prosopis juliflora), tarbush (Flourensia cernua), Mexican tea (Ephedra trifurca), and other shrubs that intermittently sweep across the entire association. In fact, so deceiving are these stands, which simulate desert, that a few investigators have interpreted the desert grassland association as desert shrub climax. However, investigations within recent years by Clements, Gardner, Whitfield and Beutner, Whitfield and Anderson, Campbell, and others have clearly revealed that this area originally was predominantly grass-covered and that the heavy disclimax shrub cover is largely a historic development. Continuous misuse of the grassland has disturbed the climactic balance of the vegetation to the advantage of these shrubs to so marked a degree that their control of much of the area appears to be complete, and perhaps permanent. It appears that originally the major portion of the desert grassland was dotted with islands of desert shrubs on such areas as rocky or gravelly knolls and hills, bluffs, talus slopes, and stretches of sand — in other words, on those sites where the grasses were unable to compete successfully with shrubs.

The fact that the area was occupied by man at an early period and the climate favored the development of grazing as the major yearlong industry, in addition to the frequency of drought, has resulted in pronounced deterioration of the original grass cover. In such range deterioration, the perennial grasses have gradually been replaced, especially in the drier areas, by summer societies of annual species of grasses such as the gramas and the three-awns, as well as forbs.

The plains that border the Rio Grande in southern New Mexico support more shrub cover than is found in the higher plains of the central and northern parts of the state, although the latter region is more elevated, somewhat colder, and is visited by higher precipitation. This lower sector of the Rio Grande is bordered
by a belt of shrub, dominated chiefly by creosote bush, approximately to the junction of the Rio Grande with the Rio Puerco.

On the basis of published descriptions of early travelers and long-time residents, both Gardner and Dittmer have made a very plausible case that in the Rio Grande sector of the desert grassland in New Mexico at least, the grass cover has markedly decreased and shrubs have greatly increased within the last century or less; moreover, Gardner has never observed in the present vegetation so much as a good cover of grass in areas where shrubs ever approach dominance. He is of the opinion that, in their original condition, the tablelands bordering the Rio Grande were generally grass-covered, with scattered shrubs in the grassland. In this connection, Johnson has reported that, in the lower Rio Grande Valley of New Mexico, shrubs are now in possession of sites where black grama was cut and baled for hay within the memory of living residents.

Gardner, Campbell, and others, in studying successional stages on misused ranges in New Mexico, have concluded that, under protection from grazing, such stages eventually will terminate in climax desert grassland vegetation. However, it is obvious to those familiar with successional processes that, owing to the arid climate and other factors, stages in secondary succession leading eventually to the re-establishment of climax vegetation on deteriorated areas are indeed very slow to develop, even under the most favorable conditions, as compared with the situation in belts of higher precipitation. This is especially true in localities where relatively pure stands of desert shrub constitute the present cover.

From the standpoint of practical average present-day management of rangelands, the ultimate re-establishment of climax desert grassland vegetation on ranges now covered with stands of creosote, mesquite, tarbush, etc. is rarely to be expected. The present extensive shrub cover on desert grassland apparently has not only come to stay; these and other unpalatable shrubs will
continue to take over more and more desert grassland. This gloomy prospect appears to be inevitable unless a marked change takes place in the management of much of our range land.

Although there exists a basic uniformity in the vegetative cover throughout the desert grassland in the state, certain noteworthy variations, known as faciations, do occur, especially in relation to differential temperature and annual and seasonal precipitation. It definitely would be worth while to discuss these faciations as well as the vegetation of such specialized areas as the lava flows, the sand dune areas, the white gypsum sands near Alamogordo, or the river valleys. However, the limitation of space forbids any excursions into these subjects, interesting as they be.

The most characteristic species of grass in the desert grassland are black grama, normally occupying the uplands, and tobosa grass, more commonly found in swales and flat drainageways. With these are associated several other important codominants including several dropseeds, especially sand dropseed (Sporobolus cryptandrus) and mesa dropseed (S. flexuosus), bush muhly or hoe grass (Muhlenbergia porteri), blue grama (Bouteloua gracilis), plains bristlegrass (Setaria macrostachya), several three-awns (Aristida), small amounts of burro grass (Sclero­ pogon bervifolius), vine-mesquite grass (Panicum obtusum), cane beard­grass (Andropogon barbinodis), poverty three-awn (Aristidadivaricata), and cottongrass (Trichachne californica). In moist areas such as swales and draws, alkali sacaton (Sporobolus air­oides) and big sacaton (S. wrightii) are locally very common.

The chief herbaceous perennial associates in the desert grassland are desert zinnia (Zinnia grandiflora and Z. pumila), desert marigold (Baileya multiradiata), hog or rat potato (Hoffman­seggia spp.), dove weed (Croton texensis), globe mallow (Sphaer­ alcea spp.), loco weed (Astragalus spp.), silver nightshade (Solanum elaechnifolium), paper flower (Psilostrophe tagetina), filaree (Erodium cicutarium), spectacle pod (Dithyrea wislizeni), stickleaf (Mentzelia spp.), and others. The most conspicuous annuals in the association are spiderling (Boerhavia spp.), Tide-
stromia spp., wild buckwheat (*Eriogonum* spp.), annual three-awn (*Aristida adscensionis*), and annual grama grasses. The most characteristic shrubs and half-shrubs are creosote bush, mesquite, the New Mexico state flower (*Yucca elata*), desert sumac (*Rhus microphylla*), allthorn (*Koeberlinia spinosa*), tarbush, lotebush (*Condalia* spp.), Mexican tea, snakeweed (*Gutierrezia* spp.), *Acacia* spp., *Mimosa* spp., and various cacti, such as barrel cactus or bismaga (*Ferocactus wislizenii*), *Echinomastus intertextus*, *Thelocactus uncinatus*, Turk's head (*Echinocactus horizonthalonius*), pencil cactus (*Opuntia leptocaulis*), Engelmann's prickly pear (*O. engelmannii*), *O. macrocentra*, two chollas, *O. imbricata* and *O. spinosior*, Texas rainbow (*Echinocereus dasyacanthus*) and, in the southwestern corner of the state, the true rainbow cactus (*E. rigidissimus*).

