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TECHNICAL NOTE

U.S. DEPARTMENT OF THE INTERIOR - BUREAU OF LAND MANAGEMENT

ECOLOGICAL CHARACTERISTICS OF PINYON-JUNIPER
WOODLANDS ON THE COLORADO PLATEAU
A LITERATURE SURVEY

by Mark Zarn



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PART I

THE COLORADO PLATEAU

A magic land of wild canyons, high windswept plateaus, rugged volcanic mountains, arid sand deserts, and bizarre shale badlands, the Colorado Plateau encompasses some 130,000 square miles between the Rocky Mountain and Basin and Range physiographic provinces (see Map). There, even the casual observer can understand many of the well-exposed and dramatic geological features, and aridity and inaccessibility have preserved an abundance of archeological sites dating to prehistoric times.

The varied structural geology of the Colorado Plateau, which has been uplifted as much as three miles since the Cretaceous Period (Table 1), consists of extensive areas of nearly horizontal sedimentary formations, structural upwarps which have formed striking topographic features, and igneous structures which include large central-type volcanoes, cinder cones and volcanic necks, high lava-capped mesas and plateaus, and dome mountains formed by intrusive forces. The surface of the Plateau lies at an average elevation of slightly over 5000 feet, but some plateaus and peaks exceed 11,000 feet. Narrow, steep-sided canyons formed by deeply incised drainage systems display brilliantly colored walls. Even though water has been the chief formative agent of many of its features, the Plateau today is an arid land where periods of drought alternate with violent seasonal flash-floods made more severe by the expansive areas of naked rock characteristic of much of this region. Human populations remain sparse and widely dispersed, averaging only about four persons per square mile (Hunt 1974).

While Cretaceous and older continental structures form the major structural elements which define the Colorado Plateau, the physiography of the province results from later Cenozoic crustal movements and igneous activity. The Plateau and the Southern Rocky Mountains lie on the high point of a tremendous Cenozoic arch, a geantecline reaching westward from the central United States almost to the Pacific Coast. The large block-faulted area of the Great Basin makes up the collapsed western flank of this arch. The Colorado Plateau, a mildly faulted segment of this flank, remains structurally attached to the Rocky Mountain geantecline (Hunt 1974). Hunt (1974:440-445) discusses the Cenozoic history which led to the formation of the Colorado Plateau.

FORMATION OF THE COLORADO PLATEAU

The earliest stages in the formation of the Colorado Plateau began about 490 million years ago, during the Paleozoic and Mesozoic Eras. At that time, the land mass which was to become the Colorado Plateau occupied a flat area near the edge of a sea upon which sediments were deposited. As deposition occurred, these areas appear to have subsided completely

beneath the water.

At the close of the Mesozoic Era, near the end of the Cretaceous Period--about 60 million years ago--compressive forces uplifted these sediment beds in a huge block. The Plateau underwent little structural change during this period other than some folding and warping of some of the sediment layers. A long cycle of erosion followed which wasted away the uplifted block to a level plain at or near sea level. Later, during the Tertiary Period of the Cenozoic Era, other very thick sediment beds were laid down over the area. The drainage system which developed over these beds would become the present-day Colorado River Basin.

Another period of uplift followed during which the Colorado Plateau reached its present-day elevation; some faulting took place during the process. Stream gradients on the Plateau increased due to the uplift and began to cut vigorously down through the rock strata. Over a period of about 20 million years this stream erosion produced the intricately dissected landscape of today. This erosional process has been so profound that folds and warping dating back to the Cretaceous Period have been exposed; these include the San Rafael Swell, Comb Ridge, and the Waterpocket Fold (Crampton 1964).

During the last erosional cycle, huge masses of molten rock pushed up through the sedimentary strata, bulging them but not breaking through. As erosion proceeded these structures were left behind as laccolithic mountains, which persist today as the LaSal, Henry and Abajo Mountains, all in Utah (Crampton 1964).

STRUCTURAL AND TOPOGRAPHIC UNITS OF THE COLORADO PLATEAU

Grand Canyon Section

The Grand Canyon Section comprises the high southwest part of the plateau and consists of complexly deformed Precambrian rocks overlain by about 4000 feet of Paleozoic formations, which are exposed in Grand Canyon and along the southwestern edge of the Plateau.

In the western portion of this section, a series of northerly trending faults have formed large blocks which delineate the transition between the Colorado Plateau and the much more extensively faulted Basin and Range Province.

About one-third of the Grand Canyon Section has been covered by Tertiary and Quaternary lavas from the San Francisco Mountain Volcanic field, and from some isolated volcanoes north of Grand Canyon. By the time the earliest of these lavas had erupted, the ancestral river had already cut deeply into Grand Canyon; some of the later flows poured down its walls and into the bottom of Grand Canyon. Radiometric dating of these lavas indicate that Grand Canyon was within 50 feet of its present depth 1.5 million years ago.

When Sunset Crater erupted in about the mid-eleventh century A.D., it buried a Pueblo Indian village with cinders and debris (Hunt 1974).

Datil Section

The Datil Section encompasses the south rim of the Colorado Plateau in New Mexico and eastern Arizona, where it forms a large area covered by thick lavas dating from middle Tertiary to Holocene times.

Principal structural features in this section include the upwarp at the Zuni Mountains, the large central-type volcano at Mount Taylor, the numerous smaller volcanic necks and craters around it, and the extensive lava-covered mesas and valleys to the south. These lavas extend southward into the Basin and Range Province; hence that boundary of the Colorado Plateau is arbitrary. Along the eastern edge of the Datil Section, the Basin and Range Province extends northward along the Rio Grande depression to the Southern Rocky Mountains; the boundary between this depression and the uplifted Colorado Plateau is sharply defined by the westernmost faults of the depression (Hunt 1974).

Navajo Section

The structural depression to the north of the Grand Canyon and Datil Sections is the Navajo Section. About one-half of it lies on the Navajo Indian Reservation. Broad flats on shaley formations, separated by low cuestas where more resistant sandstones crop out, characterize the Navajo Section. Colorful Triassic formations produce the Painted Desert, which extends far northwest of the national monument. In the San Juan Basin, the lowest part of the structural depression of the Navajo Section, Tertiary and Cretaceous formations resemble a series of stacked saucers which become progressively smaller near the top, forming outward-facing cuestas. Erosion of volcanic formations in this section has produced numerous volcanic necks, notably those of Shiprock, New Mexico and Agathla Peak in Monument Valley.

Canyon Lands Section

Canyons are the dominant feature of the Canyon Lands Section, which lies north of the Navajo Section. Four large upwarps occur there; the Uncompahgre Upwarp, the Monument Upwarp, the Circle Cliffs Upwarp and the San Rafael Swell. Between these upwarps lie structural basins, a large one beneath the Henry Mountains and another between the Kaibab and Circle Cliffs Upwarps. The northwest-running basin south of and parallel to the Uncompahgre Upwarp differs from other basins in the Section in that it contains thick deposits of salts.

The canyons of this section occur mostly in upper Paleozoic and lower Mesozoic sandstones. Jurassic and Cretaceous formations embrace thick shales which form badlands, arranged in belts between cuestas and benches arising

from resistant sandstone layers.

In some localities, the resistant canyon-forming sandstones have been turned up sharply along the flanks of asymmetric anticlinal upwarps to form the immense hogbacks locally known as "reefs" which, like the canyons, form nearly impossible barriers to travel. The thick sandstones found here erode into characteristic dome-like forms, as exemplified at Capitol Reef National Park, named for its domes which suggest the dome of the nation's capitol building in Washington, D.C. The nearly horizontal sandstone formations behind the canyon rims form bare, knobby rock surfaces deeply dissected by narrow, rock-walled gulches and small canyons. The dunes and sandy deserts of this section arise from the extensive areas of friable and earthy sandstones.

The laccolithic Henry Mountains, LaSal Mountains, and others are structural domes produced by the forceful upward injection of molten igneous rock which formed stocks. The injection of these plug-like masses domed the overlying rocks and those adjacent to them. As the stocks rose higher, they widened; the wider the stock, the deeper and higher the dome. Where the stocks encountered weak shales, the magma was squeezed sideways in them to form laccoliths.

The rounded summits of the higher peaks result from their exposure to intensive frost action during the glacial stages; the lower parts of the mountains still faithfully reflect the underlying geologic structure. The contrast between summits and lower slopes reflects differences in erosion processes (Hunt 1974).

Uinta Basin Section

The Uinta Basin Section to the north of the Canyon Lands Section forms an embayment between the Middle and Southern Rocky Mountains. This Section is the deepest portion of the Colorado Plateau structural bowl; structurally it lies four miles lower than the southwest rim of the Grand Canyon Section. About two miles of Mesozoic formations and another two miles of Tertiary formations overly the Paleozoic layers beneath the basin. These layers rise gently southward to the Canyon Lands Section and steeply northward onto the south flank of the Uinta Mountains. The Tertiary formations of the Uinta Basin Section form northerly-sloping, broad hilly benches, as well as the south-facing escarpments known as the Roan Cliffs. Where Cretaceous members rise southward from beneath the Tertiary formations, they form the south-facing Book Cliffs, a 2000 foot escarpment which extends about 100 miles across the southern edge of the Basin and overlooks the Canyon Lands Section (Hunt 1974).

High Plateaus Section

The western edge of the Colorado Plateau consists of northerly-trending fault blocks, many of which are lava-capped and form plateaus. None of

these plateaus are lower than 9000 feet in elevation; a few reach 11,000 feet. Beneath the lavas lie Mesozoic and Tertiary formations. Wide, flat-bottomed structural valleys, or grabens, which run north and south, separate the plateaus. Erosion has reduced the colorful Tertiary sedimentary deposits at Bryce Canyon National Park and Cedar Breaks National Monument to badlands. At the southern end of the High Plateaus, Zion Canyon resembles many of the canyons in the Canyon Lands Section.

Three great southward-facing escarpments that overlook the Grand Canyon Section delineate the southern boundary of the High Plateaus. Tertiary formations comprise the Pink Cliffs, the northernmost of these escarpments. Upper Mesozoic sandstones form the middle escarpment, known as the White Cliffs. Lower Mesozoic layers comprise the Vermillion Cliffs, the southernmost escarpment. Collectively, these escarpments are known as the Grand Staircase of Utah.

While a structurally high rim of the Colorado Plateau, the High Plateaus Section differs from the southern and southwestern rims in having been raised by faulting. Deformation, which began in late Cretaceous time, continued intermittently throughout Tertiary and Quaternary time. Since some of the faulting is recent, and the western edge of the High Plateaus Section lies along an active seismic belt, these fault blocks may still be moving (Hunt 1974).

CLIMATE

Climatic maps show the saucer-like form of the Colorado Plateau; precipitation is greater and evaporation less along its rims and on the high peaks than in the interior regions. The average annual precipitation is less than 10 inches in much of the interior, but it exceeds 20 inches on the high southwest rim. The rain shadow created by the High Plateaus is partly responsible for the aridity of the interior.

The high evaporation rate on the Colorado Plateau also accounts for its aridity. Effective moisture is even less than indicated by the average annual precipitation rate, especially during the growing season. Up to 95 percent of the precipitation is lost to evaporation, transpiration, and seepage into the ground.

Summers are hot and winters are cold. The frost-free period, about 200 days along the Colorado River, diminishes to 160 days in most interior uplands, and to 100 days or fewer on the rims and mountains.

Climatic changes which took place in the late Quaternary altered the processes presently at work on the now-arid Colorado Plateau. Erosion, prominent during dry periods, gave way to alluvium deposition on floodplains and colluvium accumulation on hillsides during wetter times. Some mountain-tops were glaciated during the Pleistocene; other periglacial peaks underwent changes attributable to severe freezing and thawing.

At the end of the thirteenth century A.D., a dry period documented by tree-ring studies caused early Pueblo Indians to abandon many of their settlements. They moved south and east to more favorable climates, including the Rio Grande Valley (Hunt 1974).

Four important factors which influence local climate include latitude, altitude, orientation of mountain ranges, and sources of moisture. Over the Colorado Plateau, seasonal weather changes result mostly from the seasonal migration of two large high pressure centers: the "Pacific High" and the "Bermuda High". In winter, the Pacific High lies in its most southerly position and is relatively weak. Storms pass around its northern edge, crossing the West Coast sometimes as far south as Baja, California. The Bermuda High, far out at sea and also quite weak at this time, exerts little influence on cold-season climate. So winter storms track across Nevada, Utah and Colorado more frequently than over Arizona and New Mexico from October through March. After the storms pass over the western mountain ranges and the high peaks of Utah, they diminish in intensity; the relatively few storms that track across Arizona and New Mexico do not have to cross the highest ranges of the Sierra Nevada, and so are relatively heavy.

As the Pacific High strengthens and moves northward in spring, storms become less frequent and move across the country at ever-increasing latitudes. By late spring to early summer, the Bermuda High has developed its western extension into the Gulf of Mexico, and warm, moist air from that source begins to track across the Southwest from a southeasterly direction. Again, this flow gradually decreases; western Arizona and southwest Utah receive much smaller amounts of spring and summer rainfall than their eastern regions or the more easterly states of Colorado and Utah. In September, both the Pacific High and Bermuda High begin to weaken, and the Pacific Ocean becomes the major storm source by October (Landsberg 1961).

VEGETATION

Desert shrub and grassland grow in interior regions of the Colorado Plateau; its rims and isolated peaks are forested. Most of the Colorado Plateau lies within the Upper Sonoran Zone, which encompasses elevations between 2500 and 7500 feet. Only at the bottom of Grand Canyon, below about 2500 feet, do the creosote bush, mesquite, and other life forms characteristic of the Lower Sonoran Zone invade the Plateau.

In the Upper Sonoran Zone, differences in moisture availability largely dictate the occurrence of several different plant communities. Differences in soil type resulting from variations in both altitude and geology in turn control the effective moisture for a given rainfall. Gravel-covered terraces at upper elevations usually support sagebrush and grama grass, but at lower altitudes the same soil might grow shadscale and curly grasses. Several shrubs and even scrub oak grow on very sandy soil at upper levels, but blackbrush takes over with increasing frequency as one moves lower. Impermeable soil over shale formations support mat saltbush; grassy vegetation predominates on loamy soil. Cracks and crevices in rocky benches and ledges

support a variety of xerophytes, including bitterbrush, scrub oak, mountain ash and juniper.

The pinyon-juniper woodland thrives near the upper reaches of the Upper Sonoran Zone; the lower boundary of this woodland forms the so-called arid timberline. Below lies a treeless land of desert shrubs; above the woodland lie the more heavily forested zones and the alpine tundra.

Phreatophytes occur in the Upper Sonoran Zone where groundwater is available; water quality helps determine the species present. Along many alluvial floodplains water may be alkaline and fairly deep beneath the soil surface. In these places greasewood is the predominant plant. Saltgrass occurs commonly where groundwater is alkaline but shallow. Good quality groundwater supports cottonwood, rabbitbrush and sacaton grass.

Above the pinyon-juniper woodland lie forests of the higher zones. The Transition Zone occurs between 7500 and 9500 feet; it has yellow pine and Douglas fir as its characteristic tree species. The Canadian and Hudsonian Zones consist mostly of spruce and fir forests from 9500 to about 11,500 feet; above these zones lies the Alpine Zone with its small herbs and grasses. In physiognomy, these zones resemble their counterparts of the Southern Rocky Mountains.

Vegetation maps of portions of the Colorado Plateau may be misleading. For example, perhaps one-quarter of the Canyon Lands Section is bare rock, including surfaces along canyon walls and rims as well as flats and badland topography in the shale formations (Hunt 1974).

HYDROLOGY

Other than narrow strips along its southern and western edges which drain elsewhere, over 90 percent of the Colorado Plateau drains to the Colorado River at Grand Canyon. Table 1 presents average annual discharge rates for principal streams on the Plateau. These measurements cannot be closely compared owing to different years of record and wide fluctuations in annual discharge rates, but they do illustrate that the combined discharges of rivers above Grand Canyon equal, or slightly exceed, the discharge rate of the Colorado River at Grand Canyon. This indicates that runoff from the central Colorado Plateau is less than is lost through evaporation and seepage.

Most streams which arise on the Colorado Plateau are intermittent. Some mountain streams are perennial for short distances, but even the largest of these discharge only a few thousand acre-feet per year, and even in flood rarely extend very far from the foot of the mountains; their water is lost in the desert to seepage and evaporation.

Springs, important water sources on the Plateau, differ widely in size, quality and mode of occurrence. In mountains, springs may be quite numerous; many flow year-round and may yield up to several gallons per minute. Water quality in mountain springs is uniformly good. Many of these springs flow

Table 1. Average annual discharges (in acre-feet) of streams on the Colorado Plateau (Hunt 1974).

Colorado River, above mouth of Dolores River	6,000,000
Dolores River, near its mouth	870,000
Green River, at mouth	5,100,000
San Juan River, near mouth	2,100,000
Colorado River, above confluence with Little Colorado River	14,400,000
Little Colorado River, near mouth	240,000
Colorado River at Grand Canyon	13,000,000

from the toes of boulder fields, where snow collecting between boulders melts slowly and feeds subsurface streams which lose little or no water to evaporation. Foot-hill springs, fewer and smaller than those from mountains, have generally good water, although it might be considerably higher in dissolved solids. Many of these springs may be found at the edge of gravel benches; subsurface streams draining the mountains recharge them. Discharge from much smaller and less frequent desert springs seldom amounts to more than seepage; up to a third of these may have concentrations of alkalines, salts or heavy metals too great for human use.

In some areas on the Colorado Plateau, natural depressions in the rocks called "tanks" provide important--and sometimes the only--sources of water. The Powell Survey named the Waterpocket Fold in southern Utah for its abundance of such tanks.

Wells provide other local sources of water over the Plateau. In some of the structural basins, aquifers occur within a few hundred feet of the surface, but groundwater occurring there is of uncertain quality and limited quantity. Much is too alkaline for use.

Municipal water supplies, depending on their source, also vary widely in quality. Water originating in mountains is of the highest quality, having little more than 100 ppm total dissolved solids (tds). Stream or well water used by some desert towns may contain 800 to 100 ppm tds, with hardness of 250 to 300 (Hunt 1974).

SURFACE DEPOSITS AND SOILS

Glacial and Periglacial Deposits

On the Colorado Plateau, glacial deposits exist only on parts of the High Plateaus, the LaSal Mountains, San Francisco Mountain, and at the White Mountains on the south rim of the Plateau in east-central Arizona. These are the only areas on the Plateau known to have been glaciated. Moraines and other deposits attributable to the Wisconsin stage of glaciation are well-developed here; other deposits present represent earlier glaciations. While few glaciers existed on the Colorado Plateau, the climatic changes associated with glaciation found several forms of expression. Unglaciated mountaintops underwent intensive frost action that developed extensive boulder fields, which are prominent on the upper slopes of the Henry Mountains. The tops of the Henrys are so rounded as to obscure the structural geology there; igneous rocks have been as broken down as sedimentary rocks.

In parts of the Plateau along northern exposures, especially along some escarpments west of the Abajo Mountains, so much snow buildup took place during some parts of the Pleistocene that debris avalanches developed during periods of thaw. Some of these are scores of feet high and nearly a mile long. They are related to colluvial deposits which are wide-spread

on shale slopes at the sides of canyons and mesas. In some places, colluvial deposits of two or more ages may be distinguished because of alternating periods of colluvium deposition and erosion resulting from climatic changes.

Pleistocene glaciers in the Rocky Mountains sent large amounts of meltwater down the Colorado River, leaving thick deposits of gravel. Later, the gravel fill was partly excavated and the gravel left in terraces high above the river. Pleistocene terraces occur commonly up to about 500 feet above the river; a few higher terraces might be Tertiary (Hunt 1974).

Sand, Soil, Loess

Sand dunes occur both in crescentic forms and linear ridges over large upland areas of the Colorado Plateau. Active sand dunes usually overlie older, stabilized dune sand; active sand is loose, while older sand shows iron-staining and slight consolidation. The stabilized sand dates to early Holocene and perhaps late Pleistocene, and forms the source of sand for active dunes. Where poorly consolidated sandy formations become exposed, dunes form. When dunes migrate from those formations onto shaley layers, they diminish in size and eventually disappear.

Because of the slight agricultural use to which Colorado Plateau soils are put, they have received only slight study. Most soils are lithosols--derived from only slightly weathered parent material. Even so, three very different soil types, representing as many separate geologic ages, can be identified.

Development of the oldest and most weathered of these soils took place in pre-Wisconsin time. Pebbles in the upper layer of these soils, even those of granite, have weathered to clay. The upper clayey layer, where fully preserved, reaches thicknesses of a few feet. Below this, the rocks have retained their shape, but have been changed to clay. In this layer, and in some lower layers, thick *caliche* accumulations occur. Fresh parent material underlies the *caliche*. A pre-Wisconsin Chestnut soil of agricultural value is found along the Utah-Colorado border; it developed on an ancient loess deposit.

In other parts of the United States, Pleistocene glacial meltwaters deposited loess soils; on the Colorado Plateau, deserts to the west and southwest formed the origin of loess soils on the Plateau.

Alkaline soils predominate over most of the Plateau except on the mountains, where more rainfall and organic material serve to make the soil acidic. Where frost action on mountaintops churns the ground, soils resemble those of the arctic; they exhibit no layering but have both organic and mineral fractions mixed throughout the weathering profile.

Soils of Wisconsinan age, such as those developed upon early Wisconsinan glacial deposits and their gravel outwash, show a leached layer at the top a foot or two in depth. Pebbles in this section, while fresh, are likely

to be deeply stained with iron oxide, as are the sand and silt. Holocene soils usually do not show evidence of oxidation, and the leached layer is only a few inches thick. Both Wisconsinan and Holocene soils are farmed along some floodplains (Hunt 1974).

Alluvial Deposits and Arroyo-Cutting

Two kinds of alluvial deposits may be found on the Colorado Plateau. One type, forming as the floodplains along some valleys have been built up as the main stream overflows its banks and deposits a layer of silt on the valley floor. These deposits are relatively homogeneous along the valley, regardless of formations crossed; floodplain surfaces are nearly level.

Where the main stream has flows insufficient to carry away all of the sediment brought to it by its tributaries, alluvial deposits form as coalescing fans built into the main valley by the tributaries. The surface of such a floodplain is not flat, but consists of broad low fans apexing at each tributary.

Many streams are now incised into arroyos cut into the alluvium. From five to over 50 feet deep and a few to several hundred feet wide, arroyos are deep, steep-walled, flat-bottomed channels characteristic of ephemeral streams; they maintain a vertical headwall as they extend themselves upstream. The alluvium consists mainly of fine-grained sediments, but lenses of sand or gravel also occur. Vertical fissures break the silty face; the nearly vertical banks collapse along these cracks. Arroyos are difficult to cross, although their steep walls may round off with age. Surface water getting into vertical fissures back from a bank discharges underground into the arroyo bed by a process known as piping. Pipes may extend several yards back from an arroyo bank, where the roofs, subject to collapse, form a hazard for livestock.

Three ages of alluvium occur in most valleys. The oldest dates to late Pleistocene and contains bones of such Pleistocene animals as the elephant, the camel, the horse, and the long-horned bison. During the middle Holocene, a relatively wet period in southwestern deserts, another layer was deposited. It contains bones of modern fauna, excluding the horse, which became extinct in North America at the end of the Pleistocene and was later reintroduced by the Spaniards. With these bones occur hearths and some stone artifacts of prehistoric Indians--basketmakers--who had not yet developed either the bow and arrow or pottery. They used the atlatl (throwing stick) and spear as weapons. The basketmakers were succeeded in about A.D. 500 by the Anasazi, whose town and camp sites can be observed on top of the middle Holocene alluvium and are obviously younger. The youngest of the three alluvial deposits accumulated during the period of Spanish occupation and contains historical artifacts.