At higher elevations, particularly on ridges, hills, and low mountain areas in the association, the range supports several species of plants not, or only sporadically, represented at the lower levels. Those species of grass already presented as characteristic of desert grassland usually become less abundant as elevation increases, whereas others here become more prominent in the composition, the most important of these being increasing amounts of blue grama, hairy grama (*Bouteloua hirsuta*), side-oats grama (*B. curtipendula*), and in some areas galleta grass (*Hilaria jamesii*). The important new shrubs and half shrubs are Apache plume (*Fallugia paradoxa*), hedgehog cactus (*Echinocereus* spp.), ocotillo (*Fouquieria splendens*), sotol, century plant (*Agave* spp.), mountain mahogany (*Cercocarpus* spp.), and datil (*Y. baccata*). In some areas, especially on rocky, gravelly, or sandy ridges and foothills, stands of beargrass (*Nolina*) sometimes are found associated with scrub oak.

**MIXED PRAIRIE OR MIXED GRASSLAND ASSOCIATION.** This association derives its name from the fact that the climax composition consists of both mid grasses and short grasses in more or less equal amounts. It is closest to the true prairie of midwestern
United States, as the mid grasses of the mixed grassland are also those of the true prairie. However, the annual precipitation of the two is very different, that of the mixed prairie being 10 to 15 inches less than that of the true prairie of midwestern United States.

In New Mexico, the mixed prairie association covers the typical rolling grassland plains of the lower elevations in the northern, central, and eastern portions of the state, with occasional extensions at somewhat higher elevations into the southern portions; it covers a much larger area than does any of the other associations.

A semiarid climate prevails throughout the mixed grassland, and annual precipitation varies from about 9 inches in portions of San Juan County in the northwestern corner to 18 inches along portions of the eastern boundary of the state. The summer precipitation (April 1 — September 30) varies from 76 per cent of the annual total in the northeastern counties to 61 per cent in the northwestern sector.

Although the general physiography and vegetative character of the mixed prairie in the state are sufficiently uniform to impart to the area a fundamental unity, nevertheless climatic, topographic, and soil factors are responsible for significant differences in vegetative composition in different portions of the association.

Throughout the association, in all communities, blue grama grass is the climax dominant and with it are associated several codominants in a variety of combinations, the most widespread of these being galleta grass. In places, particularly on sandy flats, gravelly ridges, and rocky hillsides, hairy grama may equal or occasionally exceed blue grama in abundance. Also, side-oats grama is often an important component, particularly on many sandy soils, gravelly plains and slopes, and in low areas — such distribution revealing its postclimax nature. In places, vine-mesquite grass is often rather common in association with blue grama, usually although not always in the lower spots. On sandy loams and sandhills, little bluestem (Andropogon scoparius) is a
common associate and with it are often to be found sand blue-stem (A. hallii) and Indian grass (Sorghastrum nutans). In low saline areas, stands of alkali sacaton are common, in places developing pure stands and, along the larger draws and ephemeral creeks, more particularly in the more southerly stretches of the association, expanses of big sacaton are to be seen.

The most common herbaceous plants in the association are stickleaf (Mentzelia spp.), thistle (Cirsium spp.), loco weed (Astragalus spp.), milkweed, blazing star (Liatris punctata), prairie clover (Petalostemum spp.), milkwort (Polygala alba), and slender scurfpea (Psoralea tenuiflora) which in the eastern part of the state is exceedingly abundant.

The most characteristic shrubs and half-shrubs of the association are snakeweed ( Gutierrezia spp.), rabbit brush (Chrysothamnus spp.), and soapweed (Yucca glauca), mesquite in the more southerly stretches; beargrass, particularly on limestone and sandstone ridges and hills; saltbush (several species, but especially Atriplex canescens), and on level or depressed saline areas, greasewood (Sarcobatus vermiculatus), and winter fat ( Eurotia lanata). In the eastern part of the state Mimosa borealis is very common. Certain cacti abound in the grassland and on slopes and hills as well as often in sandy areas. Most important are cholla (O. imbricata), New Mexican prickly pear (O. phaeacantha), O. ballii in the eastern part of the state only, O. hystrix, O. polyacantha, O. clavata, green pitaya (Echinocereus viridiflorus), hedgehog cactus (E. coccineus, E. gonocanthus, and E. triglochidiatus).

On the Staked Plains soapweed and cholla, so common in parts of New Mexico, are uncommon except in localities where the grasses are unable to compete, such as in sandy, gravelly, broken rocky, and disturbed areas.

Since the more southerly portions of the mixed prairie association are transitional with northern stretches of desert grassland, such desert grassland species as black grama and bush muhly are to be found in these transitional areas of mixed grass-
land in limited amounts. This is true in the lower elevations of the Canadian River drainage as represented by the general Tucumcari–Conchas Dam–Logan area which, although geographically far removed from the ecotone region in the eastern part of the state, because of its low elevation is also a transitional area between the two associations. In these transitional areas, blue grama definitely ranks as the dominant species, but with it are often found varying amounts of black grama, especially on sandy and gravelly soils, and bush muhly, at present confined largely to the protection of various shrubs, although unquestionably formerly much more widespread.

On the rolling plains in the higher rainfall belt of 16 to 18 inches that spans portions of the eastern border of the state, including the lower Canadian Valley and the general vicinity of Tucumcari, another low grass, namely buffalo grass (*Buchloë dactyloides*), enters the association as an important element of the composition. As would be expected, blue grama is still the dominant climax grass and galleta grass also abounds, but buffalo grass may make up from 15 to 30 per cent of the total composition.

Another modification in the mixed prairie composition is to be seen on the rather high plains east and south of the mountain ranges in parts of Union, Colfax, Mora, Harding, and San Miguel counties. In general these plains are located on the Canadian River caprock and below the foothills and high mesas reaching north of Las Vegas and east of Raton. Although blue grama here continues to be the dominant grass under climax conditions, western wheatgrass (*Agropyron smithii*) enters and becomes the chief codominant, making up at least 15 per cent of the composition. Galleta grass and Texas timothy (*Lycurus phleoides*) are also important components, and some of the mid grasses already mentioned are moderately abundant. In the vicinity of Raton several true prairie species are to be found, especially in the crevices and malpais.

*An ecotone is the transition zone between two communities.*
This same situation holds with little modification over the plains and gentle slopes of the upper Rio Grande west, north, and immediately south of Taos, portions of the lower Chama River drainage, and the Rio Puerco and San Juan river drainages adjacent to the foothills of the Jemez Mountain chain. Several new species appear in the composition in this area: needle-and-thread grass (*Stipa comata*), Indian ricegrass (*Oryzopsis hymenoides*), prickly poppy (*Argemone hispida*), spiny saltbush (*Atriplex confertifolia*), and big sage (*Artemisia tridentata*). The northwestern sector of the state is especially interesting in that some elements of its vegetation affiliate it with that of the Great Basin of Utah and Nevada.

As the ranges in the mixed prairie association deteriorate under the impact of drought and grazing misuse, a number of species of plants increase markedly in the grasslands. Of the grasses, species of three-awn, ring muhly (*Muhlenbergia torreyi*), and sand dropseed are most common, while of the shrubs and half-shrubs snakeweed, rabbitbrush, spiny saltbush, and big sage increase most vigorously.

Much of the area that formerly supported mixed grassland in the north central and parts of the northwestern portions of the state are now covered by extensive stands of big sagebrush. In the Great Basin country of Utah, Nevada, and western Idaho, big sage is regarded as a climax community on large areas of fine, light, deep, nonalkaline soil where it is well adapted to both climate and soil. Although islands of this sage originally were doubtless to be found in the area in New Mexico under discussion, its present abundance and dominance are definite disclimax owing to continued misuse of grasslands. Sagebrush has characteristically invaded level grassland areas and alluvial fans in parts of the mixed prairie, where it has developed solid extensive stands. Like creosote bush and mesquite in the desert grassland association, it has become so firmly entrenched that it is now nearly impossible for the original climax vegetation to overcome it. In other words, it appears that sagebrush has now
come to stay in large areas of the north central and northwestern parts of the state.

In the areas dominated by sagebrush, the most characteristic subdominants are spiny saltbush, rabbitbrush, *Tetradymia spinosa*, winterfat, and in some areas Mormon tea (*Ephedra viridis*). Also, in places in the northwestern sector two shrubs, cliffrose (*Cowania*) and *Purshia* abound, and the most characteristic cacti are *Sclerocactus whipplei*, *Opuntia plumbea*, and *Coloradoa mesa-verde*. It is worthy of note that cholla reaches its northwestern limit about four miles south of Cuba.

**Woodland Biome**

This biome is characterized by small trees usually not more than thirty, and at most forty, feet tall. Usually they are well spaced, with grassland in the open spaces, but under proper conditions they are capable of forming a canopy and, therefore, of producing a real, although low, forest. Typically these trees belong to three genera, the junipers, the pines, and the oaks.

In its total southwestern distribution, the woodland climax has suffered more from climatic desiccation than has any other, with the result that probably less than one-fourth of the original area covered by the community remains at present in climax condition with a closed canopy and proper ground cover, and this occurs only at the higher elevations. Over a large part of its lower levels, the climax is reduced to a single species of juniper that displays the habit of a low shrub. Moreover, this type of savanna has been greatly extended within the last three-quarters of a century as a result of drought, grazing misuse, and the scattering of juniper seeds by sheep and birds.

In New Mexico, woodland ranges from about 4,500 to 7,500 feet elevation, with local variations, of course. Typically, it inhabits the foothills and lower parts of the mountains, with a rolling to very rough topography, that ranges from 1,000 to 2,000 feet above the surrounding plains, although it also occupies
ridges, knolls, breaks, dissected mesa edges, escarpments, and rocky outcrops.

The average annual precipitation rate in the woodland biome ranges from 13 to 20 inches. An annual fall of as little as 10 to 12 inches supports no trees except widely spaced junipers.

It is an interesting question as to what prevents the encroachment of woodland into the grassland associations, and several attempts have been made to solve this problem. Thus, Woodin and Lindsey, in a study of woodland in New Mexico east of the Continental Divide, concluded that differences in mean temperature during the growing season as well as differences in latitude are unimportant compared with the influence of precipitation in the distribution of woodland. Pearson, working on the factors that control the distribution of forest types in the San Francisco Mountains of Arizona, concluded that deficient moisture is the limiting factor in the encroachment of piñon-juniper woodland upon the desert, and that low temperature is the factor inhibiting its ascent into the ponderosa pine (*Pinus ponderosa*) community where moisture conditions are more favorable. Other workers have also studied this problem from the standpoint of temperature and precipitation and there is not complete agreement among them.

While precipitation and temperature are important factors, most investigators have ignored another highly important factor, namely competition, which in essence may be said to constitute competition for soil moisture. In grassland, the soil is usually fine and the root systems are distributed largely within the upper few inches to a foot of soil; therefore, precipitation is utilized before it has an opportunity to penetrate deeply. It is not only very difficult for juniper and piñon seedlings to become established in soil that contains such an extensive network of grass roots which utilize all the moisture, but roots of these tree species characteristically penetrate deeply into the soil and thus require deep moisture that is not available in grassland. On rocky and gravelly knolls, for example, grasses are much less able
to compete, the moisture penetrates more deeply, and piñon and juniper seedlings are better able to become established.