Periods of arroyo-cutting alternated with periods of alluvial deposition, and most of the arroyos were wider and deeper than present ones. Alternating episodes of alluviation and arroyo-cutting reflect, at least in part, the alternation of wet and dry periods. But the present cycle of arroyo-cutting and other erosion may also be attributable to land use practices. In almost every settled valley, arroyo-cutting commenced 10 to 15 years after the valley was first settled. Erosion during the past 50 years has been severe; present channels may be much wider, and not only destroy towns, homes, fields and road, but also lower water tables beneath the alluvium. This loss of water supply in the desert is one of the most damaging effects of arroyo-cutting (Hunt 1974).

Prehistoric Indians may have been responsible, through agricultural and other land uses which disturbed the land, for arroyo-cutting that predates historical alluvium deposition. But the evidence remains uncertain, since the climate changed also. For example, tree-ring studies have identified a decade-long drought which occurred at the end of the thirteenth century. Centers of Indian occupation along at least two streams, Cune Wash in Monument Valley and Bull Creek at the north end of the Henry Mountains, shifted gradually upstream then, probably in response to drying of the streams. But some evidence suggests that land use practices of the Indians caused some erosion (Hunt 1974).

Desert Varnish

Stains of iron and manganese oxides, known as desert varnish, decorate the canyon walls of the Colorado Plateau with colorful patterns, some, particularly in Glen Canyon, having the effect of tapestry. Desert varnish occurs on all manner of rock surfaces including gravel, boulder field, and stones or boulders on hillsides, from canyon bottoms to mountain tops.

The way in which the stain was deposited remains a puzzle; most likely the iron and manganese were dissolved in water. Some may have been leached from within rock formations and deposited at the surface. At other localities, the minerals must have been brought from farther away by surface water or by groundwater.

Iron and manganese deposition still occurs today along seeps in the canyon country, but on a very much smaller scale when compared to the dry areas of desert varnish. Today, fresh rock surfaces are being exposed where desert varnish is being removed from these dry surfaces. This desert varnish predates cliff dwellings and other prehistoric remains dating back to at least A.D. 500, since these dwellings were built against stained cliffs. Most desert varnish deposits probably date back to a wetter period (Hunt 1974).

DESERT LANDFORMS

Pediments and Badlands

Extensive benches, planed by erosion of the bedrock and usually covered by gravel, lie around the foot of mountains and along the base of escarpments on the Colorado Plateau. These surfaces show their greatest development on shale formations; their origin is clearly revealed along the foot of the Book Cliffs and at the base of the Henry Mountains. Water is lost by seepage and by evaporation when streams originating in mountains discharge into an area of lower rainfall. This loss in stream volume reduces the ability of the stream to carry its bedload; gravel transported from the mountains is deposited, and the lower stream course becomes aggraded.

Desert streams carry water infrequently, when heavy rains cause local floods. These streams can erode their beds at such times, especially in softer formations unprotected by gravel, to levels below those of gravel-laden streams draining from the mountains. Eventually the streams draining the mountains become perched, then captured and turned into the lower stream valley. This new channel and its associated pediment, formerly free of gravel, become the dumping ground for sediment being carried by the captured stream. Gravel, deposited at the point of capture, forms a fan which gradually spreads down-stream from the point of capture to cover the pediment. As erosion progresses and as more streams cut downward, the gravel-covered pediments remain as gravel-capped benches high above the drainage lines.

Since gravel resists erosion, the gravel-capped pediments form remnants of benches reduced by erosion which attacks the sides of the benches, undermining the gravel cap. Erosion on the pediment surface takes place very slowly. But in the badland hills at the head of such pediments, severe erosion occurs during each rainstorm when precipitation moves large amounts of sediment across the pediment sloping from the foot of the badlands. The energy of the water on the pediment apparently is fully consumed in transporting its load of mud from the badlands; it is incapable of cutting into the shale underlying the pediment.

Shale formations on the Colorado Plateau supply most of the sediment to its streams; almost all of that sediment comes from erosion of steep slopes in the badlands. The much larger area of pediment contributes little sediment until it eventually becomes gullied by arroyos which initiate a new cycle of badlands (Hunt 1974).

Mesas, Cuestas, and Hogbacks

Cretaceous formations on the Colorado Plateau consist of massive shale units from 500 to more than a thousand feet thick, alternating with more resistant sandstones from 50 to over 100 feet thick. Where formations lie flat or nearly so, sandstones cap flat-topped mesas, whose slopes retreat as erosion of the shale undercuts the sandstone cap and collects as talus on the slopes.

Broken sandstone fragments collecting on the slope weather and disintegrate faster than the slope retreats and do not collect there as an armor plate. Badlands form at the foot of the shale slope, and pediments slope from the badlands. When the formations dip gently, cuestas form; hogbacks occur where dips are steeper.

Jurassic and Triassic formations, also of shale and sandstone, form mesas, cuestas and hogbacks. In contrast to the gray color of Cretaceous shales, those units in Jurassic and Triassic formations display bright colors, mostly red but also variegated with greens, browns, yellows and purples. The Glen Canyon Group, a thick sequence of sandstone in the Upper Triassic and Lower Jurassic, form the hogbacks and cuestas which outline such broad folds as the San Rafael Swell, Circle Cliffs Upwarp, and Monument Upwarp. These are symmetrical folds with steep flanks and hogbacks on the east, and flanks and cuestas on the west.

Hogbacks are the protruding, eroding edges of steeply dipping, resistant formations, and form some spectacular scenery on the Colorado Plateau. One hogback, the Waterpocket Fold, rises 1000 to 1500 feet and extends for nearly 75 miles. Its steep, rugged cliffs can be crossed in only a few places, even on foot.

Where formations dip less steeply than in a hogback, the resistant formations produce cuestas, ridges with escarpments facing updip and long, gentle slopes facing downdip.

Such asymmetrical divides as hogbacks and cuestas erode most steeply on the updip side as removal of soft strata causes undercutting of resistant ones. As a result, the divide retreats down the dip in a process known as monoclinical shifting. With continued erosion, position of both ridges and valleys retreat in a downdip direction (Hunt 1974).

Alcoves, Arches, Bridges and Tanks

Overhanging cliffs in sandstone formations occur commonly and almost characteristically on the Colorado Plateau. They range in size from diminutive to gigantic; some afforded protection to ancient Pueblo cliff dwellings. They form by lateral cutting of streams dependent on the relative progress of vertical and horizontal cutting by the stream, by the splash behind the plunge pool under waterfalls, and by groundwater seepage softening the cement in the sandstone, which permits loosened sand grains to be blown away.

An alcove arch developing along the outside of a meander may ultimately become a natural bridge, especially where meanders in a canyon are closely spaced enough to enable the stream to cut through an alcove and thereafter flow through it and under the arch which remains. Arches also develop away from streams, by weathering on uplands.

Locally referred to as "tanks", the depressions in sandstone surfaces resulting from erosion play an important role in the water economy of the Plateau when they fill with water after rainstorms. Desert travelers depend on these natural cisterns for water on some parts of the Plateau. Tanks were formed in three ways: as plunge pools below waterfalls, as pot-holes in the sandstone beds of now-dry rivers, or as upland areas which collected standing water which in turn dissolved the cement in the sandstone and enabled the wind to blow away loosened sand grains after the water evaporated.

Although many attribute formation of the unusual landforms to the action of wind erosion, in most cases the wind merely removed grains of sand which became loosened by water as it dissolved the cement holding them together. These erosion forms, much older than the cliff dwellings on the Plateau, probably date to the Pleistocene. Then the climate was less arid and the processes which brought about these formations took place at a greater rate than they do today (Hunt 1974).

Pedestal Rocks, Monuments

Where resistant sandstone crops out from between thicker beds of massive, earthy, less resistant sandstone to form caps, pedestal rocks are abundant. Rain falling on the cap runs off the top, adheres to the bottom side of the cap for a short distance, then falls to the ground, forming a drop curtain. Much less water moves slowly down the pedestal as a film; it is this water which does most of the work of erosion by dissolving the cement in the sandstone so the loosened grains can be blown away. Though pedestal rocks are shaped in part by the wind, little or no sandblasting occurs.

Monuments develop where fissures, or joints, break formations of thick sandstone deposits. The monuments develop in resistant rock that form cliffs which retreat as the sandstone breaks at the joints and falls away. The huge blocks, often only a few feet wide but up to several hundred feet long, break into smaller pieces when they fall away and strike ground at the base of the cliff, where disintegration by weather is accelerated. Oddly, the slopes at the base of monuments almost lack large talus blocks of sandstone.

MINERAL DEPOSITS

Sedimentary formations give rise to most of the mineral resources on the Colorado Plateau (see Figure 1); most of the production consists of uranium and fossil fuels.

Cretaceous formations in the Navajo Section, the High Plateaus, and the Uinta Basin contain extensive coal deposits. Less extensive coal beds occupy some parts of the Canyon Lands Section. Production of these fields has waned since railroads stopped using steam locomotives, but recently coking coal production has been expanded to supply steel plants in the western

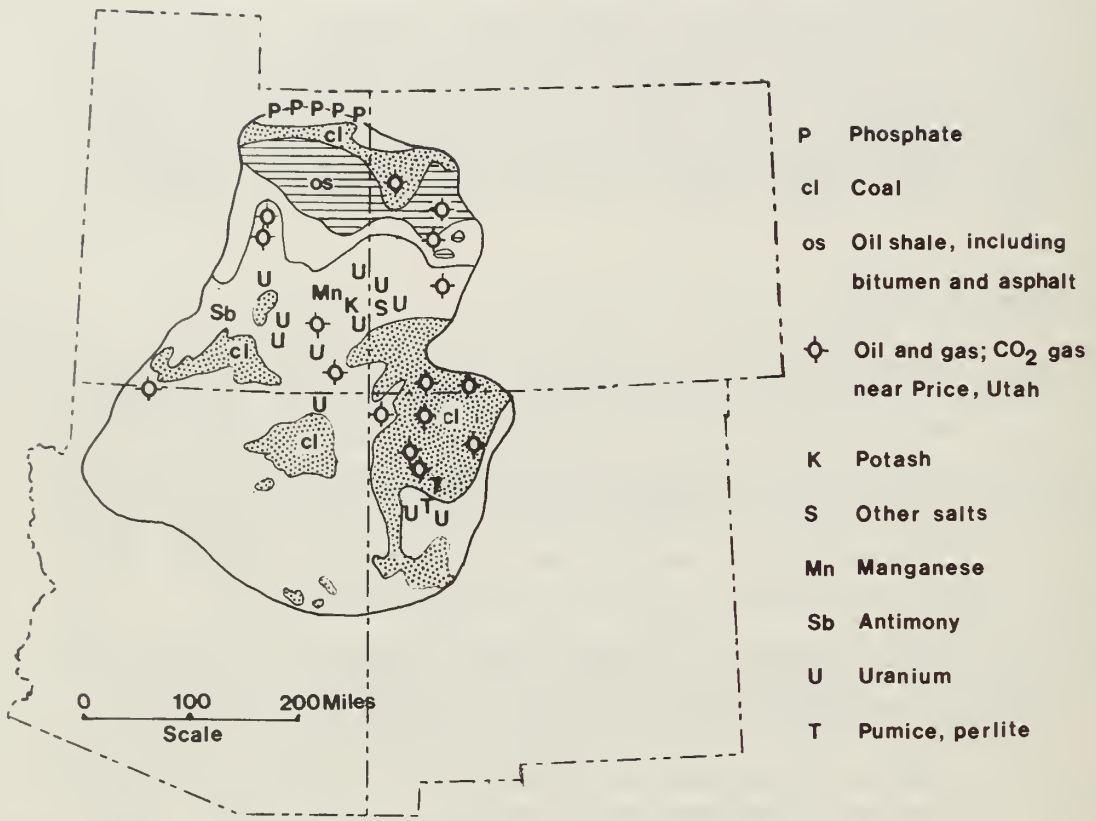


FIGURE 1. Principal mineral deposits on the Colorado Plateau [from Hunt 1974].

United States, and strip mining to supply steam plants that generate electricity has increased greatly.

In the San Juan Basin of the Navajo Section and in the Uinta Basin, oil and gas deposits have been developed; recent oil and gas discoveries have been made in the central part of the Canyon Lands Section. Carbon dioxide gas has been produced for the manufacture of dry ice near Price, Utah.

Huge oil shale deposits underlie the Uinta Basin and future development will no doubt occur. These deposits may contain as much oil as the combined total of oil already produced and oil in reserve. But the cost of developing these deposits is still prohibitive, and demand for the little available water is too great.

In the 1950's, the Colorado Plateau saw a true uranium rush; roads blazed into the wilderness by prospectors still remain important routes of back-country travel in some areas. Several major deposits were discovered and brought into production.

While production of other deposits has been minor, important deposits of potash and other salts underlie the salt anticlines southwest of the Uncompahgre Upwarp (Hunt 1974).

PART II

PINYONS AND JUNIPERS OF THE COLORADO PLATEAU

I. *Pinus edulis* Engelm., Colorado Pinyon

Species Description

Size: Trees to 15m tall (Cronquist et al. 1972), 10.5m (Kearney and Peebles 1964), 40-45 ft. (Phillips 1909). Trunk crooked and twisted, diameter to one meter (Tueller and Clark 1975).

Bark: Irregularly furrowed, broken into small scales. Old bark yellowish-brown to reddish brown (Tueller and Clark 1975).

Leaves: Mostly two per fascicle, length 2-4 or 2-6 cm, sharp-pointed margins entire, fascicle sheaths deciduous, 8 or fewer resin ducts in leaves.

Staminate cones: About 6mm long, bright yellow soon fading (Cronquist et al. 1972).

Ovulate cones: Subterminal or lateral, 2-5cm long and nearly as wide, ovoid, short-stalked (206 mm long), usually brown at maturity, 14-sided scales thickened and knobbed at the apex, inconspicuous dorsal umbro (Cronquist et al. 1972).

Seeds: Large, 10-16mm long, brown, wingless (Cronquist et al. 1972), narrowly winged (Tidestrom 1925), 6-10 thick-shelled cotyledons.

Distribution: Colorado Plateau region of southwest Wyoming, western Colorado and northern Arizona. Extends east of the Continental Divide in Colorado, extreme western tip of Oklahoma, west Texas, New Mexico, adjacent Chihuahua, Mexico and eastern Arizona (Cronquist et al. 1972).

Pinus edulis, the most well-known of the pinyon pines, grows from 4000 feet in Oak Creek Canyon, Arizona, to 9000 feet on the east side of Monarch Pass, Colorado. It forms woodland with alligator, one-seed and Utah junipers; at the upper edge of the woodland it also associates with Rocky Mountain juniper (Lanner 1975).

II. *Pinus monophylla* Torr. and Frem., Singleleaf Pinyon

Species Description

- Size:** Low tree, 5-15m tall, trunk short and usually divided with two to three main branches, rounded or flat-topped and open with age. Young trees have rising branches which form a compact pyramidal crown (Tueller and Clark 1975).
- Bark:** On older trees, narrow flat ridges with thin, close, dark brown, sometimes reddish-brown scales. On young trees, smooth dull gray (Tueller and Clark 1975).
- Branches:** Glandular, puberulent at first (Tueller and Clark 1975).
- Leaves:** Mostly single, small proportion of two-needled fascicles. Single leaf characteristic is due to early abortion of one of the original two-needle primordia (Cronquist et al. 1972). Leaves 3-5cm long with entire margins, pale green with dark green lines, stiff and prickly, curved toward the branch, fascicle sheaths deciduous. One season's growth of leaves usually remains on the tree for about five years but may persist for 10 to 12 years (Brush 1947).
- Staminate flower:** Dark red spikes, catkins 6mm long, short-stalked pistillate flowers in purplish clusters (Tueller and Clark 1975).
- Ovulate cones:** Subterminal or lateral, 3.5-5.5cm long, equally wide, broadly ovoid, brown short-stalked, thick-scaled, scales four-sided, knobbed at tips, inconspicuous dorsal umbro (Tueller and Clark 1975).
- Seeds:** Large, 13-17mm long, brown and wingless (Cronquist et al. 1972), narrowly winged (Tidestrom 1975), thin-shelled, 6-9 cotyledons. Seed well-rounded at base, tapering with prominent ridges to an acute point (Tueller and Clark 1975).
- Distribution:** Throughout the Great Basin, southern Idaho (Cassia County), northern and western Utah, northwest corner of Arizona and across Nevada to eastern and southern California and Baja California (Cronquist et al. 1972).

The principal range of *Pinus monophylla* lies to the north and west of *P. edulis*. It occurs as low as 2000 feet near Palm Springs, California, and as high as 10,000 feet in the White Mountains of California (St. Andre et al. 1965). On Frisco Peak in southwest Utah, the species reaches 9700 feet where it grows with Great Basin bristlecone pine (Lanner and Warnick 1971). Along the southwestern portions of the range of *P. edulis*, single-leaf pinyon grows mainly in mountains south of the Mogollon Rim, forming an arc from northwest Arizona to southwest New Mexico (Lanner 1975).

III. *Juniperus osteosperma* Torr., Utah Juniper

Species Description

- Size:** Small monoecious (sometimes dioecious) tree or arborescent shrub, 3-6m tall (Tueller and Clark 1975), 2-5m tall (Shreve and Wiggins 1964). Trunk 1-3cm thick, with base to 8cm in diameter, sometimes several upright branches nearly equal in size to main stem, arising from about ground level to form rounded crowns. Branchlets stiff, twigs relatively stout, near 2mm in diameter, scaly or shreddy (Tueller and Clark 1975).
- Bark:** Reddish-brown or gray brown, weathering to ashy white, thin and fibrous, shreds in long strips or flakes off in rhomboidal scales (Tueller and Clark 1975).
- Leaves:** Scalelike, mostly opposite, in twos or very rarely in threes, occasionally in whorls of three on vigorous shoots, 2-3mm long, old leaves on large twigs sometimes to 5mm, acute to acuminate; leaves without glands or inconspicuously glandular, light yellowish green, closely-appressed, margins denticulate, resin gland deeply imbedded in the mesophyll and visible on some old leaves as a thin linear depression. Juvenile leaves arol-like and sharply pointed, to 5mm in length, decurrent at base (Tueller and Clark 1975).
- Staminate Cones:** Four to five mm long at anthesis of anthers (Tueller and Clark 1975).
- Ovulate Cones:** Mature in second year, globose to oblong-globose, 6-10mm long, covered with a dense bloom, bluish-glaucous at first, reddish-brown beneath the bloom when mature. Flesh thin, dry and fibrous or mealy (Tueller and Clark 1975).
- Seeds:** One to two seeds (Shreve and Wiggins 1964), one seed (Cronquist et al. 1972), ovoid, acute at apex, strongly one-to-four angled, light brown at the base and darker above, cotyledons 4-6 or 3-6 (Tueller and Clark 1975).
- Distribution:** From Providence and Panamint Mountains, California, to southern Wyoming, Colorado and northern Arizona, barely touching the fringe of the Sonoran Desert at Mojave, Arizona (Tueller and Clark 1975).

The Utah juniper is the most important member of its genus occurring in the pinyon-juniper woodland. Virtually always it associates with *Pinus monophylla* in the Great Basin; at lower elevations under conditions too arid for any pine, the Utah juniper forms open pure stands and even occasionally extends to the edge of salt flats. On the Colorado Plateau, the Utah

juniper is the constant associate of *Pinus edulis*, and again forms pure stands where the pinyon cannot survive. The species covers expansive areas of Nevada, Utah and northern Arizona (Lanner 1975).

IV. *Juniperus monosperma* (Englem.) Sarg., One-Seed Juniper

Species Description

- Size:** Erect shrubs or small trees, usually with multiple stems at or below ground level, as high as 6m (Cronquist et al. 1972), 15m (Shreve and Wiggins 1964). Plants spreading to form low, open brush-like crown. Trunk may be low and buttressed, to one meter in diameter. Twigs stout, 2mm in diameter, clustered at end of stout branches, scaly or shreddy, gray or brown (Tueller and Clark 1975).
- Bark:** Thin, furrowed, ashy-gray, stringy or shreddy, red-brown inner bark (Tueller and Clark 1975).
- Leaves:** Scalelike, mostly opposite but sometimes in whorls of three on the thicker twigs, paired, 2-3.5mm long, ovate to ovate acuminate, closely appressed, yellowish-green, tips often spreading. Usually glandular with flat or depressed elliptical resin gland located on the abaxial side. Leaves may be vigorous shoots up to 8mm long and like juvenile leaves, sharp-pointed, up to 5mm long, decurrent at base, foliage inclined to branch at ends of branches (Tueller and Clark 1975).
- Staminate Cones:** Terminal, 3-4mm long, glaucous-brown, globular, 3-10 microsporophylls (Tueller and Clark 1975).
- Ovulate Cones:** Subglobose, 4-6mm long, mature cones dark blue, succulent (Tueller and Clark 1975).
- Seeds:** One or rarely two, with 4 sharp edges, may be less than 4mm long, rarely 5mm long. Broadly ovoid, slightly grooved between ridges, chestnut brown with paler hilum, bilobed, 2 cotyledons, matures in a single season.
- Distribution:** To the upper margins of the Sonoran Desert in Arizona; southern Nevada to Colorado, Kansas, and Texas, then southward into Chihuahua and Nueva Leon, Mexico (Shreve et al. 1964). Cronquist et al. (1972) do not mention this species' presence in Colorado, Kansas or southern Nevada, but do list its occurrence as far east as north-west Oklahoma.

One-seed juniper commonly forms woodland with alligator juniper and also associates with Colorado pinyon, Mexican pinyon (var. *bicolor*), and singleleaf pinyon in sub-Mogollon Arizona. At low elevations and on sites too xeric for pinyon establishment, it frequently occurs in pure open stands (Lanner 1975).

V. *Juniperus scopulorum* (Sarg.), Rocky Mountain Juniper

Species Description

Size: Erect shrubs or small trees, monoecious but rarely dioecious. Often over 10m tall (Cronquist et al. 1972), 6m (Kearney and Peebles 1960). Crown often conical, trunk diameter to 45cm, sometimes with long pendulous secondary branches, heartwood reddish to purplish, xylem without vessels, tracheids without spiral thickenings. Twigs slender, about 1mm in diameter, smooth, flattened and reddish-brown (Tueller and Clark 1975).

Bark: Dark reddish to gray-brown, furrowed, thin, fibrous and shreddy (Tueller and Clark 1975).

Leaves: Scalelike, mostly opposite, paired, appressed, sometimes in whorls of three on vigorous shoots, 1-4mm long, green or blue-green, entire margins, rhombic-ovate, obtuse to subacute, usually with an oblong obscure gland on the back, imbedded in the mesophyll beneath the vascular tissues near the leaf base. Juvenile leaves needle-like, up to 7mm long, decurrent at the base (Tueller and Clark 1975).

Staminate Cones: Terminal, small, 2-3mm long, brown, about 6 microsporophylls, catkins terminal on short branches (Tueller and Clark 1975).

Ovulate Cones: Subglobose, 4-8mm in diameter, mature cones bluish to purple glaucous, succulent when fresh. Germinates freely during the second spring (Tueller and Clark 1975).

Seeds: Two, 4-5mm long, yellowish to light brown (Tueller and Clark 1975).

Distribution: Southern British Columbia, southeast Alberta, Montana and western North Dakota, southern to eastern Nevada, Arizona, New Mexico and western Texas (Cronquist et al. 1972).

Juniperus scopulorum does not comprise a major component of pinyon-juniper woodland, but is often found along the woodland's upper edge, commonly in the southern Rocky Mountains and on the Colorado Plateau where it mingles with *Pinus edulis* (Lanner 1975).

VI. *Juniperus deppeana* Steud., Alligator Juniper

Species Description

Size: Tree reaching 20m (65 ft.) at maturity (Tueller and Clark 1975).

Bark: Thick, divided into scaly squares.

Leaves: Juvenile leaves awl-shaped in whorls of three; mature leaves scale-like, usually in pairs. Resin glands elongate; gland beside multiple epidermis often adjacent to surface epidermal cells between fiber bands; resin glands rupture to give exudate on back of scale leaves (Tueller and Clark 1975).

Cones: Dark red-brown, formed by coalescence of flower scales, globular mass covered with bloomy skin, about one-half inch diameter, mealy, resinous but not succulent, reach maturity at end of two growing seasons.