In New Mexico, it is well known that heavy grazing in woodland invariably results in denser stands of trees; also, that within the last three-quarters of a century misuse of grassland has resulted in the extension of junipers into adjacent desert grassland and mixed grassland. There is an old saying in the Southwest to the effect that cattle are the best friends the forests have. This means that as grasslands adjacent to woodland become misused, competition from grasses is reduced and the woodland species gradually encroach upon the grassland.

Throughout New Mexico the vegetative composition of woodland varies considerably in relation to annual precipitation, temperature, altitude, latitude, rate of evaporation, and perhaps seasonal distribution of rainfall.

Woodland usually consists of one-seed juniper (*Juniperus monosperma*) and piñon pine (*Pinus edulis*), sometimes with more or less oak (*Quercus* spp.), and carries an understory of grassland and forbs and a scattering of shrubs. However, other species of juniper and pine, as well as a variety of shrubs, enter the biome as the altitude and the latitude change. Juniper characteristically exceeds pine in abundance and cover over most of the woodland association and, in some areas, particularly lower elevations, piñon may be entirely lacking. Only at the highest elevations is the pattern reversed, giving a higher ratio to piñon over juniper.

In addition to one-seed juniper and piñon pine, the basic components of woodland in most of the state, Rocky Mountain juniper (*J. scopulorum*) enters at about 6,000 feet elevation or its latitudinal equivalent throughout much of the state; moreover, Utah juniper (*J. osteosperma*), limited largely to the western part of the state, is sometimes associated with one-seed juniper or piñon. Then, too, alligator juniper (*J. deppeana*) is common with one-seed juniper in the mountain areas of the southern and western parts of the state, being heaviest west of
the Continental Divide with major concentration in the Gila National Forest, where in places it assumes the dominant role in the composition. In the southwestern part of the state another species of pine, the Mexican piñon (P. cembroides) is a woodland component.

In woodland a number of species of oak often are to be found in various combinations with juniper and piñon; in places the oaks may form solid stands of their own. Most common of these are wavyleaf oak (Q. undulata), Arizona white oak (Q. arizonica), Emory oak (Q. emoryi), gray oak (Q. grisea), shrub live oak (Q. turbinella), and Gambel oak (Q. gambelii). Some of these oak species reproduce extensively by sprouts from underground branches, forming dense thickets.

Associated with juniper, piñon, and oak in the woodland biome are a number of species of shrubs such as big sagebrush in the north central and northwestern parts of the state only, mountain mahogany (Cercocarpus spp.), barberry (Berberis spp.), ash (Fraxinus spp.), serviceberry (Amelanchier spp.), mock orange (Philadelphus microphyllus), skunk bush (Rhus trilobata), scarlet sumac (Rhus glabra), Fendlera, Apache plume (Fallugia paradoxa), New Mexico privet (Forestiera neomexicana), soapweed (Y. glauca), datil (Y. baccata), beargrass, and cholla. In places mesquite is common as an associate of one-seed juniper. In the southern part of the state, others such as desert sumac (R. microphylla), Mearn’s sumac (R. choriophylla) Schott’s yucca (Y. schottii), mescal or century plant, buckbrush (Ceanothus spp.), manzanita (Arctostaphylos pungens), and madron (Arbutus texana) in the Guadalupe Mountain area only, are common components of woodland vegetation.

One of the most common woodland forbs is Indian paintbrush (Castilleja integra); others are globe mallow (Sphaeralcea spp.), Gaura neomexicana, ragweed, rubber plant (Hymenoxys spp.), and aster.

Much of the juniper-piñon woodland consists of rocky soil on which grasses are poorly developed. The common woodland
grasses are chiefly those of the mixed prairie, but with the addition of others. The main species is blue grama which is usually dominant in the open parks and valleys, although in places it is accompanied by considerable amounts of hairy grama, side-oats, and galleta. Others are June grass (*Koeleria cristata*), sandhill muhly (*Muhlenbergia pungens*), spike muhly (*M. wrightii*), bull-grass (*M. emersleyi*), deergrass (*M. rigens*), several three-awns, sand dropseed, black dropseed (*Sporobolus interruptus*), Arizona fescue (*Festuca arizonica*), and in the northern part of the state western wheat. In the west-central and northwestern sectors Indian ricegrass is scattered in the lower levels of the juniper-piñon belt.

**Coniferous Forest Biome**

The coniferous forest in the Rocky Mountains has two subdivisions, the Petran subalpine and Petran montane. Contrary to the procedure followed thus far of beginning with the lowest elevations and working upward; the plan now will be reversed, and the higher of the two, the Petran subalpine, will be presented first.

**PETRAN SUBALPINE FOREST ASSOCIATION.** In New Mexico, the Petran subalpine reaches from timberline down to the upper limit of the ponderosa pine-Douglas fir forest. It includes stands of spruce, fir, and aspen, open grassy slopes, small parks, and wet mountain meadows. Elevations range from about 8,500 to 12,000 feet with considerable variation attributable to exposure. This association covers approximately 4,000 square miles, the major portion of it lying in the Sangre de Cristo Range extending from just north of the Colorado state line to a point opposite Santa Fe. Less extensive stands are found in the other larger mountain masses of the state.