Distribution: West Texas to Arizona and Mexico.

The largest representative of its genus in the the Southwest, *J. deppeana* attains heights exceeding 60 feet and diameters in excess of three feet. Alligator junipers occur with Colorado pinyons in Arizona, from west of Flagstaff east to extreme west-central New Mexico, north of the Mogollon Rim. One-seed juniper and several evergreen oak species may occur in woodland with alligator junipers on the Colorado Plateau, as well (Lanner 1975).

LIFE HISTORY OF COLORADO PLATEAU PINYON PINES

Growth and Development

The pinyon pines probably grow more slowly than any other group of species in the genus *Pinus*. The Colorado pinyon reaches maturity between 75 and 200 years, and may grow to an age of 400 years. The singleleaf pinyon normally reaches ages of from 100 to 200 years. Specimens only 4 to 6 inches in diameter growing in thin, dry soil may be 80 to 100 years old. Those pinyons in deeper soils grow more rapidly, attaining diameters from 10 to 12 inches in 150 to 160 years (Graves 1917, Tueller and Clark 1975). Only very young plants, usually first-year seedlings, can tolerate shade (Graves 1917).

Bradshaw and Reveal (1943) described four age classes in *P. monophylla*, including characteristics for age, height, basal diameter, conical shape, and bark. Blackburn (1967) described six age classes. Seedlings, up to one foot in height, had basal diameters of 3/8 inch and mean ages of seven years. Mature old trees varied in height from 11 to 20 feet, had basal diameters of six to fourteen inches, and mean ages of 102 years. At this stage of development the crowns are usually open, sparse, and expose the trunk and larger branches. Lower branches tend to prune off and bark fissures deepen as trees approach the decadent age class.

Pinyon pines generally lack easily observed, periodic phenophases. Observed phenophases begin with the onset of leader elongation and proceed through the emergence of male and female cones, pollination, attainment of full cone size, and opening of the cones. Timing of the phenophases is complicated because male and female cones emerge in May or June from buds formed the previous year. Growth of these conelets ceases in August and resumes again the following May and continues to July when cones reach full size. Cones mature by September of the second year and open the latter part of September or in October. Discharge of pollen takes place in only a few days. Often these relatively inconspicuous phenophases can be easily seen only in the upper branches, making the dating of each event even more difficult (Tueller and Clark 1975).

Reproduction

Male and female flowers, borne separately on the same tree, appear during late spring or early summer. Male flowers occur in groups of cylindrical catkins around the base of young shoots. They vary in color from yellowish to reddish. Female flowers appear as small green to purplish conelets at or near the tops of new shoots. Pollen dispersal reaches its peak during the last week of March (Tueller and Clark 1975).

Female cones develop slowly after pollination, reaching only one-seventh the dimensions of ripe cones during the first summer (USDA 1948). The cones mature in the autumn of their second year, opening in the latter part

of September or in October. Pinyons do not begin to bear cones until about their twenty-fifth year when they are from three to four feet tall (Tueller and Clark 1975). *Pinus monophylla* bears abundant seeds every two or three years (Graves 1917). The reproductive rate of this species faces severe limitations as a result of the infrequency of abundant seed years, unfavorable climate, seed infertility, rapidly declining rates of germination in the seed produced, and loss of seed through consumption by animals and people. *Pinus edulis* has a seed year only about every fifth year. Its reproduction is limited by unfavorable climate, seed infertility, rapidly declining germination rates in the seed produced, and seed loss due to insects. *Pinus edulis* produces 10 to 200 seeds per cone, which fall to the ground under trees within a few weeks after the cones open (Tueller and Clark 1975).

Optimum germination in *P. edulis* occurs at about 70° F; the largest and fastest growing seedlings sprout at this temperature (Kintigh 1949). One study reported an 88 percent germination rate from seeds of this species (USDA 1965). Temperatures of 40 degrees F are very near the minimum for germination of pinyon pine (Kintigh 1949).

Pinyon seeds germinate naturally during the first spring following dispersal, but under favorable conditions may germinate during the summer or early fall. Seeds of some species may germinate the second or even the third year after dispersal (USDA 1948). For some species, including *P. edulis*, germination takes place best in the dark, under a cover of litter or fine soil (Tueller and Clark 1975). Fungi, insects, birds, rodents, and larger animals including man, often reduce the natural seed supply considerably both before and after the seeds mature (USDA 1948).

Natural hybrids of *P. edulis* and *P. monophylla* occur in northern Utah (Lanner and Hutchinson 1972).

Diseases and Parasites

Pinyon pines resist disease more readily than most other conifers with which they associate (Phillips 1909). The false mistletoe (*Razoumofskya*) affects pinyons much less than it does junipers or ponderosa pine, and pinyons are not affected by witch's broom as are Douglas-firs (*Pseudotsuga menziesii*) in the Southwest (Phillips 1909, Tueller and Clark 1975).

The following diseases are known for pinyon pines (Hepting 1971):

Root Diseases and Trunk Rots:

Verticicladiella wagnerii causes a root disease.

Fores pini causes red heart or red ring rot.

Fores pinicola causes brown crumbly rot.

Polyporus schweinitzii causes a carbonizing, cubical root and butt rot.

Stem Diseases:

Cronartium occidentale, blister rust.
Arceuthobium campylopodum divaricatum, pinyon dwarfmistletoe.

Foliage Diseases:

Bifusella pini causes tarspot needle cast.
Coleosporium jonesii, leaf rust.

Pinyonia edulicola causes spindle-shaped needle gall in *Pinus edulis*. Infested needles die and drop off prematurely. Spindle-shaped gall occurs in landscape plantings of *P. edulis* but has not yet been reported from native tree stands (Tueller and Clark 1975). Another insect causing much more damage in urban plantings than in active pinyon stands is the pinyon stunt needle midge (*Junitiella* sp.) which causes severe needle stunting in *P. edulis*. Infested needles, about one-third normal length, show slightly swollen bases. Needle drop, which occurs after insect emergence, can result in serious defoliation (Brewer 1971).

The pinyon pine sawfly (*Neodiprion edulicalus*) causes periodic serious defoliation of *Pinus monophylla* in the eastern Great Basin. Light infestations show most feeding by sawflies in the upper one-third of the crown, near branch tops. Heavy feeding can completely defoliate trees in one season; three successive years of complete defoliation is enough to kill some trees (McGregor and Sandrin 1968).

The pinyon needle scale affects *Pinus monophylla* throughout its range and *P. edulis* in Nevada, Utah and New Mexico, and by repeated infestation, weakens trees and subject them to attack by the bark beetle *Ips confusus*. As infestation by the beetle progresses, foliage thins and needle length is reduced drastically, severely weakening or killing small trees (McCambridge and Pierce 1964).

Keen (1958) reports that a cone beetle (*Conophthorus* sp.) and a cone moth (*Dioroctria albovitella*) cause the most damage to pinyon pines. Other insects which attack pinyons include a pitch nodule moth (*Petrova monophylliana*), scale insects (*Matsucoccus* sp., *Desmococcus* sp., *Pitycoccus rugulosus*) and the lodgepole sawfly (*Neodiprion rohweri*) (Tueller and Clark 1975).

No published literature concerns fungi which attack pinyon pines.

LIFE HISTORY OF COLORADO PLATEAU JUNIPERS

Growth and Development

Junipers characteristically grow quite slowly. Herman (1953) studied *J. osteosperma* in Utah for 10 years and reported a growth rate for the species of 0.6 percent per year. The Rocky Mountain juniper, a species of the upper edges of the woodland on the Colorado Plateau, takes 300 years to grow to 30 feet (Tueller and Clark 1975). The average age of stands of *J. osteosperma* in Wyoming has been reported as 150 years (Wight and Fisser 1968).

In northern New Mexico and Arizona, *J. scopulorum* seedlings took 8 years to grow one foot. They remain small and grow uniformly during the first 40 years, reaching average heights of 13 to 14 feet. Then the rate of growth declines; 80 year old trees average 18 feet tall. After the eightieth year they grow about .55 feet per decade, reaching 30 feet in 300 years (Howell 1941). Life span of the species averages 250 to 300 years (Tueller and Clark 1975). Dodge (1936) reported one specimen from Logan Canyon, Utah to be 3000 years old.

Blackburn (1967) described maturity classes for *J. osteosperma* from eastern Nevada. Seedlings (trees up to one year old) averaged one foot in height with awl-shaped needles. Immature trees show basal diameters of 1/16 to 1/2 inch; they have a mean age of ten years. Mature vigorous plants vary from 2 to 13 feet tall, average 92 years old and have pointed crowns and often several branches at ground level. Decadent plants, from 8 to 20 feet in height, have basal diameters of 6 to 14 inches and a mean age of 240 years. Their crowns are round and flattened with many dead or dying branches; other branches are heavy and often twisted and gnarled.

The Utah juniper displays four phenophases: pollen shedding and flowers open, onset of leader elongation, first conspicuous flower formation, and cessation of leader elongation (Tueller and Clark 1975). Tueller and Clark recommend that observers consider that pistillate flowers first become conspicuous during late summer and then open the following April when staminate flowers discharge their pollen, and that fruits ripen in November and December of the second year following pollination and remain on the tree until March or April of the following year.

Reproduction

Juniperus scopulorum is normally dioecious but occasionally monoecious. *Juniperus osteosperma* occurs normally as a monoecious plant but a few specimens are dioecious. *Juniperus monosperma* appears as a dioecious plant almost exclusively (Tueller and Clark 1975).

Juniper flowers are characteristically small and unisexual. The male flowers, yellow to yellowish-brown in color, form catkins. These staminate cones bear 3-6 pollen sacs; they are peltate and appear either solitary or in clusters. Cone formation begins in summer or early fall and the flowers discharge their pollen the following spring. In *Juniperus scopulorum*, pollen-shedding occurs in April (Tueller and Clark 1975).

Three to eight pointed scales bearing one or two ovules form the green female flowers. These scales gradually become fleshy, uniting into a berry-like indehiscent conelet which matures in the first season in *J. monosperma* and in the second season in *J. osteosperma* and *J. scopulorum*. In the latter two species, the conelet attains essentially its full size during the first summer but requires a second summer to mature the seeds (USDA 1948, Tueller and Clark 1975). Juniper berries are resinous, sweet, or nearly dry depending on the species. Coloration ranges from blue and blue-black to reddish, often with a conspicuous bloom. On the Colorado Plateau, *J. scopulorum* and *J. monosperma* have blue-colored berries, while berries of *J. osteosperma* are reddish in color (Tueller and Clark 1975).

Seeds number from one to six (USDA 1948). Cones of Utah junipers have one seed (Vasek 1966), those of one-seed junipers have one but rarely two seeds, and those of the Rocky Mountain juniper, two seeds. Based on data collected from *J. scopulorum*, seed-bearing in *Juniperus* species begins at 10 years with optimum seed production between 50 and 200 years. While trees bear some seeds each year, they produce particularly heavy crops at two to five year intervals (Tueller and Clark 1975).

Juniper seeds germinate naturally in early spring. In some species, such as *J. monosperma*, germination takes place in the first spring after dispersal. In others, such as *J. scopulorum*, germination occurs in the second year; seeds from some other species do not germinate until the third year. Seeds which do not germinate in the first spring following dispersal must undergo a period of after-ripening which may be as long as 14 to 16 months (Tueller and Clark 1975).

Germination rates for *J. scopulorum* may vary from 32 to 58 percent and average 45 percent (Tueller and Clark 1975). Vasek (1966) reported a 17 percent germination rate for 45 year old seeds of *J. osteosperma*. Fifty percent of *J. monosperma* seeds germinated after 21 years; germination rates in the study varied from four to 70 percent (Johnsen 1959). Impermeable seed coats and embryo dormancy account for the need for an after-ripening period (Tueller and Clark 1975).

Diseases and Parasites

Diseases and parasites affecting junipers have been investigated much less thoroughly than they have been in pinyon pines (Tueller and Clark 1975). The following diseases are known to affect junipers (Gill 1953, Vasek 1966, Tueller and Clark 1975):

Rot Diseases:

Fomes juniperanus
Fomes texanus

Blights:

Phomopsis sp., juniper blight

Stem Diseases:

Gymnosporangium sp., witch's broom (girdles and kills branches)

Foliage Diseases:

Gymnosporangium sp., leaf rust (on leaves and young stems)

Mistletoes (*Phoradendron juniperinum*, *P. bolleanum*) parasitize junipers but cause no serious damage (Vasek 1966, Gill 1953).

Insect pests on juniper include round head borers (*Callidium californicum* and *C. juniperi*) which attack twigs and limbs, flat head borers (*Chrysobothris* sp.) which attack the wood and long-horned beetles (*Methia juniperi*, *Styloxis bicolor*) which girdle limbs and twigs (Tueller and Clark 1975).

Several insects feed on the flesh of junipers and eat the seeds. They include grasshoppers (*Melanoplus* sp.) which feed on berries and ants (*Solenopsis* sp.) which eat seeds, especially at lower elevations (Phillips 1909). Certain caterpillars (*Ithome* sp.) feed on berry flesh and seeds, especially in *Juniperus californica* (Keen 1958).

Inhibitory Effects

Junipers as well as pinyons exhibit inter- and intra-specific inhibition. *Juniperus osteosperma* inhibits plant growth beneath its crown through compounds present in litter, which included polymers and monomers of leucoanthocyanidin or catechin and another unidentified compound (Jameson 1970a). In *J. monosperma*, litter accumulation was the major factor reducing growth of blue grama grass (Jameson 1966d); root competition also caused reduction in grasses (Jameson 1970b). Pinyon-juniper woodlands show many such competitive relations which have important management implications (Tueller and Clark 1975).

PART III

PINYON-JUNIPER WOODLANDS OF THE COLORADO PLATEAU

Description

The pinyon-juniper woodland, or pigmy forest, consists of a vegetational association of scrubby conifers belonging to the genera *Pinus* and *Juniperus*. On the Colorado Plateau, principal components of the woodland include *Pinus edulis*, the Colorado pinyon, as the most characteristic *Pinus* of the Plateau; *P. monophylla*, the singleleaf pinyon, a species characteristic of the Great Basin which intergrades with *P. edulis* in a few places along the western edges of the Colorado Plateau; *Juniperus osteosperma*, the Utah juniper, most important species of its genus found in pinyon-juniper woodland; *J. monosperma*, the one-seed juniper; and *J. scopulorum*, the Rocky Mountain juniper, which occurs only in the upper limits of the woodland on the Colorado Plateau (Woodbury 1947, Lanner 1975). Many other vegetational elements occur along with *Pinus* and *Juniperus* in the woodland, mostly in subordinate positions. Map 1 shows the potential distribution of pinyon-juniper woodlands on the Colorado Plateau. While most of the woodland lies between 5000 and 7000 feet above sea level, it breaks these elevational boundaries in many places. Moreover, the forest within this elevational range displays so many interruptions and discontinuities that large unbroken areas of forest seldom occur (Woodbury 1947).

Lower elevational limits normally occur around 5200 feet both in the Great Basin and on the Colorado Plateau. In the Virgin River Basin just off the Colorado Plateau in extreme southwestern Utah, the woodland extends downward to 3700 feet in the Beaver Dam Mountains, and to 3200 feet in the Dixie Corridor where Arizona, Utah and Nevada meet (Woodbury 1947, West et al. 1975).

Upper limits of the woodland community vary from about 6500 feet on north-facing slopes of the Kaibab Plateau, Arizona (Rasmussen 1941) to approximately 8400 feet on south-facing slopes of the Book Cliffs in Carbon County, Utah (Hardy 1945, Woodbury 1947, Isaacson 1967). On the south side of the LaSal Mountains, San Juan County, Utah, the upper limit is reached near 7500 feet and in Cedar Canyon, Iron County, Utah, near 7800 feet (Woodbury 1947).

Valleys, washes, canyons and mesas account for many discontinuities in the woodland. There the pigmy conifers occupy coarser soil areas on upper slopes, while finer soils lower down support other types of vegetation. These discontinuities tend to interrupt the general zonation of the forest and sometimes to upset the normal canted arrangement of the zone of opposite sides of a mountain (Woodbury 1947).

The scrubby forests made up by pinyons and junipers are especially characteristic of the semi-arid regions of the West between the Sierra Nevada and Rocky Mountains, and extending southward from southern Idaho and southwestern Wyoming into Mexico (Woodbury 1947). Pinyon-juniper woodland

occupies 160,931 square kilometers (41,286 square miles) or 32.9 percent of the land area of the Colorado Plateau (West et al. 1975), generally occurring on foothills which are intermediate in elevation between low valleys (4000 to 6000 ft.) and high mountains (8000 to 13,000 ft.) (Woodbury 1947).

In the northern portions of the Colorado Plateau, *Juniperus osteosperma* forms the bulk of the woodland at lower elevations, but tends to be increasingly replaced by *J. monosperma* as one moves south. At higher elevations, *P. edulis* occurs in varying proportions throughout the woodland (Woodbury 1947).

Graham (1937) found *P. edulis* to be a component of secondary importance in the Uinta Basin. He found it nearly missing north of Vernal but about equally abundant with juniper in the west end of the basin, on the Tavaputs Plateau in and western Colorado. Hardy (1937) found pinyons to comprise from 17 to 48 percent of woodland near Price, Utah; they averaged 26.4 percent. Woodbury (1947) found pinyons to comprise 64 percent of the woodland on sample plots on Black Mesa, Arizona. At the mouth of Red Canyon, Garfield County, Utah, near the upper limit of the woodland, he found 80 to 90 percent pinyon pines.

Pinyon-juniper woodland varies greatly in density. Generally, stands are more open at lower elevational limits and become more dense as elevations increase until the ecotone at the upper limit is reached where the stand thins rapidly and is replaced by other vegetation. Near its lower limits, the forest often thins more gradually, leaving a straggling line at the bottom. Even here a sharp line of demarcation often exists at the ecotone, especially in discontinuous areas (Woodbury 1947). Trees seem to grow fastest, attain the largest size and reach maximum development just below the upper edge of the zone; here the density is also greatest. In a dense stand of woodland, crown cover and crown:root ratios approach 40 percent. Crown:root ratios in sparser stands are sometimes as low as five percent (Woodbury 1947).

Pinyon-juniper woodland forms one of a series of altitudinal zones characteristic of mountainous regions. Daubenmire (1943) placed it below the ponderosa pine zone and above the oak-mountain mahogany zone in his treatment of vegetational zonation in the Rocky Mountains. From studies in the Uinta Basin, Graham (1937) placed it between the submontane shrub which occurred above it and the mixed desert shrub which occurred below it. Shelford (1963) placed the pigmy forest with ecotone woodland and bushland communities which also include oak-juniper woodlands, oak woodlands and Rocky Mountain bushland. The ecotone between pinyon-juniper woodland and the vegetational community adjoining it from above is almost always narrow, from 200 to 300 linear feet (Woodbury 1947, Rasmussen 1941, Merkle 1952).

In northern areas of the Colorado Plateau, submontane shrub communities replace the ponderosa pine forests more characteristic further south. Gambel oak (*Quercus gambelii*) is the chief component of submontane shrub and associates also with bigtooth maple (*Acer grandidentatum*), mallow ninebark (*Physocarpus malvaceus*) and serviceberry (*Amelanchier* sp.), squawbush (*Rhus* sp.), antelope brush (*Purshia* sp.), and snowberry (*Symphoricarpos* sp.), as well as some broadleaf evergreens that include the myrtle bosleaf (*Pachystima myrsinites*), mountain balm (*Ceanothus velutinus*), manzanita (*Arctostaphylos* sp.) and mountain mahogany (*Cercocarpus* sp.) (Woodbury 1947).

In the Uinta Basin, Graham (1937) found that oak was largely missing from the submontane shrub community, having barely entered the basin on the west and south sides. *Artemisia* had replaced *Quercus*, modifying the aspect considerably. On the Kaibab Plateau in northern Arizona, submontane shrub appears as a narrow belt of oak brush climax lying between the woodland and montane forest climaxes (Rasmussen 1941). In the Navajo country of north-eastern Arizona, Woodbury and Russell (1945) observed that pinyon-juniper woodland was rapidly replaced either by oaks and other brush or by ponderosa pine, or by both. The pine and oaks which appeared to occupy the same altitudinal belt tended to diverge on an edaphic basis, the oaks taking better-developed soils and the pines occupying rockier sites.

On the southeast slopes of the Abajo Mountains, Utah, pigmy conifers attain elevations of 6500-6600 feet on east slopes and 6800-7000 feet on south slopes where they form ecotones with oaks and ponderosa pines in areas of 200-300 feet in elevation. On these slopes, ponderosa pines begin at 6800 feet and range upward along rocky slopes and gulches, whereas the oaks occupy the smoother slopes with deeper soil (Woodbury 1947).

At its lower reaches, the pinyon-juniper woodland often contacts desert shrub communities. In the Great Basin and the northern part of the Colorado Plateau, sagebrush (*Artemisia tridentata*) often dominates these brush communities, but further south, the lower elevational limit of sagebrush is often reached before that of the woodland; here, sagebrush is replaced by blackbrush (*Coleogyne ramosissima*) which forms the ecotone with the pigmy conifers and extends downward below them (Woodbury 1947).

Daubenmire (1943) discusses an oak-mountain mahogany zone below the pigmy conifers in the Rocky Mountains. Nichol (1937) recognizes a zone of chaparral containing much scrub live oak (*Quercus turbinella* and *Q. fendleri*) lying below the pigmy conifers and above the grass of the lowlands in Arizona.

Sagebrush extends altitudinally from about 3000 to over 10,000 feet but the great bulk of typical stands lies between 4500 and 7000 feet. Thus sagebrush not only occurs at all altitudes where the pigmy conifers occur but also at higher and usually at lower elevations beyond their limits. Occasional patches of sagebrush occur in oak brush and in coniferous forests. Throughout the altitudinal range of the pinyon-juniper woodland, areas occur where both types of vegetation appear, where one or the other is absent, or where both are absent. Generally, sagebrush tends to occupy valleys, mesas or gentle

slopes with fine deep soil, while pigmy conifers utilize ridges, canyons or rough slopes with coarse, rocky or shallow soil (Woodbury 1947).

Human History of Plateau Woodlands

Although evidence of human presence on the Colorado Plateau dates back nearly 10,000 years, permanent cultures did not develop there until much later. Since the time of Christ, the Colorado Plateau has enjoyed a remarkably rich and fascinating history. Its stories include those of the thirteen-century flowering and abrupt extinction of the Anasazi Culture; the period of Spanish exploration; the arrival of white fur trappers; the development of railroads; the great Powell, Wheeler and Hayden Surveys; John Wesley Powell's epic journeys down the Colorado River; Butch Cassidy and his Wild Bunch; the heroic Mormon colonization and expansion effort; the Hualapai, Paiute, Ute, Navajo, Apache and Pueblo Indian peoples; prospecting; gold and silver rushes; Indian wars; grazing and range wars; mineral development and exploration; a uranium boom; and the establishment of over twenty national parks and monuments of natural or historic significance (McGregor 1965, Crampton 1964, 1972).

Today, Pueblo peoples whose roots go back twenty centuries to the earliest Plateau cultures still live on or near the edge of the Colorado Plateau. More recent comers include the Paiute, Hualapai, Navajo and Apache Indians who moved onto the Plateau after the Pueblo farmers abandoned it about 700 years ago. On the Plateau's eastern margins reside Spanish-speaking people whose ancestors moved up the Rio Grande Valley well over 200 years ago. On the Colorado Plateau itself, cowpokes, prospectors and Mormon farmers carry on ways of life established in the 19th century. These older communities have become increasingly affected by the overriding dominance of the American industrial metropolitan culture. Like Alaska, the Colorado Plateau has become a frontier for twentieth century America (Lipe 1976).

Humans have utilized the pinyon-juniper woodland for thousands of years. Prehistoric Indian cultures on the Colorado Plateau erected many of their habitations in or near pigmy confier forests due to pleasant climate, abundant wood supply for cooking, heating and building; medicinal and ceremonial materials; berries and nuts for food; and suitable habitat for the wildlife species used by these ancient peoples (Clary 1975).

The pinyon-juniper woodland was probably of much greater economic importance to Indian cultures than it is to twentieth century man, simply because it was no doubt utilized much more fully by people who depended for their survival upon locally available resources. Anasazi people used shredded juniper bark to fringe their sandals during the earlier cultural stages, and as they developed agricultural techniques, fashioned planting and digging implements from juniper wood. Early inhabitants of the woodland depended heavily on pinyon nuts as a staple food source and sometimes traveled over 100 miles to secure enough food to maintain themselves through winter and early spring (Fogg 1966, Gordon 1880).

Pinyon gum came into use among Indians as a waterproofing agent in the manufacture of baskets and pottery; it was also used to fashion jewelry and in the preparation of a black dye. Hopi Indians used pitch to prevent warping of their throwing sticks (Whiting 1939).

Four hundred years ago, Spanish explorers used pinyons and junipers for fuel and building material; they also used these trees for posts to fence their livestock (Clary 1975).

Humans utilize the pinyon-juniper woodland even today. Early settlers also used these trees for fuelwood, building materials and fences. Increased populations on the Colorado Plateau led to increased demand for these products among urban as well as rural people. Pinyon pines became the standard Christmas tree among many southwestern families. But with increased use and availability of fossil fuels and steel posts, demand for pinyon and juniper products to meet these needs diminished (Clary 1975).

During the last two centuries, the distribution and density of the pinyon-juniper woodland has changed markedly (Cottam 1961b, Stoddart et al. 1964) as a result of grazing (Aro 1971) and fire control practices. Some areas of the woodland have been grazed since Coronado introduced livestock to the Southwest in 1540, many year-round due to the favorable climate (Clary 1975, Springfield 1975).

Under Spanish methods of handling, livestock spread rapidly. Cattle and sheep, brought to New Mexico in the sixteenth and seventeenth centuries, had spread through California by the late 1700s. The horse probably first escaped from Spanish missions and settlements in the seventeenth century, for Pueblo and Apache Indians had horses by 1680. The horse reached Montana in the 1750s and it was in Canada by 1800 (Dasmann 1968).

Dittmer (1951) based his description of Southwest vegetation on documents of early explorers dating to 1849. In these accounts, many areas now grown over with such woody plants as mesquite, creosotebush, pinyon and juniper, were described as "grassy plains and open parklike areas with occasional scattered evergreen trees". Heavy livestock grazing and fire suppression in the late 1800s caused major changes in grassy vegetation to woodland and bushland community types (Dwyer 1975).

Prehistoric Changes in Plateau Woodlands

The record of climatic changes of the past 10,000 years, preserved in bristlecone pine growth rings (LaMarche 1974), indicates that considerable vegetation changes have occurred in that time. Major depression of vegetation zones in the past have been documented through fossil plant parts or pollen deposits (Wright et al. 1973) and wood rat middens (Phillips and Van Devender 1974, Spaulding 1974). West et al. (1975) mention one study which showed a drop of 800m in elevation for the pinyon-juniper woodland zone in southern Nevada during pluvial times. Later, when the climate

became warmer and drier (Cottam et al. 1959), woodland communities retreated upward, where many of them were separated by greater expanses of desert than they are today (West et al. 1975).

Historic Changes in Plateau Woodlands

More recently, and even with high rates of cutting for firewood, charcoal, fence posts and mine props, tremendous increases have occurred in the density and extent of woodland communities (West et al. 1975).

Cottam and Stewart (1940) examined historical records for Mountain Meadows, a favorite recruiting place on the Old Spanish Trail, which lies on a broad low divide separating the Great Basin from the Colorado Plateau in southwestern Utah. They cite records of Capt. John C. Fremont, written in 1884, which show that the entire valley was grass-covered in earlier years. At that time, two distinct meadow types existed in the valley. One, a wet wiregrass meadow, surrounded the numerous small springs in the lower valley areas. Important components of this meadow probably included *Juncus balticus* Willd., *J. xiphiodes* E. Meyer, *J. bufonius* L., *Equisetum laevigatum* A. Br., *Eleocharis palustris* L., and *Carex nebraskensis* Dewey.

The other meadow type, a dry or grass meadow, covered the divide and low foothills which sloped gently upward from the spring-fed bottomlands. The following species probably grew there: *Carex praegracilis* W. Boott, *C. douglasii* W. Boott, *C. stenophylla* Wahl., *Agropyron smithii* Rydb., *A. spicatum* (Pursh) Scribn. and Smith, *Elymus triticoides* Buckl., *Hilaria jamesii* (Torr.) Benth., *Bouteloua gracilis* (H.B.) Lag., *Oryzopsis hymenoides* (Roem. and Schult.) Ricker., *Poa secunda* Presl., *Poa annua* L., *P. longiligula* Scribn. and Williams, *P. fendleriana* (Steud.) Vasey, *Sitanion hystrix* (Nutt.) J.G. Smith, and *Sporobolus cryptandrus* (Torr.) A. Gray (Cottam and Stewart 1940).

Mormon pioneers settled Mountain Meadows in 1862; within a few years their sheep and cattle were grazing the entire valley heavily. A drought during the 1870s and early 1880s increased the forage deterioration which had been initiated by severe grazing. Then in the spring of 1884, torrential rains cut huge gullies which drained the meadows. With the meadows drained and with grazing herds on the increase, lush grassland soon gave way to desert shrub.

Today some bottomland areas formerly occupied by the wiregrass meadows are grown up almost exclusively with sagebrush (*Artemisia tridentata*), others largely by viscid rabbitbrush (*Chrysothamnus viscidiflorus*), some by grey rabbitbrush (*C. graveolens*), and still others by mixtures of rabbitbrush and sagebrush. Scattered junipers 10 to 30 years of age occupy the sagebrush, but not the rabbitbrush associations. This appears to have resulted because rabbitbrush, a very fire-resistant plant, has replaced sagebrush and junipers killed in areas swept by fires, and suggests that sagebrush became the first invader of the old wiregrass meadows after the wash developed in 1884.

On the foothills formerly occupied by grass meadows grows a sagebrush association which differs from the sagebrush community in several ways. First, the shrub cover in the valley shows a density of 6.8 percent compared with 3.8 percent in the shallow, less productive foothill soil. Second, rabbitbrush is absent from the foothills, probably because of the less versatile nature of *Chrysothamnus* and as a result of the lower incidence of fires due to the thinner vegetation. Third, thinner sagebrush cover in the foothill association allows a greater number of plant species, especially herbaceous forms. Fourth, foothill sagebrush display smaller size, fewer numbers, greater range of age classes, and a much longer life cycle than the sagebrush in the valley bottoms. Fifth, the Utah juniper is successfully replacing sagebrush in the foothills (Cottam and Stewart 1940).

Junipers have increased in the area until thousands of them now dot the entire landscape; hundreds presently grow in the former wiregrass meadow. In 1864, 1078 acres of juniper grew on the north valley drainage; by 1934, junipers had increased over 500 percent to occupy 6272 acres. On the original juniper areas, six times as many trees were found in 1934 as had been recorded in 1865; twenty times as many trees grow in the valley as a whole. Old juniper stumps or dead trees occurred only in the upper juniper belts (Cottam and Stewart 1940).

Junipers have invaded the valley bottoms only since about 1900; relatively few of them exist there now. But on the foothill slopes, juniper are vigorously replacing sagebrush. In the valley bottoms, the deep-feeding root systems of sagebrush and rabbitbrush probably prevented heavy invasion of juniper. In the foothills, where competition for space is less severe, junipers have slowly encroached on the sagebrush. Once established, the shallow root system of a juniper places it at a competitive advantage and allows it to replace sagebrush (Cottam and Stewart 1940).

Competition from grasses probably prevented junipers from invading Mountain Meadows prior to 1862. Since the disappearance of the grasses, juniper invasion has been on the rapid increase, both upward and downward in elevation, and on north and south-facing slopes. These facts seem to eliminate climate, at least during the past century, as a major factor in plant succession at Mountain Meadows (Cottam and Stewart 1940).

Christensen and Johnson (1964) used historical information, survey records and relict vegetation as sources of data to determine the presettlement vegetation of Pavant, Round and Juab Valleys in central Utah. They found that bunch grasses, mainly *Agropyron spicatum* and *Poa secunda*, covered the foothills; scattered sagebrush and Utah juniper also grew there. On level areas within the foothills, western wheatgrass, *Agropyron smithii*, grew commonly. Below the foothills on more gentle slopes and benchlands, there occurred a broad belt also dominated by bunch grasses. This grassy area intergraded into a zone dominated by northern desert shrubs, especially sagebrush. Grasses also grew conspicuously in this shrub zone. Shrub communities occurred in valley bottoms, wet meadows and salt deserts (Christensen and Johnson 1964).

By 1900, significant changes in the presettlement vegetation of these valleys had occurred. Sagebrush had largely replaced perennial grasses on the foothills and benches. In the shrub communities, grasses became less abundant. After 1870, juniper increased in density and invaded areas formerly dominated by grasses. These changes accompanied the use of the valleys and foothills as livestock grazing areas. Since 1900, several exotic plant species have become important components of the vegetation (Christensen and Johnson 1964).

Other references on historical changes in the vegetation of Utah include: Christensen 1950, 1962, 1963a, 1963b; Christensen and Welsh 1963; Cottam 1926, 1929, 1945, 1947, 1961; Cottam and Hutchings 1940; Cottam and Evans 1945; Bailey, Forsling and Becraft 1934; Mason 1963; Stewart 1941; Stoddart 1941, 1945; Pickford 1932; Tanner 1940; Wakefield 1933, 1936. These studies generally show that vegetational changes were particularly extensive in foothill and valley areas previously dominated by grass, and in pinyon-juniper and mountain brush communities of foothills and lower mountain slopes.

Much of the present pinyon-juniper woodland type in the West is a relatively recent phenomenon (West et al. 1975, Arnold et al. 1964, Smith and Rechenhain 1964, Ellis and Schuster 1968). Trees have invaded former savannah, grassland and shrub steppes, both upslope and down. Upslope invasion becomes more noticeable where forest or tall shrub vegetation is lacking in the next higher zone. In addition to the invasion of new areas, stands in existence over a century ago have shown substantial increases in tree density, replacing the formerly more abundant shrub and herbaceous understory (West et al. 1975).

Man has usually attributed these profound recent successional changes to unrestricted livestock grazing between the late 1800s and about 1935, since relict areas still show a savannah form (Blackburn and Tueller 1970, Arnold et al. 1964). But some of this vegetation may already have been altered by the Spanish, and later the American Indian reintroduction of the horse (West et al. 1975).

While livestock grazing surely played a major role in triggering changes in pinyon-juniper woodlands through reduction of herbaceous vegetation and dispersal of juniper seeds in animal feces, other effects probably accelerated succession. LaMarche (1974) showed the period from 1850 to 1940 to have been generally warmer and wetter than the periods directly before or since. These climatic trends probably favored tree seed production and the competition of trees over understory species. Changes in vegetation initiated by livestock, coupled with predator control, may have increased rodent densities, which could have further aided the distribution of the increased tree seed production (West et al. 1975).

The advent of intensive fire prevention and suppression programs favored the development of the climatic woodland climax (West et al. 1975); natural fires favor the development of herbaceous cover (Erdman 1970, Barney and Frischknecht 1973, Thatcher and Hart 1974).

Pinyon and juniper litter has increased along with the woodland itself. Jameson (1970a) has shown that phenolic compounds present in juniper scales can inhibit grass growth and may also alter decomposition and mineralization processes essential for nutrient cycling (West et al. 1975).

SUCCESSION IN PINYON-JUNIPER WOODLAND

Succession in pigmy conifers is both interzonal and intrazonal in nature (Woodbury 1947); invasion takes place both within the zone and outwardly from the zone, enabling complete pinyon-juniper dominance and zonal increase in space (Blackburn 1967).

Generally, juniper invades new areas first and is gradually replaced by pinyon (Woodbury 1947, Blackburn 1967, Blackburn and Tueller 1970). Juniper grows more slowly than pinyon; because of the slower growth of juniper, pinyon should ultimately become the dominant member of the stand (Jameson 1965a). This successional pattern rarely follows to the lower elevational limits of the woodland (Isaacson 1967).

The establishment of the individual juniper tree is the most important stage in its ecesis; factors including drought, competition and fire greatly affect this stage. Once the tree becomes established, it begins to dominate the surrounding area; both tree size and soil texture control the extent of dominance (Johnsen 1962). Arnold (1964) studied vegetation composition and production in four zones around a juniper tree. The first zone, immediately around the base of the tree, showed no herbaceous vegetation. The second zone contained several species: *Gutierrezia sarothrae* was the most abundant. No *G. sarothrae* appeared in the third zone; instead *Bouteloua gracilis* was most abundant. In the fourth zone *Agropyron smithii* showed an occurrence rate twice that of *B. gracilis*, and *G. sarothrae* was more abundant than in the other three zones. Arnold explained the differences in species composition on the basis of competition for soil moisture; tree roots absorbed and depleted soil moisture most rapidly in the third zone, accounting for the smaller amounts of *A. smithii* and *G. sarothrae* there.

FACTORS INFLUENCING SUCCESSION IN PINYON-JUNIPER WOODLANDS

Successional Superiority of Trees

The size and longevity of junipers and pinyons place them at a decided competitive advantage over understory grasses and forbs (Arnold et al. 1964). Leopold (1924) felt that grassland openings in pinyon-juniper woodlands resulted from fire and were only temporary; reinvasion of open areas constituted succession toward, rather than away from, the climax. The invasion of protected grassland by juniper and pinyon, coupled with the more rapid growth of the established trees, indicates their ability to

dominate understory species. Therefore the invasion of such grassland by woodland species seems to be a natural process of plant succession (Arnold et al. 1964).

Seed Production and Dispersal

Seed production forms the sole method of reproduction for Utah and one-seed junipers and for pinyon pines; only alligator junipers exhibit sprouting. Junipers produce large numbers of seeds almost every year, but pinyons have large mast crops only once every four to five years (Arnold et al. 1964). Animals disseminate seeds, an important factor in pinyon-juniper invasion of grassland (Parker 1945). Johnsen (1962) found that small mammals, birds and coyotes eat juniper berries and dispense the seeds in their droppings. Young juniper trees growing along fences indicate avian dispersal. Livestock, particularly sheep, also disperse juniper seeds. So does moving water. Seeds passed by animals germinate faster than other seeds (Johnsen 1962).

Seed Viability

Johnsen (1959) found that 54 percent of one-seed juniper seeds germinated after 21 years, and that 17 percent of Utah juniper seed germinated after 45 years; he concluded that a few years of drought would not seriously affect seed viability.

Climate

Good seed years followed by years of adequate moisture favor invasions by juniper and pinyon. In years of above-normal rainfall, seedling trees may take advantage of the extra moisture and become successfully established even in the best stands of grass (Arnold et al. 1964).

Grazing

Arnold et al. (1964) studied the effects of grazing on overstory and understory vegetation in the pinyon-juniper type of Arizona from 1940 to 1953. Because their study plots were located on open range and grazing intensity during the study period was unknown and because site strongly influences the understory vegetation in the pinyon-juniper type, their comparisons between grazed and protected sites (Figure 2) only indicate trends resulting from grazing. All tree species increased during the 1940 to 1953 period. Canopy intercepts by trees as a class increased about 150 percent under both protection and grazing. These increases resulted mainly from growth of already established trees (Arnold et al. 1964).

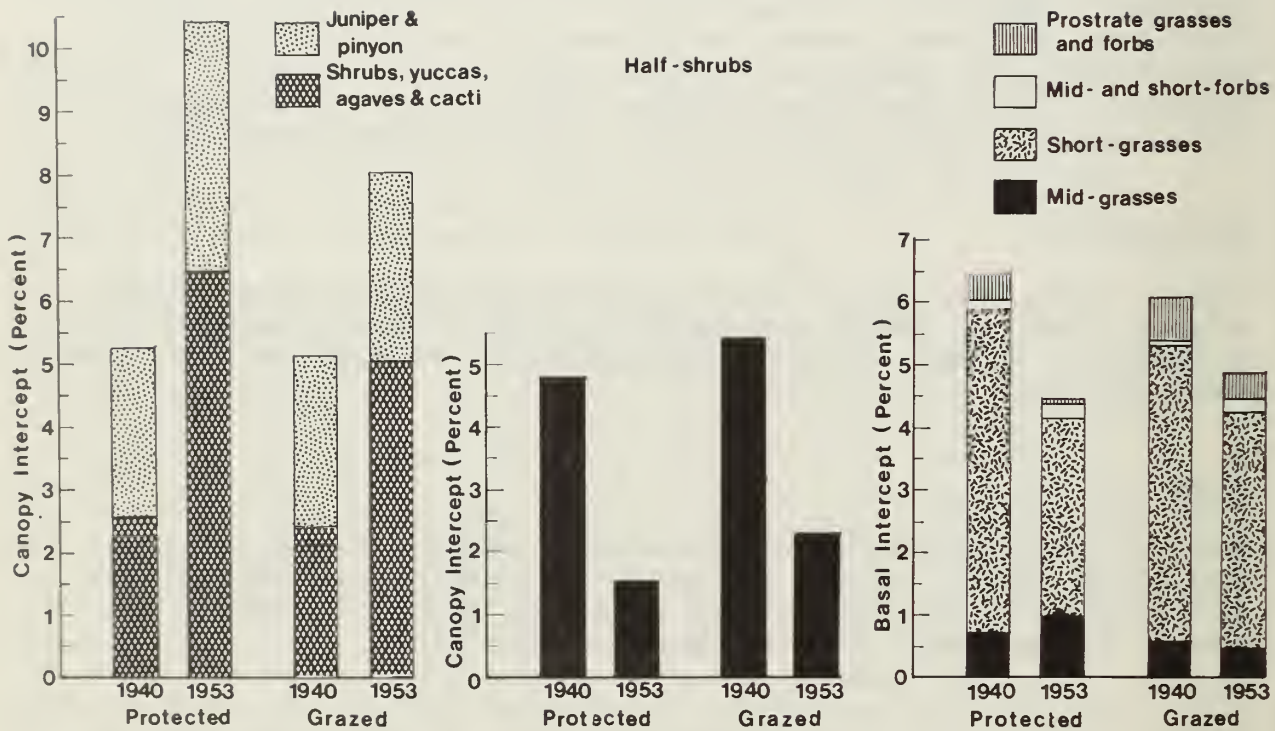


FIGURE 2. Response of plants to protection from grazing, grouped by plant-form classes, in Arizona (from Arnold et al. 1964).

Shrubs displayed greater increases in canopy intercept on protected plots than on grazed plots. Cliffrose (*Cowania stansburiana*), *Eriogonum wrightii* and *E. simpsoni*, all palatable to cattle and sheep, benefited markedly from protection. Algerita (*Berberis fremontii*) increased slightly under protection and decreased slightly under grazing. Fourwing saltbush (*Atriplex canescens*), not found on grazed plots, increased substantially on ungrazed plots. Shrub live oak (*Quercus turbinella*) and fringed sagebrush (*Artemisia frigida*) may have benefited by grazing. Rabbitbrush (*Chrysothamnus nauseosus*), an unpalatable species, decreased on both protected and grazed plots. Except for rabbitbrush, a general relationship existed between palatability to livestock and changes in intercept as influenced by grazing (Arnold et al. 1964).

Other woody perennials, usually of little importance in pinyon-juniper woodlands, sometimes become locally abundant. Generally these species maintained their position in protected plant communities. Prickly pear (*Opuntia* sp.) intercept values remained constant in protected plots and decreased slightly on grazed plots. Small numbers of pincushion cacti (*Mammillaria* sp.) occurred on grazed plots in 1953, but had not existed on any plots in 1940. *Yucca* canopy intercept increased slightly on protected sites (Arnold et al. 1964).

Mid-grasses as a class were not as abundant as short grasses, but they produced the most palatable herbage for the space occupied, and thus formed an important component of the herbaceous understory. Side-oats grama (*Bouteloua curtipendula*), squirreltail (*Sitanion hystrix*), western wheatgrass (*Agropyron smithii*) and mutton bluegrass (*Poa fendleriana*) were the most abundant mid-grasses on sites studied.

On grazed plots, mid-grasses showed a general decrease. Only squirreltail, western wheatgrass, mutton bluegrass and spike muhly (*Muhlenbergia wrightii*) increased. Any increases were less than those on protected sites. Six species decreased; side-oats grama decreased the most, more than 60 percent (Arnold et al. 1964).

Under protection, squirreltail, western wheatgrass and mutton bluegrass--all cool-season grasses--increased in basal intercept despite the increased growth of overstory juniper and pinyon. Galleta (*Hilaria jamesii*), sand dropseed (*Sporobolus cryptandrus*) and the three-awn grasses (*Aristida* sp.) decreased under protection. Galleta decreased about the same on both grazed and ungrazed plots (Arnold et al. 1964).

Short-grasses as a group declined, to be replaced by trees, shrubs and mid-grasses. Blue grama (*Bouteloua gracilis*) covered more area than any other herbaceous species on the study plots.

On protected plots, blue grama, red three-awn (*Artistida longiseta*), red muhly (*Muhlenbergia repens*) and hairy tridens (*Tridens pilosus*) decreased markedly from 1940-1953. Blue grama, red three-awn and hairy tridens also decreased on grazed plots, although not as much as on protected sites. Red muhly increased under grazing. Upon establishment of the study sites in

1940, the cover of short-grasses was greater on protected plots than on grazed plots; by 1953, this relationship was reversed. Generally, the short-grasses withstood grazing better than the taller mid-grasses (Arnold et al. 1964).

Mid and short-forb vegetation, a mixed class of broad-leaved herbaceous plants, is relatively unimportant since it comprises only a minor part of the understory vegetation. But members of this group showed local abundance. Eriogonums, milkvetches (*Astragalus* sp.) and evolvulus increased to occupy a somewhat larger area on protected plots than on grazed plots. Conversely, asters (*Aster* sp.), globemallows (*Sphaeralcea* sp.) and penstemon (*Penstemon* sp.) decreased under protection and increased under grazing. As a whole, the group increased under grazing about three times as much as under protection, but in 1953, the population was still slightly greater on protected sites than grazed plots (Arnold et al. 1964).

Prostrate species--those whose main vegetative height usually averaged less than two inches--included ring muhly (*Muhlenbergia torreyi*), the most common species found on the plots. It decreased about equally under both protection and grazing from 1940 to 1953, but still occupied seven times more area on grazed than on protected plots. Fendler three-awn (*Aristida fendleriana*) and fluffgrass (*Tridens pulchellus*), nonexistent to sparse on the plots, became abundant on local overgrazed areas (Arnold et al. 1964).

Half-shrubs, low, short-lived plants with woody bases, are generally most abundant on heavily grazed ranges, and may become established even in good stands of perennial grass in years of above-normal precipitation. Broom snakeweed (*Gutierrezia sarothrae*), by far the most abundant species, decreased markedly between 1940 to 1953 on both protected and grazed plots. Cooper actinea (*Hymenoxys cooperi*), broom groundsel (*Senecio spartioides*) and other minor species showed similar responses (Arnold et al. 1964).

Annual grasses and forbs, which reproduce solely by seed, occur most commonly on disturbed areas where perennials have been reduced. Arnold et al. (1964) did not measure for annuals in 1940, but in 1953 twice as many annuals occurred on grazed as on ungrazed plots. While grazing probably favors annuals, even on grazed ranges, annuals formed only a very minor part of the total plant cover (Arnold et al. 1964).

Arnold et al. (1964) found that trees and half-shrubs under both protection and grazing changed in proportion to the amounts present on these plots in 1940. Shrubs, other woody perennials, and mid-grasses increased under protection, while short-grasses, prostrate species and forbs decreased.

Shrubs and mid-grasses occupied more space on protected sites in 1953 than on grazed plots. In contrast, short-grasses, prostrate species and annuals occupied more space on grazed plots than on protected sites in 1953 even though they decreased under both protection and grazing. Thus grazing may favor short grasses, prostrate species and annuals over palatable shrubs and mid-grasses. However, the amount of understory vegetation may be controlled by the tree overstory and may not reflect grazing effects. Displacement of understory plants by juniper resulted in a loss of 70 percent

of the perennial grasses, forbs and half-shrubs between 1940 and 1953 at one of the protected plots (Arnold et al. 1964).