The two dominant species in the plant composition of the Petran subalpine forest are Engelmann spruce (*Picea engel-
mannii) and subalpine fir (Abies lasiocarpa). Associated coniferous species are foxtail or bristlecone pine (Pinus aristata), blue spruce (Picea pungens) and locally small amounts of white fir (Abies concolor) and Douglas fir (Pseudotsuga menziesii). Also, there is a scattering of Rocky Mountain maple (Acer glabrum), thinleaf alder (Alnus tenuifolia), and Bebb willow (Salix bebiana), the last two along streams or in moist meadows. Although the climax vegetation is made up of stands of spruce-fir with associated conifer species of less importance, subclimax communities also occur, the most important being aspen (Populus tremuloides) and subalpine grasslands.

Owing to shade and heavy acid-forming litter, the shrubby and herbaceous understory in the spruce-fir community is sparsely developed and is dominated particularly by blueberry (Vaccinium oreophilum), kinnikinnick (Arctostaphylos uva-ursi), box myrtle (Pachystima myrsinates), red elderberry (Sambucus racemosa), russet buffaloberry (Shepherdia canadensis), currant (Ribes spp.), Oregon grape (Berberis repens), prostrate juniper (Juniperus communis), pigeonbush or black-fruited honeysuckle (Lonicera involucrata), and shrubby cinquefoil (Potentilla fruticosa).

Of the herbaceous species, the most common are hellebore or “skunk cabbage” (Veratrum californicum), green gentian (Swertia spp.), blue columbine (Aquilegia caerulea), larkspur (Delphinium spp.), monkshood (Aconitum columbianum), beardtongue (Penstemon spp.), lousewort (Pedicularis spp.), baneberry (Actaea arguta), violet (Viola spp.), and Jacob’s ladder (Polemonium spp.).

In New Mexico, seral\(^5\) stages that break the general climax forest aspect are common. Not only do extensive areas of subclimax exist, but the subclimax communities are often more extensive than the climaxes. Much of this subclimax is attributable to the fact that the Indians and early settlers burned large

\(^5\)A sere consists of a series of communities that follow one another in time and lead ultimately to a recognized type of climax.
forested areas in the hope that stands of grass would appear. In the state there occur large areas of aspen which, usually coming in on areas that have burned, constitute a common subclimax community in the Petran subalpine association. It is difficult to find in New Mexico or in the Rocky Mountains an aspen tree that is more than one hundred years old. Exceedingly intolerant of shade, aspens are shallow rooted, prolific seed producers, and although reproduction is largely by suckers, seedlings are relatively rare. The species reproduces vigorously on burned forest areas and forms a protective canopy for the more shade-tolerant spruce-fir reproduction. Aspens do not do well at the highest levels in this association, their place usually being taken by grassland.

The less dense shade together with the non-acid forming humus in aspen groves, as compared with spruce-fir stands, allows the development of a luxurious shrub and herbaceous understory, where mixed societies of grasses and forbs sometimes attain a striking development. The characteristic shrubs in the aspen community, in addition to those mentioned for the spruce-fir community, are snowberry (Symphoriocarpus spp.), chokecherry (Prunus spp.), raspberry (Rubus spp.), and rose (Rosa spp.). The additional perennial forbs are bluebell (Campanula spp.), vetch (Vicia spp.), figwort (Scrophularia spp.), strawberry (Fragaria spp.), horsemint (Monarda menthaefolia), geranium (Geranium spp.), and red columbine (Aquilegia elegantula), with smaller amounts of yarrow (Achillea lanulosa), fleabane (Erigeron spp.), bedstraw (Galium spp.), golden pea (Thermopsis pellitorum), sneezeweed (Helenium spp.), paintbrush (Castilleja spp.), meadow rue (Thalictrum fendleri), and golden rod (Solidago spp.). The most important grasses are mountain brome (Bromus marginatus), slender wheatgrass (Agropyron pauciflorus), bearded wheatgrass (A. subsecundum), Thurber's fescue (Festuca thurberi), Columbia needle grass (Stipa columbiana), alpine timothy (Phleum alpinum), timber oatgrass (Danthonia
intermedia), hairgrass (Deschampsia caespitosa), blue wild rye (Elymus glaucus), and several species of bluegrass (Poa).

In the Petran subalpine forest association there is a third, the subalpine grassland community. Such grasslands may occur as small parklike openings in timber stands, on rolling tablelands interspersed with clumps of spruce, or on slopes and ridges that have been burned in the past. Although the grass and forb species of this community show considerable similarity to those of the aspen community, there are some important differences, but these will not be discussed here.

**PETRAN MONTANE FOREST ASSOCIATION.** In general, the area covered by this association in New Mexico ranges from approximately 7,000 to 9,500 feet elevation, although each mountain mass shows some variation. It covers extensive areas of the state. This forest is invariably open, clean, and often grassy, and in places such as the Jemez Mountains shows excellent reproduction of the dominant tree species, ponderosa pine. It is believed that formerly this pine came down lower on the mountain slopes than at present and this is undoubtedly true in the Zuñi Mountains, for example, where extensive logging and gross misuse of the forest cover has taken place.

For the major portions of the association in the state, annual precipitation ranges from 16 to 22 inches, although some post-climax areas with shallow rocky soil that presently support yellow pine may have as little as 14 inches. Temperature extremes do not so decisively restrict the limits of the growing season as they do in the Petran subalpine.

The dominant species in the Petran montane are ponderosa pine, Douglas fir, and white fir. The ponderosa pine-Douglas fir community is the climax cover, and either one may occur as a single dominant, or the two may grow in mixed stands. In places, forests of nearly pure ponderosa pine cover large areas; in others, extensive forests of Douglas fir occur, especially on the northern
exposures. Also varying amounts of white fir appear in the association, one of the finest examples in North America being on the east slopes of the Sandia Mountains, where a beautiful, extensive solid stand is to be seen. Of the major dominant conifers, ponderosa pine, which abounds at the lower levels of the association, is the most tolerant of dry soil and atmosphere, followed by Douglas fir and white fir which are more characteristic of higher levels. Still another species of wide range but usually of secondary importance is limber pine \((Pinus flexilis)\), although it is abundant in such places as the Jemez Mountains and Capillo Peak in the Manzano Mountains. Blue spruce is likewise of local importance only. Also, aspen occurs in groves at higher levels and is usually subclimax in burned areas.