Fire

Fire, as a natural ecological factor, repels invasions of juniper and pinyon and reverts old established woodland stands to grassland communities (Leopold 1924, Parker 1945, Humphrey 1950).

Pinyon-juniper woodland often burns cleanly on flat to gently rolling terrain. In rougher topography, islands of unburned trees remain on hills and ridges. Stands of trees on dry hillsides and ridges may be too open to carry a fire (Arnold et al. 1964).

Erdman (1970) studied three postburn plant communities and two climax stands of pinyon-juniper woodland overlying residual soils at elevations of about 7500 feet at Mesa Verda National Park, Colorado. There, a mountain brush community typified by gambel oak (*Quercus gambelii*) and serviceberry (*Amelanchier utahensis*) dominates the uplands. This community probably exists as a successional stage maintained by repeated natural fires in a large part of the Mesa Verda landscape. Successional stands studied had been burned through natural causes in 1873, 1934 and 1959, as determined by cross-dating trees affected by the fire with the Mesa Verda master chronology.

Plant succession following natural fire in Mesa Verda woodlands begins with a pioneer stage of shade and competition-intolerant weeds, *Helianthus annuus* and *Chenopodium pratericola*, and proceeds to a meadow stage dominated by the native grasses, *Oryzopsis hymenoides*, *Sitanion hystrix*, and *Poa fendleriana*. Several species of perennial exotic grasses still occurred in the most recent burn; these had been introduced to check erosion (Erdman 1970).

After about 25 years, a crown-sprouting brush element, consisting mainly of *Quercus gambelii*, *Amelanchier utahensis*, *Cercocarpus montanus* and *Purshia tridentata*, becomes the dominant vegetation. Seedlings of *Pinus edulis* and *Juniperus osteosperma* also have become established at this time. About 100 years after fire, this open shrub vegetation has become dense enough to form a thicket stage. Young trees grow up through the shrubs and eventually overtop them. The fire sere proceeds toward a climax condition as the maturing woodland gradually suppresses the brush species. After several centuries the climax consists of mature pinyon and juniper trees with an understory of a sparse shrub component, a grass (*Poa fendleriana*), prickly pear (*Opuntia polyacantha*), and several forbs. Recurrent fires have allowed a floristically rich, chaparral-like vegetation to persist as a fire climax along the uplands of Mesa Verda National Park. Current fire-suppression policies, though, are allowing a pinyon-juniper forest to slowly replace the former extensive shrub vegetation (Erdman 1970).

Barney and Frischknecht (1974) studied vegetation changes following fire in pinyon-juniper woodlands of west-central Utah. Tree species present included *Pinus monophylla* and *Juniperus osteosperma*. The initial sere following fire consisted of annuals which reached maximum development in the first three to four years. A perennial-grass-forb stage generally replaced the annual stage by the fifth to sixth year if a fair remnant of native grasses existed prior to the burn. Under natural conditions in their study area, these would consist primarily of bottlebrush, squirreltail, bearded bluebunch wheatgrass (*Agropyron spicatum*), Indian ricegrass (*Oryzopsis hymenoides*), and Sandberg bluegrass (*Poa secunda*). If shrubs dominate to the exclusion of perennial grasses before the fire, a shrub stage may follow the annual stage. If the perennial grass stand develops first, it is usually followed by sagebrush and then by juniper.

Shrubs did not become dominant elements of the vegetation on most sites until about 35 years after fire. Snowberry (*Symphoricarpus vaccinoides*) dominated a few north-facing slopes, but sagebrush was the most abundant shrub in all other areas 35 years after burning. Juniper occurred on 11 year old burns but did not become dominant for about 70 years. After 46 years, an upward trend in juniper numbers began. Junipers completely dominated 86 year old burns; other plant species showed sharp reductions in vigor and density. Burns sampled did not give sufficient information to determine the place of pinyon in the successional sequence (Barney and Frischknecht 1974).

Arnold et al. (1964) studied 16 accidental or natural fires in the pinyon-juniper type of Arizona to determine dates of burning and subsequent ecological changes. A 1953 fire on the Hualapai Indian Reservation burned a forest in which pinyon comprised 54 percent of the stand. In 1954, the burn was still a charred forest with no remaining understory vegetation and soil surfaces clear of both vegetation and litter. Adjacent unburned areas showed tree and shrub cover to be 37 to 46 percent and litter intercept to be 50 to 60 percent. Understory vegetation grew sparsely. Trees average 360 per acre; 40 percent of these were pinyon pines.

Annual plants invaded the burn first and were abundant by the second growing season; they became very abundant by the end of the third growing season when Russian thistle (*Salsola kali*) grew prominently. Annuals decreased during the fourth and fifth growing seasons, replaced by perennial forbs and half-shrubs, including globemallow (*Sphaeralcea* sp.) and toadflax penstemon (*Penstemon linarioides*). Perennial grasses had recovered considerably by the fifth growing season (Arnold et al. 1964).

An old burn dating to before 1875, lying west of Grand Canyon Village, illustrated the conversion of pinyon-juniper woodland to a big sagebrush community. Intercept measurements of young pinyon and juniper on the burned areas were less than one percent of measurements on adjacent unburned areas. But the intercept of sagebrush, the prevailing shrub, was more than seven times greater on the burned area than on the unburned area. Combined basal intercept for perennial grasses and forbs within the sagebrush-fire community was 82 percent of that observed in unburned woodland stands. Sagebrush had nearly excluded pinyon and juniper and had restricted the grasses (Arnold et al. 1964).

Arnold et al. (1964) concluded that the establishment of annuals on a burned area initiates successional recovery after fire. During the third year an annual-perennial forb stage develops; by the fourth year perennial species outnumber annuals. Half-shrubs, important by the fourth year, continue to increase into the sixth year. After this point, succession can proceed in one of two directions. If shrubs such as sagebrush and rabbitbrush are present, a perennial shrub stage is likely to develop. In the absence of shrubs, the perennial forb-grass stage may give way to a perennial grass community. A shrub stage may be converted to grassland by a second fire. Both shrub and grassland stages under protection from fires will be invaded by trees and the pinyon-juniper climax will recur (Arnold et al. 1964).

Wildlife Responses to Fire in Woodlands

McCulloch (1969) observed mule deer habitat conditions on a 50 square mile plateau of pinyon-juniper woodland, half of which had been previously burned by crown fires; burned areas were devoid of living trees. Thirteen to fifteen years after the fire, vegetative cover in the burned area consisted of numerous dead trees, sparsely scattered clumps of sagebrush and rabbitbrush, Gambel oak and dense stands of seeded grasses. Deer intensively occupied both burned and unburned areas during summers and the first of three fall-winter study periods. During a severe winter, pellets accumulated more on the burned area. Pellet accumulation rates were high in the burned zone up to one-half mile from living woodland. Grasses formed important deer food year-round on both burned and unburned areas. Cliffrose, an important deer browse species, was almost nonexistent on the burned area. If woodlands were managed only for deer, small burns in woodlands would be preferable to large burns because of the greater variety of cover and food than on large burned or unburned areas.

Mechanical Control of Vegetation

Arnold et al. (1964) studied the effects of overstory tree removal on understory plants by controlling pinyon and juniper through cabling, bulldozing and hand chopping on 29 sites. Transect data were taken on those 29 sites and on 23 sites in adjacent uncontrolled stands.

Pinyon and juniper recovered very slowly on thoroughly cleared sites. On cabled sites, where young trees were not so completely removed, small trees missed by clearing efforts responded rapidly to release upon the removal of larger overstory trees (Arnold et al. 1964).

Shrubs exhibited no uniform response to tree removal. Shrubby eriogonums at 5 years after clearing and yuccas, after 8 years, accounted for most of the shrubs and other woody perennials. Half-shrubs, especially snakeweed, increased markedly after clearing. Canopy intercept of half-shrubs increased during the second and third growing seasons after tree removal. Half-shrubs increased much less on sites cleared more thoroughly of trees by hand chopping; displacement by perennial grasses may also have taken place there (Arnold et al. 1964).

Mid-grasses, especially three-awn and side-oats grama, showed generally greater basal intercepts with an increase in the number of growing seasons after control, but less occurred on sites in their fifth and eighth growing seasons. Western wheatgrass responded rapidly to removal of pinyon and juniper, especially on heavy swale soils (Arnold et al. 1964).

Blue grama, the most important of the short grasses, increased in basal intercept through at least the fifth year after control. By 8 to 13 years after tree removal, blue grama was almost three times as dense as before control (Arnold et al. 1964).

Forbs did not respond markedly to control efforts; prostrate species did not respond consistently. Great densities of prostrate plants occurred five to eight growing seasons past control. Heavy grazing on the sites before control probably led to the abundance of prostrate species there (Arnold et al. 1964).

Annuals increased on the controlled sites during the first two post-control growing seasons and were still abundant during the fifth growing season. After this, however, they began to decline and were replaced by perennials (Arnold et al. 1964).

Clary et al. (1974) studied the effects of pinyon-juniper removal on watershed values in the volcanic-derived soils along the Mogollon Rim. Their results and conclusions probably also apply to other southwestern pinyon-juniper as well. The researchers found overstory removal by herbicide (picloram) to be the only vegetation treatment likely to increase water yield from Utah juniper watersheds; conventional mechanical removal methods did not increase water yield from this vegetative subtype. Only 1.3 percent of the picloram used in control left the watershed in runoff water, and picloram ceased to be detectable in the water within three years after application. No meaningful change in sediment yields resulted from tree removal. From the combined standpoints of water and forage production, deer response, and economics, herbicide and fire control techniques appeared to be the most effective control methods to use on pinyon-juniper woodland.

Arnold et al. (1964) calculated herbage yields from areas cleared by bulldozing and hand chopping so that full release of understory species could be measured. They found that herbage production increased until about 10 years after control operations, from 198 pounds per acre before control to about 690 pounds per acre 10 years later. They calculated a maximum expected production at about 700 pounds per acre and stated that maximum herbage production probably takes place five to ten years after control.

Clary et al. (1974) gave the potential increase in livestock carrying capacity on many Utah juniper areas as nearly 0.5 AUM per acre after tree removal, but stated that increases of 0.21 to 0.32 AUM per acre are more realistic. Much lower increases are achieved when pinyon-juniper conversions are undertaken on low potential sites or when poor seeding techniques are used.

O'Rourke and Ogden (1969) studied herbage increases following pinyon-juniper control in north-central Arizona. They associated mean calcium carbonate levels of 13 percent in the surface foot of soil, and low pinyon-juniper crown cover of 13 to 26 percent, with no increase in perennial grass herbage production four to five years following tree removal. Furthermore, because of the mechanical disturbance of the soil profile from control operations, calcium carbonate and pH levels were slightly higher, and phosphorus levels slightly lower, in the surface soil of treated areas compared with untreated sites. Such measurements seem to indicate that clearing operations may reduce the herbage production potential of cleared sites when they disturb the soil severely.

Percentage calcium carbonate in surface soil and percentage pinyon-juniper crown cover serve as expressions of the long-term moisture regime of an area. As such, they may be good indices for predicting potential understory response following pinyon-juniper control (O'Rourke and Ogden 1969).

Light slash cover can benefit grass growth on woodland areas subjected to tree removal. In Arizona, side-oats and blue grama increased more under slash, and squirreltail became established there. But Arizona three-awn increased more without slash cover. Total increase in grass cover intercept increased from 0.930 without slash to 1.990 with slash cover; herbage production on slash-covered areas increased 35 percent over slash-less plots, to 93 pounds of air-dry herbage per acre (Arnold et al. 1964). Glendening (1942) attributed this increase to protection from grazing and improved soil moisture conditions beneath the slash.

Wildlife Responses to Pinyon-Juniper Conversion

The impact of pinyon-juniper woodland conversion on wildlife remains very poorly documented; published literature discusses implications only for mule deer, rodents and rabbits. Virtually nothing is known of the impacts of woodland conversion on the hundreds of other vertebrate species associated with this ecosystem (Terrel and Spillett 1975).

Many conversion projects attempted in the past have not influenced deer use of the converted areas one way or another, but research has identified a few methods which may increase deer utilization of woodland conversions: 1) small projects near escape cover, 2) restriction of treatments to areas with prior histories of heavy deer use, 3) creation of a mid-successional vegetation community having a high species diversity, and 4) location of the treated plots on sites protected from the brunt of severe weather (Terrel and Spillett 1975).

Limiting the size of the treated area is important since deer use of converted pinyon-juniper areas declines with increasing distance from the conversion: woodland ecotone (Terrel and Spillett 1975, McCulloch 1969, Minnich 1969, Cole 1968, Terrel 1973). Measurements in Utah indicated that the sharpest decline in deer use of chained areas had declined by 0.1 mile into them (Terrel 1973, Terrel and Spillett 1975). McCulloch (1965) recommended that

treatment areas be confined to less than 120-acre blocks. Openings in wooded cover have been demonstrated to be important to deer in other vegetation associations such as ponderosa pine, mixed coniferous and spruce-fir forests, as well (Reynolds 1962, 1964c, 1966, Pearson 1968, Lyons n.d., Edgerton 1972).

Terrain remains the most important factor influencing deer movement patterns both on converted and natural woodland. Terrel and Spillett (1975) reported that deer preferred small valleys and swale sites on converted woodland, avoiding large flat expanses. They utilized hillsides more on chainings than in woodland, but hilltops more in woodland than on chainings. In southern New Mexico, Reynolds (1964a) found that slopes up to 40 percent had as many deer and elk pellet groups as more level areas, and that northeastern exposures with greater amounts of trees and shrubs and lesser amounts of herbaceous understory, showed the greatest concentration of pellet groups. Localized weather and climate variation, as well as vegetational differences, can also affect deer and elk use of converted woodland.

In Arizona, McCulloch (1968) concluded that broadly speaking, little difference in deer use existed between cleared and uncleared pinyon-juniper ranges. The units which he did identify as having exceptionally high deer use shared the following attributes: no livestock use, small size, low tree kill, no slash removal, no artificial seeding and year-long use. Tausch (1973) found that of all his eastern Nevada study sites, deer most extensively used those sites having the highest plant diversity, consisting of a mixture of brush, smaller bunchgrass and the greatest forb density. Boeker and Reynolds (1966) reported that pinyon-juniper removal has little effect on deer or elk use if slopes steeper than 15 percent and northerly exposures are left untreated in an amount of 15 percent of the area, if five percent of the juniper is retained for browse and if treatment areas do not exceed 120 acres in size.

Good coordination of livestock range improvement with game habitat preservation might be achieved by leaving existing cover on northeastern exposures, and by clearing only on slopes of less than 15 percent, since livestock use declines on slopes steeper than this. Deer use remains unaffected by the degree of slope up to 40 percent. On areas reserved for game habitat, conditions for elk and deer might be improved by removing or thinning trees which overtop shrubs where tree density exceeds 150 trees per acre, and by cutting back sprouting shrubs that are so tall as to be inaccessible to elk and deer (Reynolds 1964a).

Small mammal population responses to woodland conversion have been measured in western Utah (Baker and Frischknecht 1973) and on the Kaibab Plateau in northern Arizona (Turkowski and Reynolds 1970). These studies observed initial increases for most species, with a peak about the third year following conversion. Populations then begin to decline, leveling out at near former densities after an indefinite time. Two species, the pinyon mouse (*Peromyscus truei*) and the brush mouse (*P. boylei*), showed population declines following treatment. Three to eight years following woodland conversion, rodent populations in pinyon-juniper woodland on the Kaibab Plateau were about 60 percent of those on cleared range (Turkowski and Reynolds 1970).

Cottontail (*Sylvilagus auduboni*) population densities in one study were significantly lower on treated areas where slash was removed than on untreated areas; more rabbits occurred on treated areas where slash had been left in place than on natural woodland. Optimum observed cottontail habitat contained approximately 85 shrubs and 270 pounds of herbaceous vegetation per acre (Kundaeli and Reynolds 1972).

PINYON AND JUNIPER HABITAT RELATIONSHIPS

Climatic Relationships

Published rainfall values for pinyon-juniper woodlands vary from 8 to 25 inches (20 to 63cm) (Merkel 1952, Richmond 1962, St. Andre et al. 1965, Woodbury 1947, Pearson 1920, Rasmussen 1941, Jensen 1972, Blackburn and Tueller 1970), but the bulk of the woodland probably gets between 10 and 15 (25 to 38cm) of precipitation each year (Tueller and Clark 1975). Fritts (1965) reported annual precipitation rates for pinyon-juniper woodland of from 11.40 to 12.48 inches; high and low figures given by Colton (1958) were 23.15 and 4.66 inches, respectively.

In northern portions of the Colorado Plateau, including the Uinta Basin, Canyon Lands and High Plateaus physiographic units, weather conditions show great uniformity from day to day because of the high mountains which practically surround the region, deflecting the course of low-pressure systems (Sherrier 1933). Much of the precipitation there falls in winter and early spring, with the southern part of the region showing a higher peak at this time than the northern part. Another important period of precipitation occurs during July and August, with precipitation tapering off after October. Drought occurs commonly in late spring; June is often extremely dry. Clear skies predominate in this region throughout the year (Isaacson 1967).

In southern reaches of the Plateau, including the Navajo, Grand Canyon and Datil physiography units, precipitation occurs chiefly during two seasons. Severe summer convectional storms drop most of the moisture in July, August and September; most of the remaining moisture falls between December and March. The months of May and June are normally very dry. The extreme western portion of this region is less affected by the summer flow of moisture from the Gulf of Mexico; there the summer precipitation peak is not so pronounced. The percentage of days with sunshine remains high throughout the year (Isaacson 1967).

Mean July air temperatures vary from 67.5° F to 74.0° F across the woodland (Woodbury 1947, Pearson 1920, Merkel 1952, St. Andre et al. 1965). In Utah this figure is 69° F (Woodbury 1947) and in Arizona, 69° to 74° F (Pearson 1920, Merkel 1952). Pinyon-juniper woodland has a mean maximum temperature of 67° F, a mean minimum of 37° F, and a mean annual of 52° F (Randles 1949). Mean maximum and mean minimum July temperature in New Mexico and Arizona

are 84.5° F and 55.4° F, respectively. Evaporation rates lie between 30 and 40 inches (Pearson 1931). The frost-free period is 120 days (Woodbury 1947).

Juniperus scopulorum can tolerate temperature extremes from -35° F to 100° F, but thrives best where average minimums do not exceed -5° to -10° F and where precipitation totals 12 to 26 inches per year (Herman 1958).

Pinyons and junipers vary in their susceptibility to drought, which occurs commonly on the Colorado Plateau. Woodin and Lindsey (1954) reported water requirement for four species of *Pinus* and *Juniperus*. In order of increasing water requirements they are: *P. cembroides*, *J. monosperma*, *P. edulis*, and *J. scopulorum*. Tap roots of both pinyons and junipers display rapid elongation rates and can tolerate drought until precipitation alleviates it (Emerson 1932).

Growth of pinyon and juniper trees depends primarily on soil moisture stored from winter precipitation, especially snow. Much of the summer precipitation is lost either through evaporation or runoff following heavy thunderstorms (Tueller and Clark 1975).

Individual trees strongly influence the microclimate in their immediate vicinity. Utah junipers, for example, intercept approximately 40 percent of the precipitation falling on the crown (Skau 1960), and up to 80 percent of the direct sunlight (Tueller and Clark 1975).

Edaphic Factors

Niether the character nor the geologic origin of soils limits the general distribution of pinyon-juniper woodlands (Emerson 1932). A wide variety of parent materials and the soils derived from them underlie pinyon-juniper woodlands. Parent materials include sandstone, limestone and basalt; soils derived from them may be residual or transported (Aro 1971). Soil textures range from coarse, rocky and porous to fine compacted clays (Dixon 1935, Woodbury 1947).

Pearson (1931) described soil in pinyon-juniper woodlands as being grayish to pale brownish at the surface. Subsurface layers showed a slight concentration of clay and some cementation from salts. Beneath this was a highly calcareous soil layer; bedrock comprised the lowest layer.

In the LaSal Mountains, Utah, climax forests of pinyon and juniper developed mostly on sierozen and Brown soils in arid regions, and up into Brown forest soils (Richmond 1962). Tueller and Clark (1975) reported that woodland soils consist mostly of aridosols, although some lithosols, entisols, inceptisols, mollisols (particularly argixerolls and haplozerolls) occur as well.

Isaacson (1967) reported that parent materials in the northern half of the Colorado Plateau (Uinta Basin, Canyon Lands, and High Plateaus physiographic units) consist mostly of residuum, colluvium, and alluvium derived from sandstones and shales; some igneous rock occurs in the vicinity of the Henry and LaSal Mountains. Loess deposits cover older landscapes and provide younger parent materials in southeastern Utah (Meiners 1965). While loess profiles sometimes exceed 10 feet in depth, the usual soil profiles in this region do not exceed 3.5 feet; soil profiles are basic in nature (Isaacson 1967).

Most soils in the southern portion of the Plateau (Navajo, Grand Canyon and Datil physiographic units) develop on residuum, colluvium and alluvium derived from sandstone, limestone and shale. But volcanic material caps these sedimentary rocks in the extreme southeastern portion of the Colorado Plateau beginning near Flagstaff, Arizona. Soils beneath pinyon-juniper woodlands are basic in nature, only occasionally exceeding four feet in depth (Isaacson 1967).

Jameson (1967a) compiled the following soil characteristics for various geologic parent materials:

Parent Material	Infiltration Capacity	Moisture-holding Capacity	Fertility
Jurassic sandstones	High	Low	Low
Supai sandstones	Medium	Medium	Low
Coconino sandstones	High	Low	Low
Kaibab limestone	High	Low	Low
Redwall limestone	Medium	Medium	Medium
Triassic shales	Low	High	Low
Mesa Verda formation	Medium	Medium	Medium
Tertiary volcanics (basalt)	Medium	High	High
Quaternary volcanics	Med. to High	Low to High	Low to High
Granite	High	Low	Low
Sand and Gravel	High	Low	Low

Soil type strongly influences the growth and development of individual trees (Tueller and Clark 1975). Phillips (1909) reported that the best stands of *P. edulis* occurred on coarse gravel, gravelly loam or coarse sandy soils usually over five feet deep. Soils beneath *P. edulis* are alkaline, mostly calcareous, rocky, and very low in productivity (Howell 1941). Often they have poor soil-moisture-holding characteristics (Tueller and Clark 1975). *Pinus monophylla* occurs commonly on coarse gravelly soils, shallow deposits overlying granite, limestone or shale, and often in rock crevices (Graves 1917).

Juniperus scopulorum prefers calcareous, somewhat alkaline soils. Best growth takes place in deeper, moister soils, but the species occurs commonly in soils which are shallow and stony, with limey, cemented subsoils and subject to erosion (Herman 1958). *Juniperus osteosperma* produces more foliage and fruit per unit crown area on upland shallow hardpan soils than on more mesic sites (Mason and Hutchings 1967).

Litter fall to the soil surface beneath trees strongly aids soil wettability which decreases outward from the base of a tree to openings in the woodland (Scholl 1971).

Both junipers and pinyons have generalized root systems which adapt the trees readily to their surroundings. Lateral roots which lie 15 to 40cm beneath the soil surface often compete directly with grasses for moisture. Tap roots grow down to bedrock or to a restrictive soil layer and then become lateral; they compete less with grasses for soil moisture than do lateral roots (Emerson 1932). Soil structure often causes root systems to be rather shallow (Tueller and Clark 1975).

Soil type also influences herbage production in pinyon-juniper woodlands. Mason et al. (1967) compared vegetation and soils of No Man's Land Mesa, a relict area in Kane County, Utah. Two soil types occurred under pinyon-juniper woodlands on the mesa. The Upland sand site consisted of Preston-like loamy fine sand. The deep soil of that site could hold 8.5 inches of moisture in a six foot depth. The Upland shallow breaks site had Menefee-like very fine sandy loam; soil was shallow and could hold only two inches of moisture in the profile not considering water in bedrock cracks.

Vegetation of the Upland sand site yielded an average of about 110 pounds per acre air-dry. Vegetation composition consisted of 10 percent grasses, 5 percent forbs, and 85 percent trees and shrubs. Live understory plant density was 12 percent. Other cover included: litter and mulch, 29 percent; cryptogam, 7 percent; bare ground, 52 percent. Tree overstory density measured 14 percent. Potential cedar post production was about 0.2 post/acre/year; juniper cordwood production potential averaged 0.02 cord/acre/year, while pinyon cordwood production potential averaged 0.07 cord/acre/year (Mason et al. 1967).

The Upland shallow breaks site yielded an average of almost 800 pounds per acre of air-dry vegetation, consisting of 5 percent grasses, 5 percent forbs, and 90 percent trees and shrubs. Live plant density of the understory measured 6 percent; rock fragments covered 30 percent of the surface, litter and mulch, 29 percent, and bare ground 35 percent. Overstory density reached 24 percent. Fencepost and cordwood production about equalled production on the Upland sand site (Mason and Hutchings 1967).

Thatcher and Hart (1974) found that in northwestern Arizona, soils with vesicular, massive or platy surfaces did not produce significant quantities of grass in any stage of plant succession. Only juniper, pinyon and shrubs grew on these soils to any degree. Soils with granular sandy loam surface layers, even when quite shallow, produced relatively large quantities of grass under normal conditions.

WOODLAND VEGETATION RELATIONSHIPS ON THE COLORADO PLATEAU

Ecological Provinces of the Colorado Plateau

Isaacson (1967) studied pinyon-juniper woodlands in Arizona, Colorado, Nevada, New Mexico and Utah. Based on climatic, topographic and vegetation data, he proposed three tentative ecological provinces: the Escalante-Sevier province, the LaSal province and the Coronado province.

The Escalante-Sevier ecological province largely corresponds with the eastern portion of the Great Basin section of the Basin and Range physiographic province (Fenneman 1931, Thornbury 1965, Hunt 1974), but Isaacson changed its southeast boundary to include a portion of the High Plateaus physiographic unit of the Colorado Plateau. Vegetation of the Escalante-Sevier ecological province will be compared with vegetation of the Colorado Plateau later in this report.

The LaSal ecological province encompasses the Uinta Basin, Canyon Lands, and most of the High Plateaus physiographic units of the Colorado Plateau. It is drained by the Colorado, Green and San Juan Rivers (Isaacson 1967).

The Coronado ecological province lies to the south of the LaSal province and includes the Navajo, Datil and Grand Canyon units of the Colorado Plateau. The Little Colorado and Colorado Rivers drain it (Isaacson 1967).

Vegetation of the LaSal Ecological Province

Pinus edulis and *Juniperus osteosperma* dominate woodland stands of the LaSal province, although *Pinus monophylla* also occurs in the area. *Juniperus scopulorum* is a minor species at upper elevations. Usually the pinyon-juniper woodland grades into a mountain brush community at upper elevational limits within this province, but may also grade into ponderosa pine (*Pinus ponderosa*) or Douglas-fir (*Pseudotsuga menziesii*) communities (Isaacson 1967).

Characteristic understory species of the LaSal province include big sagebrush (*Artemisia tridentata*), chicken sage (*A. t. arbuscula*), little rabbitbrush (*Chrysothamnus viscidiflorus*), bitterbrush (*Purshia tridentata*), snakeweed (*Gutierrezia sarothrae*), white borage (*Cryptantha* sp.), squirreltail (*Sytanion hystrix*), Indian ricegrass (*Oryzopsis hymenoides*), muttongrass (*Poa fendleriana*), blue grama grass (*Bouteloua gracilis*), and dry land carex (*Carex* sp.). From middle elevations to the upper reaches of the woodland zone, birchleaf mountain mahogany (*Cercocarpus montanus*), serviceberry (*Amelanchier alnifolia*), Gambel oak (*Quercus gambelii*), junegrass (*Koeleria cristata*) and goldenrod (*Solidago* sp.) become important species also (Isaacson 1967).

Many species are restricted latitudinally within the LaSal ecological province. For example, galleta grass (*Hilaria jamesii*) occurs more commonly in southern latitudes here, as well as in the Escalante-Sevier province. Three-awn grass (*Aristida* sp.) grows predominantly in the south and central regions of the LaSal province at low elevations. Arizona fescue (*Festuca arizonica*) grows occasionally at mid and high woodland elevations. Several species, notably western wheatgrass (*Agropyron smithii*), Sandberg bluegrass (*Poa secunda*), *Phlox* sp. and *Aster* sp. occurred more frequently in the central and northern regions of the LaSal province; at higher elevations in these

regions grew also bluebunch wheatgrass (*Agropyron spicatum*), beardless wheatgrass (*Agropyron interme*), and snowberry (*Symphoricarpos* sp.) (Isaacson 1967).

Vegetation of the Coronado Ecological Province

Again, *Pinus edulis* and *Juniperus osteosperma* comprise the principal dominants; *P. monophylla* occurs, usually as a minor species, with *P. edulis* in northwestern Arizona. *Juniperus monosperma* occurs with *P. edulis* or grows in pure stands in the southeast portion of the Coronado province toward the Rio Grande drainage of the eastern Lower Basin and Range physiographic province. *Juniperus scopulorum* grows in small quantities on favorable sites throughout the province (Isaacson 1967). *Juniperus deppeana* also forms a minor component of the woodland in the central and eastern regions of the province.

The lower woodland ecotone grades consistently into grassland communities; the upper ecotone into ponderosa pine. The largest pinyon and juniper trees grow here, probably because most of the precipitation falls during the growing season. Junipers grow to 35 feet on the best sites. Colorado pinyon trees 40-45 feet tall grow on sites east of Farmington, New Mexico and in Arizona. The tallest pinyons--47 feet--are recorded from the timber:woodland ecotones on the south rim of Grand Canyon (Isaacson 1967)

Grass dominates the woodland understory in the Coronado province. Blue grama occurs most abundantly, accounting for more than 40 percent of the understory composition on Isaacson's study areas. Other important grasses include: squirreltail (*Sytanion hystrix*), three-awn grass (*Aristida* sp.), galleta grass (*Hilaria jamesii*), black grama (*Bouteloua eriopoda*), Indian ricegrass (*Oryzopsis hymenoides*), side-oats grama (*Bouteloua curtipendula*), and on somewhat moister sites, muttongrass (*Poa fendleriana*). Common shrubs and forbs include big sagebrush (*Artemisia tridentata*), *Yucca* sp., snakeweed (*Gutierrezia sarothrae*), globemallow (*Sphaeralcea* sp.), and at upper elevational extremes, Gambel oak (*Quercus gambelii*) (Isaacson 1967).

Unlike the LaSal province, changes in vegetation composition occur longitudinally instead of latitudinally. Differences in species composition as one moves from east to west may be due to differences in the amounts of summer rainfall which decrease as storms track westward (Isaacson 1967).

Of the plants concentrated in the west and central parts of the Coronado province, these seem to be the most important: cliffrose (*Cowania mexicana*), Algerita (*Berberis fremontii*), live oak (*Quercus turbinella*), and *Phlox* sp. Ring grass (*Muhlenbergia torreyi*), wolftail (*Lycurus phleoides*), bitterbrush (*Purshia tridentata*), and birchleaf mountain mahogany (*Cercocarpus montanus*) grow mainly in the central and eastern regions of the province. Squawbush (*Rhus trilobata*), rubber plant (*Hymenoxys richardsonii*), pine dropseed (*Blepharoneuron tricholepis*), Arizona fescue (*Festuca arizonica*), Kentucky bluegrass (*Poa pratensis*) and manzanita (*Arctostaphylos patula*) all occur at higher elevations (Isaacson 1967).

Isaacson (1967) emphasizes that plant species which he has relegated to specific sub-provinces will probably occur elsewhere in the pinyon-juniper woodlands. As species more common to specific geographical areas having communities in the general condition found at the present time, they do not necessarily indicate what the climax understories for those areas might be.

Canopy-Understory Relationships

Pinyon-juniper woodland consists of stands ranging from open, scattered stands of small trees to dense stands of large trees. Arnold et al. (1964) determined the relationship of understory vegetation to variations in overstory tree canopy by taking random 50 foot line transects in plots protected from grazing from 1940 to 1953. Some transects were far enough from pinyon and juniper trees to be free of their influence; the rest of the transects were grouped according to canopy intercepts of overstory trees by 10 percent intervals. Results of measurements of understory vegetation in Arizona appear in Figure 3.

In Arizona, Arnold et al. (1964) found that shrubs showed the greatest canopy intercepts where no tree overstory occurred. Total intercept of shrubs generally decreased as overstory pinyon and juniper increased, except where crown cover fell between 41 and 60 percent. Algerita and cliffrose caused the increase in shrub intercept where canopy cover was between 41 and 50 percent; cliffrose and other shrubs were responsible for the increase where canopy cover fell between 51 and 60 percent. These irregularities did not represent trends since site conditions were not the same for all transects. Overstory trees tended to reduce amounts of browse of such palatable species as winterfat (*Eurotia lanata*) and shrubby eriogonums. Occurrence of woody perennials, including cacti, agaves and yuccas, did not seem to relate definitely to overstory tree density.

Perennial grasses showed greatest basal intercepts on areas not under the influence of trees. Increasing canopy cover of pinyon and juniper caused perennial forbs and perennial grasses to decrease. When perennial grass and forb cover becomes sparse beneath trees, annuals invade the barren soil surfaces if and when excess moisture and favorable temperatures occur. Mid-grasses averaged about one-third of the total perennial grass cover under both dense and light tree stands. Half-shrubs, most abundant where tree canopy intercept was 30 percent or less, showed less than one percent canopy intercept in protected grassland openings. Where tree canopy was greater, broom snakeweed decreased with increasing overstory canopy (Arnold et al. 1964).

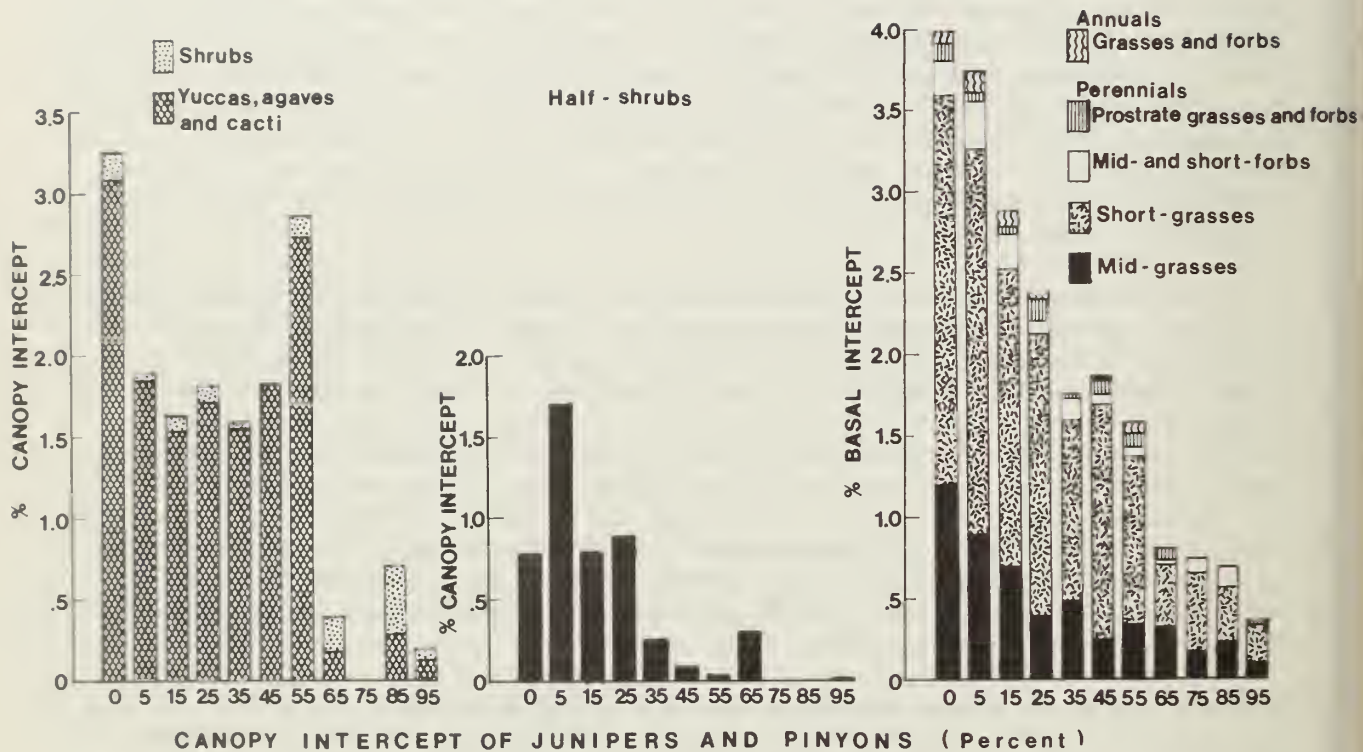


FIGURE 3. Relation of understory woody perennials, half-shrubs, and herbaceous plants to canopy intercept of pinyon and juniper trees in Arizona (from Arnold et al. 1964).

Herbage Production

In Arizona, transects with no intercept of juniper and pinyon produced 620 pounds of air-dry herbage per acre, on the average. Production dropped to 40 percent less on transects with 10 percent canopy intercepts, and to 65 percent less on transects with 30 percent canopy intercepts. Where transects had 50 percent canopy intercepts, herbage yield of forbs and grasses was 82 percent less than on sites with no tree influence (Figure 4) (Arnold et al. 1964).

An individual tree can influence species composition and growth of understory plants far beyond its canopy (Springfield 1975). Tree roots provide more competition in openings between trees than beneath tree crowns (Arnold 1964). Surface soil in openings among dense tree stands may be nearly filled with tree roots (Plummer 1958).

Bunchgrasses seem to be less generally influenced by tree crowns than sodformers. Muttongrass and little ricegrass grows beneath trees, bluegrass grows mainly in the openings, while species such as western wheatgrass, squirreltail, and snakeweed often grow around the outside edge of tree crowns (Springfield 1975). On the Coconino National Forest, Arizona, early spring grass production (muttongrass, squirreltail, prairie junegrass and western wheatgrass) was four to five times greater beneath crowns of large alligator junipers than in areas of similar size away from the trees (Clary and Morrison 1973).

Dense tree overstories may prevent any great changes in understories. During 10 to 14 years of protection from grazing on sites in New Mexico, Springfield (1959) found negligible changes in herbaceous cover where the tree canopy exceeded 30 percent, whereas density and production of desirable perennial grasses improved substantially where tree cover was less than 20 percent.

Juniper trees commonly suppress understory vegetation, especially on heavy clay soils (Springfield 1975). Juniper trees can intercept up to 40 percent of the precipitation falling on the crown (Skau 1964). But tree litter and tree root competition seem to be the primary factors involved in the reduction of blue grama stands by juniper (Jameson 1966b, 1966d, 1970).

FAUNAL RELATIONSHIPS IN COLORADO PLATEAU WOODLANDS

Pinyon-juniper woodlands vary from stunted, isolated trees on sheer cliffs to dense tree stands on flats and gentle slopes having over 1600 trees per acre, with canopy covers exceeding 60 percent on the best sites. The highly varied topography encompassed by Plateau woodlands provides diverse faunal habitats. Within the altitudinal limits of pinyon-juniper communities, the tree cover is often broken by such understory vegetation as sagebrush, scrub oak, mountain-mahogany, cliffrose, serviceberry, bitterbrush, rabbitbrush, and many herbaceous plants that provide even more diversity of habitat for faunal species (Frischknecht 1975). Appendices VIII to XI present lists of vertebrate species occurring in pinyon-juniper woodlands of the Colorado Plateau; Appendix XII is a list of birds occurring in riparian habitats.

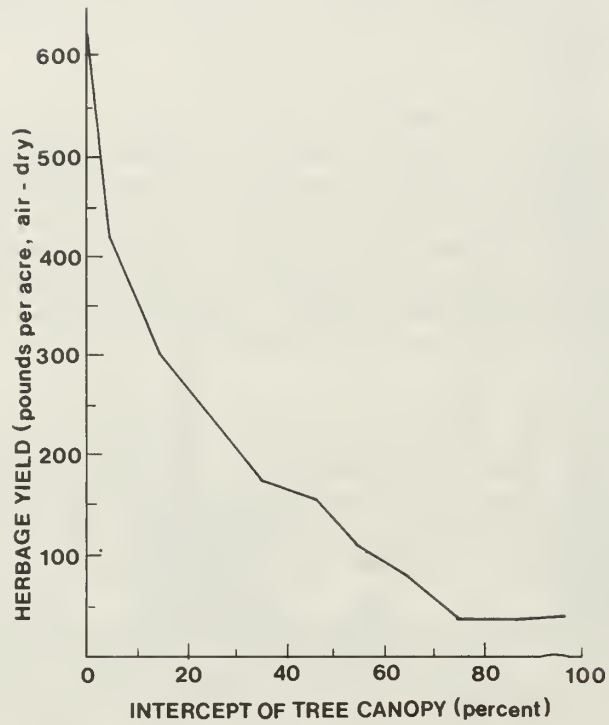


FIGURE 4. Relation of air-dry herbage yield to percent canopy Intercept of overstory pinyon and juniper in Arizona (from Arnold et al. 1964).

Big Game Animals

The mule deer (*Odocoileus hemionus*), a dominant species, is the most important big game animal occurring in pinyon-juniper woodlands. Mule deer depend heavily on woodland for cover, shelter and emergency feed during severe winters. Julander (1962) reported that on winter stress areas in northern Utah where junipers were limited or lacking, losses within deer herds were about 50 percent during the severe winter of 1948-1949; on better pinyon-juniper ranges further south, losses averaged only 9 percent.

Kufeld et al. (1973) summarized 99 deer food-habits studies conducted in the United States and Canada. Of these, 28 showed that deer ate *Juniperus scopulorum* and 16, *J. osteosperma*. Deer utilize junipers most in winter, then in spring, fall and summer, in that order (Frischknecht 1975).

Mule deer winter diet averages 74 percent shrubs and trees, 15 percent forbs, and 11 percent grasses, sedges and rushes. During the spring, the average consumption of forbs rises to 25 percent and grasses to 26 percent, while woody species drop to 49 percent of the diet. In summer, the proportion of shrubs and trees in the diet remains at 49 percent, forbs increase to about 48 percent, and grasses drop to 3 percent. Considerable regional variation can occur in these diet figures, especially for grasses and grasslike plants, and forbs (Kufeld et al. 1973).

Differences in palatability apparently exist both among species of junipers and among individual trees of the same species. Some trees may show browse lines while others nearby go untouched. This variability in palatability among individual plants could account for differences in consumption of juniper, sagebrush and other vegetation in feeding trials (Smith 1959). Smith and Hubbard (1954) reported that among 15 shrub species, Rocky Mountain juniper ranked tenth in order of preference by captive mule deer; Utah juniper ranked last.

Mule deer use of juniper for food depends on the presence of other palatable species. Winter diet of deer in one study in Utah consisted mostly of browse, especially bitterbrush, mountain-mahogany, curlleaf mountain mahogany (*Cercocarpus ledifolius*), and cliffrose (Julander 1955). In one study in southeast Utah, where the only browse species present consisted of sagebrush, juniper and pinyon, stomach analysis showed that sagebrush constituted up to 80 percent of the diet of mule deer in October (Julander 1952).

Mule deer seek the shelter of trees during heavy winter storms. Gladfelter (1966), working with white-tailed deer (*Odocoileus hemionus*) in Idaho, found that deer activity increased before storms or high winds but decreased during storms. Deer travelled along paths of least resistance, avoiding the snowdrifts which accumulated in open areas and on ridges. They bedded down much earlier in winter than in summer, often under a tree or other heavy cover. Low temperatures and high humidity accompanied increased length of bedding.

Elk (*Cervus elaphus canadensis*) use pinyon-juniper woodland as winter range in northwest Wyoming (Wight and Fisser 1968). Juniper is moderately palatable to elk in winter; they also feed on it in fall and spring. (Kufeld 1973). In southern Colorado, juniper comprised 8 percent of the elk spring diet, 4 percent of autumn and winter diet, and less than 1 percent of the summer diet (Hansen and Reid 1975).

Elk in Utah make extensive use of pinyon-juniper woodlands in winter, especially where mountain-mahogany (*Cercocarpus ledifolius*) appears in the understory. A herd of 20 to 30 elk on the Indian Peaks area of southwest Utah spends much time in woodland throughout the year. On the Dutton Range east of Panguitch, elk spend most of the summer in lower canyon bottoms having small meadows. As the rut begins in September, elk move up the mountains, wintering on south-facing slopes to elevations of 9000 feet. Pinyon and juniper trees on intermediate slopes have understories of mountain mahogany and other shrubby species. Trees serve more as cover and shelter for elk than as food (Frischknecht 1975).

On the Manti-LaSal National Forest east of Moab, winter elk use of woodland averaged 20 days per acre for six different pinyon-juniper areas from 1970 to 1974. Highest average elk use occurred on Biddlecomb Ridge (43 elk days per acre) and South Trail Mountain (42 elk days per acre). Heaviest use of South Trail Mountain amounted to 117 elk days per acre in the winter of 1970-71 (Frischknecht 1975).

Desert bighorn sheep (*Ovis canadensis nelsoni*) inhabited most of the lands of the Southwest when the white man arrived in North America. Hunting, competition with domestic livestock, and decrease in available habitat contributed to drastic population declines of desert bighorns from the 1850s to the 1950s. Today the species utilizes pinyon-juniper range in rough areas otherwise suitable for bighorn habitat (Yoakum 1971, Frischknecht 1975).

Wilson (1968) studied bighorn sheep ecology and distribution in the White Canyon area of southeast Utah. There, part of the bighorn sheep range occupies pinyon-juniper woodland. Between 124 and 144 adult sheep in scattered bunches ranged through the study areas. Adult rams utilize higher, more remote rocky areas, whereas ewes, lambs and immature rams one to three years old use steep talus slopes and lower mesas and canyons. High rims and buttes afford the most protection for these animals. On Wingate Mesa, which rams utilize during summer, use increases proportionally as tree density decreases toward the southwest end of the mesa. Lack of available free water posed the greatest limitations to the sheep population over the entire study area, but internal parasites and competition for forage and water with deer and livestock also limited population growth.

A herd of approximately 130 bison (*Bison bison*) range through the pinyon-juniper type in the Henry Mountains of southern Utah. The herd utilizes woodland habitat primarily for shelter and cover, foraging primarily on understory grasses (Frischknecht 1975).

Pronghorn (*Antilocapra americana*) occur on woodland ecotones where the pinyon-juniper community gives way to more open vegetation. Smith et al. (1965) tested fenced pronghorns for food preferences and found that these animals consumed big sagebrush, black sagebrush and juniper, in that order, and over 13 other species. Single-leaf pinyon ranked fifth in order of preference, behind cliffrose.

Wild Horses and Burros

Wild horses make extensive use of pinyon-juniper woodland in various parts of the western United States. Most bands are small, from two to eleven animals, each band having a dominant stallion. Some bands consist only of stallions, which may have been driven from other bands by dominant stallions. Colts may be born from March through October, but most come in May. Horses use south-facing slopes in winter and consume cliffrose, bitterbrush, sagebrush, rabbitbrush and oak leaves in autumn. Some rehabilitated areas seeded to grasses show heavy year-round use by horses (Frischknecht 1975). Zarn et al. (1977a, 1977b) compiled literature reviews on wild, free-roaming horses and burros.

Predators

Mountain lions (*Felis concolor*) occur in rugged canyons, rims, and wooded areas throughout the Colorado Plateau. Substantial populations still remain in south-central and southeast Utah (Wilson 1968). At one time, mountain lions occurred numerously on the Kaibab Plateau in northern Arizona, but their numbers have been drastically reduced by hunting; in the period before 1931, 781 mountain lions were taken on the Kaibab Plateau. By the late 1930s, the mountain lion population in this area stood at about 50 animals (Rasmussen 1941).