Ponderosa pine is highly intolerant of shade and, as a result, mature and near mature stands usually have a sufficiently open canopy to allow the development of a moderately dense and uniform herbaceous understory. In the upper reaches of the association the ground cover affiliates considerably with that of the Petran subalpine association, the important shrub additions being ocean spray \((Holodiscus dumosus)\), ninebark \((Physocarpus monogynus)\), and \textit{Jamesia americana}. The perennial forbs are very similar in the two, and the important additional grasses are mountain muhly \((Muhlenbergia montana)\), Arizona fescue, and pine dropseed \((Blepharoneuron tricholepis)\). Similarly, the ground cover at the lower levels of the Petran montane has much in common with that of the upper levels of the woodland biome, especially as regards the forbs and grasses. In the southern part of the state, however, these lower levels of Petran montane support plains lovegrass \((Eragrostis intermedia)\), bullgrass, and small amounts of Texas timothy.

In all forested mountain areas in the state, the usual correlation between elevation and temperature holds in a general way. Moreover, it is widely accepted that latitude is definitely subordinate to elevation in determining climatic variation. Studies in Arizona by Pearson, supported with little variation by Shreve's
investigations, show the mean temperature gradient from Kingman (3,300 ft.) to timberline on the San Francisco Mountains (11,500 ft.) to be 3.68°F for each 1,000 feet. However, the fall in temperature was found to be by no means constant for a given rise in elevation, the least difference being between the ponderosa pine and the Douglas fir stations representing a difference of 1,600 feet. Moreover, in many instances the relation between these two shows a definite inversion, the highest temperature occurring at the highest altitude, an observation that holds for both the San Francisco and the Santa Catalina mountains, and doubtless elsewhere.

These irregularities in temperature gradient are due to irregularities in the minimum temperatures, the maxima showing a very uniform gradient. Extreme minimum temperatures were usually found to be lower in the yellow pine community than at any of the higher stations, even timberline, followed closely by the alpine tundra association, whereas both above and below the yellow pine community the trend was normal. Both the lowest absolute minima and the shortest frostless period occur in the yellow pine community; in fact the frostless period is more than 30 days longer in the Petran subalpine association than in the yellow pine community. This is due to air drainage, as cold air currents descend from the high mountain slopes and spread out over the mesas and valleys below.

The daily range in temperature has been found to be greatest at the lower elevations. Thus in piñon-juniper woodland a daily range of 40 to 50 degrees is common; in the subalpine and alpine areas, where temperatures above 70°F are extremely infrequent, the range is rarely more than 20 degrees. In the spruce-fir community in the San Francisco Mountains the temperature is remarkably constant and rarely reaches 70°F, the daily range on typical sites rarely exceeding 20 degrees.

It is a widely accepted conclusion that the upper distributional level of all forest tree species is limited by low temperature, owing primarily to its effect on photosynthesis, and Bates, as the
result of his studies in the central Rocky Mountains, maintained that low winter soil temperature is the determining factor for the upper limit.

The solution of the problem of the causal factors that set the lower elevation limits of forest species is obviously more complex. However, it is significant that Blumer, Graham, Hanson, Larsen, Shaw, Shreve, Vestal, Weaver, and Whitfield concluded that low moisture is more important than high temperature in determining the lower altitudinal limits of forest tree species. Bates, Pearson, and Daubenmire have made the principal experimental contributions to this problem, although their results have not led to the same conclusions. Bates maintained that high temperature at the soil surface is the limiting factor for the lower altitudinal limit of forest tree species and that the forest zones of the central Rocky Mountains "are essentially temperature belts and only secondarily moisture belts." On the other hand Pearson, working in the San Francisco Mountains of Arizona, held that the lower elevation limits are determined by the varying abilities of tree species to withstand drought.

Daubenmire in greenhouse experiments has shown conclusively that the seedlings of different species of Rocky Mountain conifers show marked differences in their ability to tolerate high soil-surface temperatures, and that differences are correlated to a certain degree with the relative altitudinal distribution of the several species. Despite these results, he concludes that high soil-surface temperatures do not explain the lower elevational limits of forest tree species for three reasons:

A. The maximum temperature level which each species can tolerate well exceeds the maximum temperatures obtained in numerous microhabitats below its altitudinal range (shaded areas, e.g.).

B. A number of species including subalpine fir can be transplanted and grown far below their natural lower elevational limits without making compensation for the higher soil-surface temperature there.
C. The correlation between altitudinal and temperature tolerance is not absolute, yellow pine having no greater tolerance than does Douglas fir although it extends to distinctly lower altitudes; throughout those parts of the Rocky Mountains where both species occur there is a definite difference in their elevational ranges. Hence, some factor other than surface temperatures must prevent Douglas fir from extending downslope into areas occupied by yellow pine.

Daubenmire also concluded, as the result of greenhouse experiments with conifer seedlings, that all species tested were able to survive atmospheric drought far in excess of what most of the species normally encounter in nature; also all species, regardless of altitudinal range, have approximately equal resistance to such drought. He also measured evaporation rates in the field in five vegetation zones, from prairie to subalpine, in the vicinity of Moscow, Idaho, and found that there is no important difference in the evaporation rates in climax associations from one zone to the next during the season most critical for seedling survival. Therefore, it appears that no importance can be assigned to atmospheric drought as such in determining the elevation down to which each species can extend its range.