Individual mountain lions can take up to two deer per week for food. Where sufficient deer are available, lions seldom prey on appreciable numbers of smaller mammals or birds, but do take porcupines and young horses (Rasmussen 1941).

Coyotes also range throughout pinyon-juniper woodlands and into adjacent communities. Rasmussen (1941) reported that coyotes were a factor in deer predation on the Kaibab Plateau, occurring there in densities two to three times great in winter than in summer. Winter coyote droppings there showed deer hair, rabbit fur, *Peromyscus* remains and a small amount of grass. In summer, droppings were composed mostly of vegetable matter, juniper berries, service berries, prickly pear, grass, and rodent remains. Within the woodland, the coyote's main year-round food consists of small rodents.

Bobcats (*Lynx rufus*) occur in woodland habitat having cliffs, canyons and ledges. Their food consists of small rodents, some birds and an occasional fawn (Rasmussen 1941). An antelope herd productivity study conducted on the Desert Experimental Range in southwest Utah revealed that 61.5 percent of all antelope fawn mortality, excluding abandoned fawns, was due to bobcat predation. Most kills took place where juniper trees grew in dry washes, forming stringers leading out into the valley (Beale and Smith 1973).

Badgers (*Taxidea taxus*) and long-tailed weasels (*Mustela frenata*) occur in pinyon-juniper woodlands and prey largely on small mammals (Frischknecht 1975).

Small Mammals

Porcupines (*Erethizon dorsatum*) occur in woodlands as permanent residents where rocky cliffs and talus slopes in relatively inaccessible canyons provide adequate den sites and offer protection from predators. Dendrochronological studies of pinyon pine in Mesa Verde National Park revealed that porcupines have experienced four population eruptions there in the last 120 years, centered in 1845, 1885, 1905 and 1935. The 1905 eruption lasted about 12 years; the other three lasted about 20 years each (Spencer 1965).

Desert cottontail rabbits (*Sylvilagus audubonii*) range widely throughout pinyon-juniper woodlands of the Rocky Mountains and the Colorado Plateau. In undisturbed woodland, highest use by cottontails occurred where vegetation composition averaged 85 trees, 85 shrubs, and 270 pounds of grass per acre. But if adequate shrub cover exists, cottontails use an area whether or not living trees are present. Cottontail use of an area grows as shrubs increase from 53 to 85 per acre; use decreases as shrubs increase from 85 to 125 per acre. In tree-removal areas, cottontail use declined unless a mixture of 70 to 90 felled trees and shrubs remained per acre. Where shrubs alone occurred in that density, leaving downed trees did little to improve habitat. Ranges of 150 to 320 pounds of herbaceous vegetation per acre did not seem to affect cottontail use (Kundaeli and Reynolds 1972, Kundaeli 1969).

Black-tailed jackrabbits (*Lepus californicus*) and white-tailed jackrabbits (*Lepus townsendii*) occur in scattered areas throughout pinyon-juniper woodlands, concentrating there in severe winters (Frischknecht 1975).

Baker and Frischknecht (1973) studied small mammal populations in woodlands of the eastern Great Basin in west-central Utah. Of 13 species taken, deer mice (*Peromyscus maniculatus*) comprised 83 percent of the catch. Other species taken included: Great Basin pocket mice (*Peromyscus parvus*), long-tailed voles (*Microtus longicaudus*), western harvest mice (*Reithrodontomys megalotis*), Great Basin kangaroo rats (*Dipodomys microps*), Nuttall's cottontails (*Sylvilagus nuttallii*), sagebrush voles (*Lagurus curtatus*), desert woodrats (*Neotoma lepida*), pinyon mice (*Peromyscus truei*), least chipmunks (*Eutamias minimus*), rock squirrels (*Spermophilus variegatus*), and northern grasshopper mice (*Onychomys leucogaster*). In another small mammal study in nearby sagebrush-grass communities, all but the two species of chipmunks, sagebrush vole and rock squirrel were taken (Black and Frischknecht 1971).

In pinyon-juniper woodlands of the LaSal Mountains of southeast Utah occur the pinyon mouse, Mexican woodrat (*Neotoma mexicana*), white-throated woodrat (*N. albigula*), and the bushy-tailed woodrat (*N. cinerea*). At the lower edge of the woodland occur the Colorado chipmunk (*Eutamias quadrivittatus*), apache mouse (*Perognathus apache*), Ord's kangaroo rat (*Dipodomys ordi*), canyon mouse (*Peromyscus crinitus*), western harvest mouse, northern grasshopper mouse, white-tailed antelope ground squirrel (*Ammospermophilus leucurus*), rock squirrel, the Gunnison prairie dog (*Cynomys gunnisoni*) and the desert cottontail. Least chipmunks and Nuttall's cottontails occurred from upper woodland ecotones into the spruce-fir communities. Deer mice occurred in all the communities studied; so did the porcupine, except in alpine tundra (Bradley 1971).

Shepherd (1972) conducted an eight-year study of small mammals on pinyon-juniper deer range in western Colorado, where deer mice and pinyon mice were the most abundant of seven species taken. Because these mice consume large quantities of insects, they are probably more beneficial than harmful to the deer range. Pinyon mice may show population peaks over 25 times the size of population lags; combined population densities for pinyon mice and deer mice ranged from 0 to 8.15 animals per acre. Other species inhabiting the study area included the brush mouse (*Peromyscus boylei*), western harvest mouse, Mexican vole (*Microtus mexicanus*), Colorado chipmunk, and the least chipmunk.

The desert woodrat (*Neotoma lepida*), along with the pinyon mouse, characterizes pinyon-juniper woodland. Rasmussen (1941) studied desert woodrats on the Kaibab Plateau. Woodrats build their nests around the stump of a pinyon or juniper tree. One nest observed by Rasmussen contained nearly 10 bushels of materials, 85 percent of which consisted of sticks and twigs of juniper, pinyon and other available plant species. Empty pinyon cones made up 5 percent of the nest, 4 percent consisted of bones, 2 percent rocks, 1 percent opuntia cactus, 1 percent mushrooms, and 2 percent deer hide and hair. The nest contained about one-half pound of pinyon nuts and a small amount of juniper berries. In some areas of woodland, nests may reach a density of one per 1.25 acres.

Stones (1960) observed 233 woodrat nests in west-central Utah. Ninety percent were in direct association with live junipers, 6.4 percent occurred in dead trees or fallen limbs, 2.6 percent were built on open ground, and 1.3 percent were in sagebrush. While woodrats built almost all houses in junipers at the bases of trees, a few occurred in the middle portions of the tree and one was in a treetop. Food caches consisted almost exclusively of juniper berries and fresh juniper foliage; pinyon did not occur in the study area. Woodrat populations varied from one to three, to 8.5 adults per acre in a mixed juniper-sagebrush community.

Abert's squirrels (*Sciurus aberti*) occasionally forage in pinyon trees. Reynolds (1966) observed Abert's squirrels near Silver City, New Mexico, clipping terminal twigs on pinyon trees; occasionally the twigs formed almost a complete mat beneath some trees. Squirrels stripped pinyon twigs not having needles or bark; they did the same with twigs in nearby ponderosa pines. Reynolds suggested that where pinyon trees surround small clumps of ponderosa pines, a border of pinyon should be maintained around the ponderosa pines to augment the squirrels' food supply.

Birds

In a two year study of nesting ecology of the ferruginous hawk in west-central Utah, Weston (1968) observed 27 occupied nests-- 11 in Utah junipers, 1 in cliffrose, 14 on the ground and 1 on a cliff. Of 66 unoccupied nests, 20 occurred in juniper trees, 1 in cliffrose, 42 on the ground, and 3 on cliffs. Ferruginous hawks nest from March through July and migrate south by September. Bald eagles (*Haliaeetus leucocephalus*) and rough-legged hawks (*Buteo lagopus*) moved into the area by November and wintered there until February or early March. Other permanent residents of Weston's study area included the golden eagle (*Aquila chrysaetos*), Swainson's hawk (*Buteo swainsoni*), American kestrel (*Falco sparverius*), red-tailed hawk (*Buteo jamaicensis*) and great horned owl (*Bubo virginianus*).

Smith (1971) also working in west-central Utah, observed nests of the prairie falcon (*Falco mexicanus*), marsh hawk (*Circus cyaneus*), Cooper's hawk (*Accipiter cooperi*), short-eared owl (*Asio flammeus*), burrowing owl (*Speotyto cunicularia hypugaea*), and raven (*Corvus corax*). Great horned owls, red-tailed hawks, Swainson's hawks, ferruginous hawks, Cooper's hawks and kestrels nested in trees. Except for the nests of kestrels, which are built in small crevices in tree trunks, tree nests occur mainly in treetops. Ground nesters include marsh hawks, burrowing owl, short-eared owl, and some ferruginous hawks. Birds using cliff sites include golden eagles, great horned owls, red-tailed hawks, prairie falcons and ravens. Ravens choose the most remote and secluded areas for their nests.

Hardy (1945) studied the birds of the Book Cliff Mountains of eastern Utah and identified eight permanent residents. Only three of these, all tree-nesters, are obligate to pinyon-juniper woodland: the pinyon jay (*Gymnorhinus cyanocephalus*), plain titmouse (*Parus inornatus*) and the common bushtit (*Psaltriparus minimus*).

Woodbury and Russel (1945) reported that characteristic birds of pinyon-juniper woodland in southeast Utah and adjacent areas include four permanent residents: the pinyon jay, plain titmouse, common bushtit, and Bewick's wren (*Thryomanes bewickii*). Birds breeding in the woodland include: poor-will (*Phalaenoptilus n. nuttallii*), ash-throated flycatcher (*Miarchus cinerascens*), gray flycatcher (*Empidonax wrightii*), blue-gray gnatcatcher (*Polioptila caerulea*) and black-throated gray warbler (*Dendroica nigrescens*). Other birds are common to pinyon-juniper woodland but not necessarily limited to the area; they include the following permanent residents: American kestrel, great horned owl, common flicker (*Colaptes a. auratus*), hairy woodpecker (*Dendrocopos villosus*), mountain chickadee (*Parus gambeli*), white-breasted nuthatch (*Sitta carolinensis*) and house finch (*Carpodacus mexicanus*). Breeding birds not limited to the woodland include:

mourning dove (*Zenaida macroura marginella*), black-chinned hummingbird (*Archilochus alexandri*), Cassin's kingbird (*Tyrannus vociferans*), Say's phoebe (*Sayornis saya*), western bluebird (*Sialia mexicana*), mountain bluebird (*S. currucoides*), solitary vireo (*Vireo solitarius*) and chipping sparrow (*Spizella passerina*).

According to Rasmussen (1941), the most abundant birds residing in Kaibab Plateau woodlands include: golden eagle, red-tailed hawk, common flicker, pinyon jay, plain titmouse, common bushtit and rockwren. Summer resident birds are comprised of mourning dove, nighthawk, northern cliff swallow, Rocky Mountain grosbeak (*Guiraca caerulea*), black-throated gray warbler, western lark sparrow, western chipping sparrow and desert sparrow.

Balda (1969) observed 36 species of birds having a total nesting density of 267 pairs per 100 acres in the oak-juniper woodlands of southeast Arizona. Balda and Bateman (1971) studied a flock of about 250 pinyon jays near Flagstaff, Arizona for over two years. The flock fed as a unit from October to December. Pairs separated from the flock to court in relative isolation from the main flock during January and February. Most members of the flock utilized a special dining call as a cue to reassemble. Adult jays began nesting in late February to mid-March; all built their nests in a traditional 230-acre breeding ground used by the flock for at least four years. In any one year, nests were dispersed over about 120 acres. Males fed their mates during incubation and brooding. After hatching, only parent birds fed their young for the first six days; after that, helpers also brought food to the young. Communal units consisting of adults from nearby nests assisted in feeding young until late summer when all the feeding units gathered on the nut-laden pinyon slopes within the home range. There they gathered seeds, most of which they cached in the traditional breeding ground, since they appear to rely strongly on pinyon nuts for reproduction. Individuals from one flock did not mingle with birds from other flocks and returned to their own flock even after a separation of 21 miles. The flock maintained a well-defined home range of about eight square miles for two years, but left it in the fall of 1970, probably due to lack of pinyon nuts.

Principle avian nesting habitat in woodland occurs in trees, in shrubs, on the ground, or in cavities in the ground, in trees or on cliffs. See Appendices IX and XII for species lists and habitat information.

Reptiles

Diurnal reptiles represent the faunal group best adapted to withstand the hostile environment of the pinyon-juniper ecosystem (Woodbury 1933). The collared lizard (*Crotaphytus collaris*), brown-shouldered lizard (*Uta s. stansburiana*), desert whiptail (*Cnemidophorus tessellatus*), and red racer (*Masticophis flagellum*) formed the most important species in Zion National Park, Utah. The three lizards eat insects, but the collared lizard preys on other lizards. It occurs on rocky slopes and hillsides, often using rocks for lookout posts, and retreats beneath rocks for shelter.

Uta stansburiana occupies rocky, brushy areas or scrub forests. It dwells on rocks, logs and in bushes, retreating to thick brush or into rock crevices for shelter. Desert whiptail lizards, ground dwellers, do not usually climb rocks or trees. They frequent brushy areas, retreating into burrows beneath brush for shelter. The red racer occurs on foothills and in valleys and eats lizards, bird eggs, young birds and rodents (Woodbury 1933).

Rasmussen (1941) cataloged the following reptiles from Kaibab Plateau woodlands: short-horned lizard (*Phrynosoma douglassi*), sagebrush lizard (*Sceloporus graciosus*), blue-bellied lizard (*Sceloporus elongatus*), brown-shouldered lizard, collared lizard, Grand Canyon rattlesnake (*Crotalus viridis abyssus*) and the Great Basin gopher snake (*Pituophis melanoleucus deserticola*). The horned lizard, the most common reptile in the upper limits of the woodland community, average 6 to 8 animals per acre in some areas. The four other lizards occurred in the lower, more open, regions. The Great Basin gopher snake occurred in lower woodlands where sagebrush formed much of the understory.

Invertebrates

Rasmussen (1941) collected 83 invertebrate species in Kaibab Plateau woodlands, but 37 of these he took only once. Spiders accounted for 25 percent of the total number taken, Chermidae 13 percent, Formicidae 12 percent, other Hymenopterans (mostly Ichneumonidae) 8 percent, Diptera 10 percent, Cicindellidae 9 percent, Hemiptera 6 percent, Coleoptera 5 percent, Orthoptera 3 percent, and others, 9 percent.

Ants (Formicidae) predominated on the ground surface. The termite (*Reticulitermes tumiceps* Banks) formed galleries in dead pinyon and juniper limbs lying on the ground. Ground strata contained slightly more invertebrates per acre than any other strata; shrub and tree strata averaged more animals per acre than herb and grass strata. Two maximums in invertebrate numbers occurred in May; a lesser peak took place in September. The total invertebrate population was considerably less than other researchers had found in deciduous forests in Illinois (Rasmussen 1941).

Because of sparse, dry groundlitter in Zion National Park, snails, millipedes and ground beetles occur uncommonly. Cicadas become periodically conspicuous as they sing noisily in trees, having completed their larval stages underground, feeding on live roots up to four feet deep. Adult tenebrionid beetles forage at the soil surface; their larval stages burrow in the soil. Predaceous insects such as robber flies (Asilidae) and bee flies (Bombyliidae) also complete larval stages underground. Scorpions and centipedes seek shelter under rocks during daytime, searching for prey at night. Tarantulas construct underground burrows for shelter (Woodbury 1933).

Insects often destroy 90 percent of the pinyon cone crop. Small, white-yellow larvae in maturing catkins destroy staminate cones; first year cones

are injured by gall midges (Itonidae). During the second year, cone moths and cone beetles can cause extensive damage. Grasshoppers feed on the surface of juniper berries, causing the berries to wither and crack open.

Certain plants which grow in woodland openings host more insect species than do the trees. Jorgensen and Tingey (1968) reported over 300 insect species from collections on big sagebrush, rubber rabbitbrush and bitterbrush and crested wheatgrass in several shrub-grass communities among or near pinyon-juniper woodlands in west-central Utah. These four plant species hosted 20 species of thrips (Thysanoptera), some of which damaged plants (Tingey et al. 1972)

Riffle (1972) reported on two species of nematodes, *Xiphenema americanum* and *Rotylenchus pumilis*, which parasitized seedlings of *Juniperus monosperma*, reducing root weights and root collar diameters. Four of seven nematode species studied parasitized *Pinus edulis* seedlings but did not significantly reduce seedling growth.

Cryptogammic Soil Communities

Cryptogammic soil communities remain virtually unknown in the published literature, even though extensive communities of this unique association occur beneath pinyon-juniper woodlands on the Colorado Plateau.

Composed of blue-green algae (Cyanophyta) and fungi, cryptogams form a crust in the upper layers of wind-deposited sands which have collected in shallow slickrock pockets. They occur on deeper sandy soils as well. Their crustlike nature allows cryptogams to exert a binding influence on surface soil layers, prevent erosion, aid in soil water retention (Loope and Gifford 1972) and allow the eventual establishment of other plant species.

Kleiner and Harper (1972) studied environment and community organization in the grasslands of Chesler and Virginia Parks, two relatively isolated areas in Canyonlands National Park, Utah. Chesler Park had received light winter grazing until about 1962, while Virginia Park, due to difficulty of access, remained virgin. The authors analyzed 60 uniformly distributed stands, 40 in Virginia Park and 20 in Chesler Park, recording both cryptogammic and vascular species as well as cover and frequency for each. Major environmental variables and soil samples from four depths at each site were also analyzed.

Both Chesler and Virginia Parks exhibit similar gross environments and plant cover, but cryptogammic vegetation and community structure differ markedly between the two areas. Virginia Park is much richer floristically than is Chesler; cryptogammic cover is about seven times greater in the ungrazed park. Cryptogammic cover apparently acts as an important stabilizing agent against wind and water erosion for the highly erodable, sandy soils present. Cryptogams also importantly influence the chemical characteristics of the upper 5cm of soil, and differences in surface soils between the parks may be related to the presence of these species. Lower organic matter, less

available phosphate, and higher calcium content of surface soils in Chesler Park may be explained in terms of slow sheet erosion and loss of the weathered and organically enriched few centimeters of surface soil. Cryptogams can apparently utilize moisture otherwise lost by physical evaporation that would not become available to vascular plants. Because the algal associate of the lichen *Collema tenax*, the commonest component of the cryptogamic cover, is a blue-green alga, the cryptogamic organisms may likely make some positive contribution to the nitrogen economy of the community as well (Kleiner and Harper 1972). The contributions of cryptogams to total available soil nitrogen is believed to be of special significance in arid soils because of their persistence in even extreme drought (Shields 1957, Shields et al. 1957).

Looman (1964) observes that lichens and bryophytes indicate edaphic factors, and suggests that cryptophyte analysis can be useful in evaluating the quality of grassland management.

Because of their location and composition, cryptogams are quite fragile. The semi-arid conditions over the Colorado Plateau make them extremely slow-growing, as well. Footsteps in cryptogamic communities can remain for over a century, and open the way for wind and water erosion to remove the soil so tenuously bound to the bedrock. In many areas, cryptogams have been heavily damaged by wildlife, grazing livestock, and humans. More research is needed to determine the role of cryptogamic soil communities in the pinyon-juniper woodland communities of the Colorado Plateau.

Appendix VI lists some algal components of cryptogamic communities.

VEGETATIONAL DIFFERENCES BETWEEN WOODLANDS ON AND ADJACENT TO THE COLORADO PLATEAU

Isaacson (1967) described pinyon-juniper woodland characteristics from the eastern Great Basin (his "Escalante-Sevier ecological province") and compared them with woodlands on the Colorado Plateau.

Pinyon-juniper woodlands of the Escalante-Sevier province show greater uniformity of composition than do those of the LaSal and Coronado provinces of the Colorado Plateau. Utah juniper was the only juniper at all mid-elevations sampled. Singleleaf pinyon extends sporadically throughout the province but in the southeastern regions (toward the Colorado Plateau), Colorado pinyon forms a minor component of woodland and even dominates stands in some areas. Where these two pinyon species coexist, individual trees may have both single and double leaves (Isaacson 1967).

Common understory plants found throughout the province include: big sagebrush, black sagebrush, chicken sage, small rabbitbrush, bitterbrush, squirreltail, sandberg bluegrass, bluebunch wheatgrass, Indian ricegrass, Nevada bluegrass (*Poa nevadensis*), needle and thread grass (*Stipa comata*), white borage (*Cryptantha* sp.), and *Phlox* sp. Big sagebrush, chicken sage, small rabbitbrush, bitterbrush, squirreltail, Indian ricegrass and white borage also occur in the LaSal ecological province (Isaacson 1967).

Some important understory vegetation varies with both elevation and latitude. Of species occurring in southern latitudes, galleta grass and buckbrush (*Ceanothus greggi*) are probably the only species not found in northern latitudes. Cliffrose appears to be important only in the southern portion of the Escalante-Sevier province (Isaacson 1967).

Several of the plants occurring in middle latitudes of the province join the general woodland community listed above at higher elevations; specific elevation varies directly with latitude. They are: serviceberry, snowberry, mountain-mahogany and Idaho fescue (*Festuca idahoensis*). All these species except mountain-mahogany probably enjoyed wider distributions before the lands became subject to heavy livestock and game concentrations. Mountain-mahogany generally occurs at elevations above pinyon-juniper woodlands in southern portions of the province (Isaacson 1967).

Species more common to the northern latitudes of the province include balsam root (*Balsamorhiza sagitata*), *Phlox longifolia*, and larkspur (*Delphinium* sp.). The lower woodland ecotone usually grades into sagebrush-grass communities in the Escalante-Sevier province. Isaacson did not observe upper woodland ecotones there (Isaacson 1967).

Appendix XIII presents distributional data for major perennial plant species on and adjacent to the Colorado Plateau.

RIPARIAN HABITATS

The aridity of pinyon-juniper woodlands makes the riparian habitats which interfinger them especially important. In addition to their obvious role of providing water to wildlife and plant species, riparian zones ameliorate the harsh climatic regimes of adjacent woodland habitats, and offer a wide variety of niches for plant growth, foraging, shelter and reproduction.

Humans depend heavily on riparian habitats as well, and use them for personal water supplies, irrigation, agriculture, grazing, and in the case of streams and rivers, transportation both along waterways and terrestrial corridors. As a result, wildlife, grazing, and other values have deteriorated from past abuses. A discussion of riparian habitat types follows.

Hanging Gardens

Hanging gardens form where water seeps from cliff faces to trickle down the rock. The presence of water hastens the disintegration of the rock surface and allows its colonization by plants. Algae form in the first series at these seeps. Mosses become established next; ferns and angiosperms follow. Hanging garden communities, more or less temporary features of the landscape, may pass into either a dry bare rock type upon loss of ground water supplies or a small stream community with increased ground water supplies.

In areas overlain by limestone formations, travertine deposits may form in hanging gardens. Rainwater, absorbing small amounts of atmospheric carbon dioxide, dissolves small amounts of limestone in the form of calcium bicarbonate. This solution passes downward through the porous sandstone aquifer and eventually emerges through the seep or spring. Water seeping over the plants in the hanging garden restricts their supply of atmospheric carbon dioxide, which the plants instead extract from the calcium bicarbonate solution. Insoluble calcium carbonate remains, which is often deposited directly over the plants, eventually causing their death. New generations grow over older ones until several feet of travertine may be laid down. Ferns and angiosperms become readily established on travertine deposits and succession advances as higher plant forms slowly crowd out lower ones (Woodbury 1933).