Of special interest are Daubenmire's experimental results. He reported definite differences among species of conifers with respect to the abilities of their seedlings to survive almost identical conditions of soil drought. In general, those species that grow at relatively high elevations can tolerate very little desiccation, whereas those that are characteristic of low elevations can survive periods of soil drought several times as long without apparent injury.

Since the intensity and duration of soil drought, on the basis of field studies of a number of investigators, are known to increase downslope, this factor appears to offer at least a partial explanation of the differences in lower altitudinal range limits of different coniferous species. Moreover, the significance of this difference among the species is greatly magnified by the fact
that the species of low elevation have the most rapid rates of root penetration.

Finally, Daubenmire points out that the importance of soil moisture as a governing factor in setting the lower limits of altitude of forest tree species in the Rocky Mountains may still be little more than a theory, but there has accumulated an impressive body of field data and physiological tests to substantiate it.

Petran Alpine Tundra Biome

The older literature envisioned an arctic-alpine tundra that was regarded as occupying the arctic regions of the world, as well as high elevations in mountain areas. The present tendency, however, is to favor two divisions of tundra, namely arctic tundra and alpine tundra. The alpine tundra in the western hemisphere represents relict communities that were left behind on high mountain areas as the main body of tundra retreated northward in the wake of melting glaciers.

The tundra biome is composed of several associations, but our concern is with the Petran alpine tundra association, confined to the Rocky Mountains. Two branches of the main Rocky Mountain mass extend into northern New Mexico, namely the San Juan Range on the west of the Rio Grande Valley and the Sangre de Cristo Range to the east. The latter, reaching its northern limit at Poncha Pass in southern Colorado is the highest and most extensive range in the state and reaches south between, and a little beyond, Santa Fe and Las Vegas as a broad, well-defined range that in places is divided into two. It has three groups of peaks in New Mexico that rise to the 13,000 foot level and support alpine tundra.

In New Mexico, the Petran alpine tundra must be interpreted as including the arctic-alpine zone and a large part of the Hudsonian zone as delimited by Merriam and by Bailey. It caps the highest peaks of the Sangre de Cristo Range, with small amounts on the White Mountains and Mt. Taylor and traces on the
VEGETATION OF NEW MEXICO

Jemez, Sandia, Mogollon, and Capitan mountains. In general, it stretches from elevations of about 11,000 to 13,160 feet atop Wheeler Peak, the highest elevation in the state, although locally it may drop as low as 10,500 feet, particularly on steep northeast slopes. The total area of this association is about 400 square miles.

Annual precipitation varies from 30 to 45 inches, and the tundra is largely covered by deep snows for eight or nine months of the year; in fact, on some of the cold slopes snow banks endure throughout the summer, melting completely only in exceptionally warm or dry years. There is rarely a frostless night throughout the cold short summer.

In general, the Petrjan alpine tundra association may be regarded as extending from the tops of the highest mountain peaks to timberline. Neither in New Mexico nor elsewhere is there an absolute tree line, nor is it possible to draw a sharp line between the Petrjan subalpine forest and the Petrjan alpine tundra since stunted trees grow singly or in patches almost to the mountain summits. However, there is a tree line and it is the line at which the forest cover stops, giving way to open alpine vegetation with occasional clumps of stunted, gnarled trees in the depressions. Timberline is here defined as the line at which trees cease to have an erect, treelike form and thus where Engelmann spruce, bristlecone pine, and subalpine fir are barely able to persist, doing so only in stunted, gnarled, bushy, or prostrate form. These species may extend in scattered distribution or in thin stands in protected localities for several hundred feet beyond the actual timberline.

Some of the investigators who have studied the ecology of alpine tundra are convinced that the most important climatic and soil factors that influence alpine vegetation are winter rather than summer factors, and that the most advantageous time for studying alpine tundra is winter.

Adams and his associates, working on Mt. Marcy, New York, concluded on the basis of observations and brief instrumental
records of climate that the most important factors in determining timberline are effective temperatures, wind, and depth of snow. They found the daily range of temperature to increase with elevation, except that the range just below timberline was slightly greater than just above. Of particular interest is the fact that the greatest change in amount of effective temperature at all stations occurred between the points just below and just above timberline despite the short distance of 75 feet in elevation between the two points, and that this change corresponds with the abrupt break between the subalpine or fir-spruce and alpine associations. This at least suggests that the amount of effective temperature may be the principal cause producing the sharp line of demarcation between the two communities.

Somewhat similar conclusions were reached by Pearson for the San Francisco Mountains. Here it appears that the upper limit of Engelmann spruce distribution in tree form is usually determined not by deficient heat supply for photosynthesis, but by conditions that affect the availability of moisture as limited by low temperature, high evaporation, abrasive action of wind and snow, and in some cases lack of soil. Occasionally he found moderately deep pockets of soil located among boulders sheltered from wind — and thus seemingly favorable to tree growth in all respects save temperature — which, however, lacked trees. He therefore concluded that the final upper limit of both Engelmann spruce and foxtail pine is determined by low temperature. Of interest in this connection is one of Pearson's tables, giving the duration of different temperatures, which shows that the alpine association had, in 1918, 23 per cent less hours above 42° F. than did the Engelmann spruce forest.

Despite the apparent importance of effective temperature in determining timberline, wind movement near ground level is evidently another limiting factor in conifer distribution at alpine levels, and this is determined chiefly by the density of forest cover. The lowest wind movement is found in the Engelmann
spruce-subalpine fir community; the highest records occur in alpine tundra where forest cover is lacking.

Adams, in studying the relation of wind action to stunted trees on Mt. Marcy, found that trees above timberline are confined to the depressions and suffer more from northwest winds than those from any other direction. As a rule, tree height corresponds to the depth of the depression and the trees form a very dense canopy at a certain level that doubtless corresponds with the depth of snow in winter. Moreover, the trees continually send up branches above this level but they are gradually and definitely killed back, injury to them above snow level generally being on the northwest and not indicating a high degree of mechanical action. At the approach to timberline the stature of the trees is gradually reduced, and the farthest outposts are usually limited to those portions of the topography that afford adequate protection from the wind, which by desiccation kills the seedlings that succeed in germinating on exposed areas.

Daubenmire, writing of subalpine fir, showed that in a small grove of trees at upper timberline in Wyoming, the lower branches formed a dense layered mat, well protected from desiccation by snow. In a zone immediately above this mat all buds were sheared off the bole by abrasive ice particles that were blown over the snow surface with strong force. Buds on the windward side of a tree standing erect in the clump were killed each year by ice blasting or winter desiccation.

Evaporation is still another important factor influencing alpine vegetative cover. It is controlled mainly by temperature, relative humidity, and wind. Low temperature obviously favors low evaporation and in general the evaporation rate tends to increase with elevation. This is so despite the influence of lower temperatures at higher elevations, since this influence is more than counterbalanced by the high wind movement. As a result evaporation is quite high in the arctic tundra.

The Petran alpine association of the Rocky Mountains is not
so rich in communities as is the Arctic alpine of the far north, owing largely to the paucity of hydroseres,\textsuperscript{6} and the greatest similarity between the two appears in comparisons that relate to the climax proper. The number of dominants in the alpine tundra is large, although the leading role is taken by a relatively small group.

Alpine tundra in New Mexico, as elsewhere, is very uniform in life forms, growing to a height of only a few inches above ground level, where wind velocity is much reduced. It is a treeless zone at and above the level of the last dwarf Engelmann spruces, subalpine firs, and bristlecone pines, and is characterized by low, often matted, vegetation of hardy alpine plants, some of which occur on the Arctic tundra of the far north and reach their southernmost limits on the New Mexican peaks.

Seres in this biome are very limited although both xeroseres and hydroseres occur. The xeroseres are the more conspicuous and consist of mosses, lichens, and forbs, followed ultimately in succession by grasses and sedges that take over as the climax develops. Hydroseres are not common, for when it rains in the alpine area the precipitation is largely absorbed by the soil; moreover, the snows melt slowly. Hence those streams that do occur show little fluctuation in flow and there is no flood plain resulting from high-level flow. The hydroseres vegetation consists largely of sedges and rushes that grow along the margins of ponds or in marshes.

Typically, the alpine tundra is made up of dominant sod-forming or densely-bunched grasses and sedges among which are numerous subdominant forbs that in general constitute mixed societies, a large number of them being endemic to the association.

Of the alpine tundra grasses, the bluegrasses (\textit{Poa} spp.) furnish the largest number of species, followed by the wheatgrasses (\textit{Agropyron} spp.), the oat grasses (\textit{Danthonia} spp.), and the fes-\textsuperscript{6}The different stages of a series of successions that begins in such places as ponds, lakes, and marshes and becomes drier, constitutes a hydroseres.
cue grasses (*Festuca* spp.), although spike trisetum (*Trisetum spicatum*) is the most abundant of all. Mountain timothy (*Phleum alpinum*), tufted hairgrass (*Deschampsia caespitosa*), ticklegrass (*Agrostis hiemalis*), and Columbia needlegrass (*Stipa columbiana*) also occur. Of the sedges and rushes the genus *Carex* is best represented in number of species, followed by *Juncus, Luzula*, and *Kobresia*.

In accordance with the general rule, the alpine societies of forbs are best developed in subclimax and disturbed areas where the control of the dominant grasses and sedges is not yet complete. Although the length of the growing season at these high elevations is very short, at most two and one-half months, these forbs are distributed, as regards their period of flowering, into three groups, namely spring, summer, and late summer flowering species. Naturally, the length of these three seasons is short as compared with their duration at lower elevations, and one must realize that here as elsewhere there is more or less overlapping of the seasonal lists.

Spring lasts through late June and early July and during it such species flower as primrose (*Primula*), alpine forget-me-not (*Eritrichium elongatum*), elk slip (*Caltha leptosepala*), buttercup (*Ranunculus*), whitlow grass (*Draba*), clover (*Trifolium*), meadow rue (*Thalictrum*), arctic spring beauty (*Claytonia megarhiza*), sandwort (*Arenaria*), *Stellaria*, chickweed (*Cerastium*), wild onion (*Allium*), and kitten tails (*Bessyca alpina*). The summer aspect prevails during most of July and early August and is characterized by a number of species of somewhat taller stature. Important among these are avens (*Geum turbinatum*), lungwort (*Mertensia*), knotweed (*Polygonum*), wormwood (*Artemisia*), Jacob's ladder (*Polemonium*), pussy's toes (*Antennaria*), blue columbine (*Aquilegia*), death camas (*Zigadenus elegans*), cinquefoil (*Potentilla* and *Sibbaldia procumbens*), alum root (*Heuchera parviflora*), and larkspur (*Delphinium*). The major dominants of late summer are bluebell (*Campanula*), gentian (*Gentiana*), painted cup (*Castilleja*), saxifrage (*Saxifraga*), stem-
Less catchfly (Silene acaulis), stonecrop (Sedum), lousewort (Pedicularis), and a number of composites, the more common being alpine yarrow (Achillea), mountain dandelion (Agoseris), fleabane (Erigeron), Haplopappus pygmaeus, Helianthella parryi, goldenrod (Solidago), groundsel (Senecio), and rubber plant (Hymenoxys acaulis).

Shrubs are rare, the only ones to be found being shrubby cinquefoil (Potentilla dasiphora) and currant (Ribes). The only trees to be seen are rare depauperate specimens of Engelmann spruce, alpine fir, or foxtail pine, with occasional willow trees (Salix) that do not exceed twelve inches in height and are confined to alpine bogs and meadows.

Principal Sources of Reference