Floral composition of hanging garden communities strongly controls faunal elements. Algae, dominant in the first series, furnishes food for some insects and snails, such as *Petrophysa zionis* in Zion Canyon, Utah. Flower-visiting and leaf-eating insects visit communities populated by ferns and angiosperms. Bumblebees and sphinx moths, especially, may visit the hanging gardens during the profuse early summer bloom of plants such as the small-flowered columbine (*Aquilegia micrantha*). While these insects breed elsewhere, they visit the hanging gardens to forage. Spiders, especially orb-weavers (*Teragnatha* sp.), spin their webs over the water to snare insect prey. Canyon wrens, song sparrows and other birds visit hanging gardens in search of food. So do small mammals when the gardens do not occur on inaccessible cliffs (Woodbury 1933). Hanging garden communities are generally restricted to the canyon country of the Colorado Plateau; they shelter many rare endemic plant species.

Small Streams, Pools and Potholes

As the headward erosion of canyons opens new drainage channels in the rock strata, it exposes underground reservoirs of water held in the porous sandstone. Water drains from these aquifers and trickles down the rock walls, often in the thin sheets which produce hanging gardens. Gradually the waters concentrate and develop into small channels, which are the antecedents of small streams. They are usually lined with algae and populated by snails and a few insect larvae.

Cliffs become undermined where groundwater emerges because the mineral cements holding sand grains together dissolve. As undermining proceeds, more water from underground reservoirs may drain into the enlarging channel; this water may be drawn from seeps which formerly discharge elsewhere. These early stages of stream development may support growths of algae, aquatic ferns and some angiosperms, especially along the stream margins.

Surface drainage from storms increases as streams advance headward. As a result, larger and larger periodic floods follow heavy precipitation. The large quantities of silt and sand carried by these floods adversely affect the aquatic biota by scouring them with sand, smothering them with mud, or sweeping them downstream with the violent current. Much of this flood water

enters the mainstream from hanging canyons, which pour their water over high cliffs in spectacular water falls. In larger canyons, dozens of these may be visible from a single vantage point during a violent thunderstorm. The falling water often gouges out holes in the sandstone at the base of the cliff which, between floods, may be kept filled with clear water from springs and seeps. Small pools often develop along other parts of drainage courses, known locally as tanks. These potholes may remain filled with water after the stream itself runs dry and furnish important sources of water to many animals (Woodbury 1933) as well as habitat for several invertebrate and amphibian species (Findley 1975).

Between floods, algae restock the scoured pools; so do other animals and plants if the interval between floods is long enough. Woodbury (1933) observed the early stages of succession in a pool following a flood in Zion National Park. The flood, which occurred in August 1926, left a clean sandy floor in the pool. By September, algae had begun to grow in the clear, mineral-rich water. During the following summer, two visible types of algae were present; one was loose-floating (*Spirogyra* or *Zygnema*) and the other adhered to the pool bottom (*Chara*). In the second summer following the flood, a single cattail (*Typha* sp.) appeared in the pool and watercress grew there by the third summer. Larvae of the canyon tree frog (*Hyla arenicolor*) appeared in the pool following reestablishment of the algae, but probably fed on other organisms. Water striders (*Gerris rufoscutellatus*) and whirligig beetles (*Gurinus plicifer*) also migrated to the pool from nearby areas.

Ponds and Swamps

As streams and rivers change courses within their valleys, primarily as a result of periodic floods, they leave rock-strewn and sand-covered flood plains of irregular contour. Seeps and springs may drain into depressed areas of these flood plains, notably where the depressions are deep enough to reach the surface of subterranean water. The sluggish streams and ponds which result may develop swampy conditions. Again, such features are temporary in nature; they may be reclaimed by the stream when it later changes its course, or be filled with silt or talus and become a stage in a terrestrial sere (Woodbury 1933).

Plants such as cattails, rushes and sedges inhabit these areas. Mosquitoes, dragonflies, amphibians, garter snakes and blackbirds constitute the characteristic fauna appearing there. Areas where seepage occurs in insufficient quantities to form a stream and evaporates from the surface to leave heavy concentrations of soluble salts, are grown up in salt grass (*Distichlis spicata*). Back from the ponds on land, but still where their roots can reach soil water, grow willows and cottonwoods. On drier ground can occur almost any component of the particular deciduous forest characteristic of the area.

These waters host profuse growths of algae, bacteria and protozoa, but are generally unsuited to fish life. They furnish good habitat for mosquitoes, dragonfly larvae and amphibians, including leopard frogs (*Rana pipiens*)

and Sonoran toads (*Bufo compactilis*). Snails also occur among the algae, and tabinid fly larvae flourish in the bottom mud. Water striders colonize the water surface, and lycosid spiders may often occur numerously over the water along edges of the ponds. Dragonflies and damselflies use cattails and rushes as perches, and forage for insects in the air over the water surface. Redwing blackbirds nest among the cattails; they seek food not only in the swampy areas but in neighboring communities as well (Woodbury 1933).

Rivers

Many of the smaller rivers on the Colorado Plateau support little aquatic life due to the work of tremendous periodic floods which keep them scoured clean. Lower forms such as algae and diatoms become established in eddies and pools between floods, but never develop extensively in the main current. Woodbury (1933) concluded from historical records that disturbance of the soil cover since white settlement has produced an increased scouring action by floods.

Fish, especially minnows and suckers, and aquatic insects constitute the primary fauna of such rivers. Trout may descend from higher elevations to frequent the less turbid streams, especially in early summer when the water is cool and at its clearest, but usually disappear with the advent of summer floods. Suckers are primarily vegetarian feeders while minnows and trout prey on insect forms.

Water striders occur on the surface of eddies and pools near shore. On banks kept wet by the irregular rise and fall of the water level, the beetle *Onophron obliteratum utahense* digs tunnels through the wet substrate in search of food. The larvae of some tiger beetles (including *Cicindella tranqueberica*, *C. vibex*, and *C. oregona*) have burrows in damp sand just above reach of ordinary river levels. They emerge as adults in summer to live in the sandy areas along shore, utilizing surface and aerial strata in addition to their burrows. Lycosid spiders (including *Pardosa sternalis* and *P. lapidicina*) occupy spaces along flood plains and river margins. Adult Sonoran toads occur commonly in the moister areas along the flood plains. The wandering gardner snake (*Thamnophis elegans vagrans*) moves freely between river pools and smaller streams in search of food. Dippers (*Cinclus mexicanus*) occur commonly, taking fish and insects directly from the stream. Spotted sandpipers (*Actitis macularia*) forage along shorelines, but seldom go above the high water mark.

The valley floors and lower slopes of permanent stream drainages host a varied deciduous flora. The ameliorating influence of the river acts both to furnish moisture directly to the air in the form of evaporation and to make available an abundant supply of soil water to plants, either directly to roots submerged in the underground reservoir, or indirectly by capillary movement up through the soil. Thus plants having rapid transpiration rates can function normally here, and occur commonly.

Plants which require soil water at their roots grow along stream margins and on flood plains; they seem not to be limited by soil texture. These plants may also occur up on talus slopes supplied with spring water. This group of plants includes cottonwoods, willows, velvet ashes, boxelders and water birches. Cottonwoods and willows, appearing principally on the flood plains, act as pseudopioneers on areas left bare by floods where seedling roots can rapidly penetrate the soil water. Willows grow fastest at first and produce dense mats of vegetation which the cottonwoods eventually suppress as they grow tall enough to overtop them. The movement of the river shifts this vegetative cover periodically.

Other plants are limited by soil moisture but do not require water at their roots, so their occurrence is not quite so narrowly restricted. They include the Gambel oak, hackberry, New Mexico locust, squawbush, big-toothed maple and singleleaf oak.

The deciduous forest associated with riparian situations occurs mainly on canyon floors, long primary routes for movements of humans and animals. The great quantities of vegetation distributed through many strata provide numerous ecological niches and make this habitat the most important community of the canyons. It has also undergone some of the most severe damage by humans through development of agricultural land, irrigation projects, and grazing (Woodbury 1933).

BIG GAME POPULATIONS

Deer

Pioneers began to arrive on the Colorado Plateau in the 1850s and found plentiful deer populations there. Many settlements were established during this time; most supported prospectors and miners. Because many trade and store goods remained in very short supply, wild game formed a primary source of meat and hides for these people. Professional market hunters eventually began to make great inroads on wild game populations; by the 1860s they may have killed about 100,000 big game animals per year in the state of Colorado alone. Colorado enacted its first game laws in 1867 and established the branch of state government which would ultimately evolve into its Division of Wildlife.

The early 1900s represented a low point in deer populations (and big game populations in general), but sound wildlife management practices put population levels into better balance with forage resources and available habitat, so that deer populations began to increase by the 1920s, and peaked in the late 1940s or early 1950s. Deer population levels began a gradual decline in the 1960s which has continued to the present (Colorado Division of Wildlife 1975, Utah Division of Wildlife Resources 1975).

Total deer harvest for 1975 from State of Colorado game management units on the Colorado Plateau totaled 9361 animals. In Utah, 33,798 deer were harvested from the Colorado Plateau in 1974. These figures include deer taken from all habitats, not just from pinyon-juniper woodland (Colorado Division of Wildlife 1976, Utah Division of Wildlife Resources 1975).

Elk

Elk herds occurred commonly throughout mountain and valley areas of northern and central Utah, Colorado, northern New Mexico and northern Arizona prior to white settlement. Unrestricted hunting followed settlement until the elk had been largely eliminated from its natural ranges by the turn of the century. In Colorado, no elk hunting license was required from 1897 to 1902, but elk seasons were closed from 1903 to 1929. During the early years of this closure, the elk population in Colorado numbered between 500 and 1000. By 1929, populations had increased enough to reopen the hunting season, which yielded a harvest of 895 bulls. By 1940, the population had increased to the point that antlerless elk could be taken.

In Utah, elk were given protection with closed seasons from 1898 to 1925, when interstate transplant programs had reestablished populations enough to allow hunting. Elk seasons took place on a limited basis until 1967, when the Utah Board of Game Control authorized the first "open bull" hunt on five elk units. By 1970, this type of hunt took place statewide and was continued until 1975 (Utah Division of Wildlife Resources 1975, Colorado Division of Wildlife 1976).

Hunters harvested a total of 2991 elk on portions of the Colorado Plateau within the state of Colorado in 1975. This total includes elk taken from all habitat types, not just pinyon-juniper woodland (Colorado Division of Wildlife 1976).

Desert Bighorn Sheep

Earliest records from southeastern Utah reported a fair abundance of desert bighorn sheep when white men first ventured into that part of the state. Petroglyphs and pictographs of the Basket Maker and Pueblo peoples, the first recorded human inhabitants of the Colorado Plateau, show bighorn in practically all the areas they inhabited over 1500 years ago. Father Escalante, John Wesley Powell, and the early Mormon pioneers who made the legendary Hole-in-the-Rock crossing of the Colorado River all mentioned bighorn sheep in their journals. After permanent white settlements became established, the bighorn sheep herds were never considered large enough to form an important food source. Sketchy records down to recent years indicate only occasional sightings by cowboys and miners.

Increased interest in uranium mining in the 1940s and 1950s brought a large influx of people into backcountry historically inhabited by bighorn. The few desert bighorn sheep occurring in the state today are believed to be

but a remnant of their former numbers (Utah Division of Wildlife Resources 1975).

Increased interest by game managers in recent years, followed by intensive studies, revealed a limited huntable bighorn population east of the Colorado River in San Juan County. Utah held its first desert bighorn sheep hunt in 1967. Regulations specified that only mature trophy rams would be legal. Open seasons on desert bighorn rams in Utah were held from 1967 to 1972. During that time, hunters harvested a total of 24 animals. Utah closed hunting seasons on desert bighorn in 1973 and 1974 (Utah Division of Wildlife Resources 1975); seasons were reopened in 1975 (2 rams harvested) and 1976 (4 rams harvested).

Bison

The state of Utah obtained a parent herd of bison from Yellowstone National Park, Wyoming, in 1941; three bulls and 15 cows comprised the herd. The herd was released near Robber's Roost Ranch north of the Dirty Devil River on the San Rafael Desert. The animals, particularly the bulls, dispersed immediately; some moved several miles north and northeast of the transplant site. Five more bulls were obtained from Yellowstone Park in 1942 to offset this loss, and were released with the remainder of the herd near Robber's Roost Ranch. The major portion of this herd eventually moved south across the Dirty Devil River and settled in an area adjacent to the Henry Mountains. The first sanctioned hunt was held in 1950 (Utah Division of Wildlife Resources 1975).

Ten either sex permits were issued for bison in 1974; nine permittees went afield and harvested seven bison (Utah Division of Wildlife Resources 1975).

Pronghorn

Pronghorn occurred in foothills and lower valleys throughout the Colorado Plateau before white settlement. As towns and agricultural developments increased in size, pronghorn populations decreased as the animals were forced from favorable habitat to less desirable desert ranges. Soon populations declined to isolated small bands. Even though the arid deserts formed less than desirable pronghorn habitat, they undoubtedly offered the protection necessary to keep the remaining antelope from being completely eradicated.

Unregulated livestock grazing reached an all time high in the early 1900s and eventually extended even to desert regions. The resulting competition for forage and water caused a further decline in pronghorn populations. Utah granted total protection to the pronghorn in 1898; they were not again legally hunted in the state until 1945.

In Colorado, sportsmen enjoyed their best hunting success in 1960 when 94 percent of hunters bagged a pronghorn. Success has generally declined since 1960, averaging 80 percent from 1967 to 1972. In 1972, fewer licenses were issued in an attempt to increase pronghorn herd sizes. The state further reduced the number of licenses in 1973 to compensate for winter losses, predation and reduced production in some areas (Colorado Division of Wildlife 1976, Utah Division of Wildlife Resources 1975).

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APPENDIX I

TREES OCCURRING IN PINYON-JUNIPER WOODLAND

ON THE COLORADO PLATEAU

PINACEAE

- Pinus edulis*
Colorado pinyon
P. monophylla
Singleleaf pinyon
P. ponderosa
Ponderosa pine
Pseudotsuga menziesii
Douglas fir
- Western edge of Colorado Plateau.
Upper woodland ecotones, especially in eastern portions of the Colorado Plateau.
Upper woodland ecotones, especially in eastern portions of the Colorado Plateau.

CUPRESSACEAE

- Juniperus deppeana*
Alligator juniper
J. monosperma
One-seed juniper
J. osteosperma
Utah juniper
J. scopulorum
Rocky Mountain juniper
- ncAZ to wcNM.
nw and cAZ to wNM along Mogollon escarpment; western edges of Colorado Plateau.
Upper woodland ecotones.

FAGACEAE

- Quercus gambelii*
Gambel oak
Q. undulata
Wavyleaf oak

ULMACEAE

- Celtis reticulata*
Hackberry
- Canyon floors, lower slopes in moist, shaded situations.

ACERACEAE

- Acer grandidentatum*
Bigtooth maple
A. negundo
Boxelder
- Canyon floors, lower slopes.
Canyon floors.

OLEACEAE

- Fraxinus anomala*
Singleleaf ash
F. cuspidata
Fragrant ash
F. velutina
Velvet ash
- Canyons, rocky slopes.
THREATENED; nAZ: Grand Canyon National Park, 5500-7000 ft.
Canyon floors.

ELEAGNACEAE

- Eleagnus angustifolia*
Russian olive
- INTRODUCED.

APPENDIX II

SHRUBS OCCURRING IN PINYON-JUNIPER WOODLAND
ON THE COLORADO PLATEAU

EPHEDRACEAE

- Ephedra torreyana* Lower woodland ecotones.
Torrey ephedra
E. viridis
Mormon tea

LILIACEAE

- Agave utahensis kaibabensis* THREATENED; nAZ, sUT: 3000-7500 ft.
Kaibab agave
Yucca angustissima
Narrowleaf yucca
Y. baccata
Datil yucca
Y. kanabensis Endemic to sc and swUT, nAZ.
Kanab yucca
Y. utahensis
Utah yucca

FAGACEAE

- Quercus turbinella*
Shrub live oak

POLYGONACEAE

- Eriogonum corymbosum davidsei* ENDANGERED; CO, nNM, UT: sagebrush and
pinyon-juniper foothills.
E. darrovi
E. densum THREATENED; AZ, wCO, NM, UT: shaded canyons,
foothills, 4000-6500 ft.
E. fasciculatum
California buckwheat
E. microthecum
Slender eriogonum
E. oslundii THREATENED; UT: sagebrush, pinyon-juniper
woodland.
E. ripleyi THREATENED; nAZ: among pinyons near 6000 ft.
E. simpsonii
Simpson's eriogonum

POLYGONACEAE (cont.)

Eriogonum wrightii
Wright's eriogonum

CHENOPODIACEAE

Atriplex canescens
Four-wing saltbush
A. confertifolia
Shadscale
Sarcobatus maniculatus
Black greasewood

BERBERIDACEAE

Berberis fremontii
Fremont barberry

SAXIFRAGACEAE

Fendlera rupicola
Fendlerbush
Jamesia americana
Cliff jamesia
Philadelphus microphyllus
Littleleaf mockorange
Ribes aureum
Golden currant
R. cereum
Squaw currant
R. velutinum
Desert gooseberry

Rock crevices, cliff bases, dry canyons.

ROSACEAE

Amelanchier alnifolia
Saskatoon serviceberry
A. mormonica

A. pallida
Pale serviceberry

A. utahensis
Utah serviceberry

Cercocarpus betuloides
Birchleaf mountain-mahogany

C. intricatus
Littleleaf mountain-mahogany

C. ledifolius
Curl-leaf mountain-mahogany

C. montanus
Alderleaf mountain-mahogany

Coleogyne ramosissimum
Blackbrush

Cowania mexicana
Cliffrose

Fallugia paradoxa
Apache plume

Holodiscus dumosus
Mountain spray

Peraphyllum ramosissimum
Squawapple

Prunus virginiana
Western chokecherry

Purshia tridentata
Antelope bitterbrush

Rosa stellata

THREATENED; nAZ: dry, rocky areas, 6500 ft.

ANACARDIACEAE

Rhus glabra
Smooth sumac

Moist canyon slopes.

R. radicans
Poison ivy

Uncommon; moist shaded banks.

R. trilobata
Squawbush

R. trilobata simplicifolia
Utah squawbush

ACERACEAE

Acer glabrum
Rocky Mountain maple

RHAMNACEAE

Ceanothus fendleri
Buckbrush

C. greggi
Desert ceanothus

C. velutinus
Snowbrush ceanothus

VITACEAE

Vitis arizonica
Canyon wild grape

Canyon floors, lower slopes, often beneath oaks.

ELEAGNACEAE

Shepherdia rotundiflora
Roundleaf buffaloberry

GARRYACEAE

Garrya flavescens
Silk-tassel bush
G. wrightii
Wright's silk-tassel

ERICACEAE

Arctostaphylos patula
Greenleaf manzanita
A. pungens
Pointleaf manzanita

POLEMONIACEAE

Leptodactylon pungens
Prickly phlox
Phlox hoodii
Hood's phlox

RUBIACEAE

Gallium collomae

ENDANGERED; cAZ: Mogollon escarpment, 6500 ft.

CAPRIFOLIACEAE

Sambucus caerulea
Elderberry
S. racemosa
European red elder
Symphoricarpos longiflorus
Longflower snowberry

Dry slopes.

CAPRIFOLIACEAE (cont.)

- Symphoricarpos oreophilus* Upper woodland elevations.
Mountain snowberry
S. oreophilus utahensis Upper woodland elevations.
Utah snowberry

COMPOSITAE

- Artemisia arbuscula*
Low sagebrush
A. bigelovii
Bigelow sagebrush
A. cana
Silver sagebrush
A. filifolia
Sand sagebrush
A. tridentata
Big sagebrush
Chrysothamnus nauseosus
Rubber rabbitbrush
C. viscidiflorus
Rabbitbrush
Gutierrezia sarothrae
Broom snakeweed
Laphamia palmeri Sandstone crevices.
Palmer laphamia
Petradoria pumila
Rock-goldenrod
Tetradymia canescens
Gray horsebrush

APPENDIX III

FORBS OCCURRING IN PINYON-JUNIPER WOODLAND
ON THE COLORADO PLATEAU

LILIACEAE

- Allium acuminatum*
Hooker onion
- A. cernuum*
Nodding onion
- A. nevadense cristatum* Stony soil.
Nevada wild onion
- Brodiaea pulchella*
Bluedicks
- Calchortus nuttallii*
Sego lily
- Disporum trachycarpum*
Fairybells
- Smilacina racemosa* Shaded canyons.
False solomonseal
- S. stellata* Shaded slopes.
Star-flowered solomon plume
- Triteleia lemmonae* THREATENED; nAZ: under pines, 5000-7000 ft.
- Zigadenus paniculatus*
Foothill death-camas

IRIDACEAE

- Iris missouriensis* Moist situations.
Blueflag

MORACEAE

- Humulus americanus*
American hop

LORANTHACEAE

- Arceuthobium campylopodum* Parasitic on pinyon pines.
Pine dwarfmistletoe
- A. vaginatum* Parasitic on ponderosa pines.
- Phoradendrum juniperum* Parasitic on *Juniperus osteosperma*.
Juniper mistletoe

SANTALACEAE

- Comandra pallida* Sandy soils.
Comandra
C. umbellata
Common bastard toadflax

POLYGONACEAE

- Chorizanthe thurberi*
Thurber chorizanth
Eriogonum alatum
Winged wildbuckwheat
E. heracleioides
Wyeth silkbugwheat
E. inflatum
Desert trumpet
E. jamesii rupicola Sandstone crevices.
Slickrock sulfur flower
E. lanatum

E. ovalifolium
Round-leaved eriogonum
E. racemosum
Redroot eriogonum
E. thompsonae Rocky slopes.
Thompson eriogonum
E. thompsonae albiflorum
White-flowered Thompson eriogonum
E. thompsonae atwoodii ENDANGERED; nAZ, sUT: in pinyon-juniper
woodland.
E. t. thompsonae THREATENED; nAZ: sandy soil in sagebrush and
lower pinyon-juniper woodland, around 4500 ft.
E. zionis coccineum ENDANGERED; nAZ, sUT: 7000=8000 ft.

Polygonum convulvum Roadsides, cultivated areas.
Cornbind
P. ramosissimum
Bushy knotweed
P. sawatchense Sandy areas.
Sawatch knotweed
Rumex crispus Sandy soils.
Curly dock
R. hymenosepalus
Canaigre
R. mexicanus
Mexican dock
R. utahensis
Utah dock

CHENOPODIACEAE

Chenopodium album

Lambsquarters

C. fremontii

Fremont goosefoot

C. incisa

Ragleaf goosefoot

C. pratericola

Narrowleaf goosefoot

Salsola kali

Russian thistle

INTRODUCED; disturbed soils.

AMARANTHACEAE

Amaranthus graecizans

Pigweed

NYCTAGINACEAE

Abronia fragrans

Fragrant sand verbena

A. pumila

A. salsa

Allonia pillosa

Hairy allonia

Mirabilis multiflora

Wild four-o'clock

Sandy soils.

CARYOPHYLLACEAE

Arenaria eastwoodiae adenophora

Eastwood sandwort

A. macradenia

Shrubby sandwort

Silene rectiramea

Rock crevices.

ENDANGERED; nAZ: s. rim, Grand Canyon 6500-7000 ft.

RANUNCULACEAE

Aquilegia desertorum

THREATENED; nAZ: 7000-8000 ft.

Cimicifuga arizonica

THREATENED; cAZ: wooded canyons, 550-7000 ft.

Clematis columbiana

Virgin's bower

Clematis hirsutissima arizonica

Vine over trees, shrubs in canyons, along roads; often in shade.

THREATENED; nAZ: s. rim, Grand Canyon to Flagstaff, 7000-8000 ft.

Delphinium nelsonii

Nelson larkspur

D. parishii

Desert larkspur

RANUNCULACEAE (cont.)

- Ranunculus inamoenus subaffinis* ENDANGERED; nAZ, sUT.
Ranunculus juniperinus
Sand buttercup

PAPAVERACEAE

- Argemone corymbosa* Roadsides, sand dunes, washes.
Prickly-poppy

BERBERIDACEAE

- Berberis repens* Wooded canyons, often under oaks.
Creeping hollygrape

CRUCIFERAE

- Arabis gracilipes* THREATENED; AZ: hot sandy canyons, lower foothills to 8000 ft.
A. pendulina
A. oxylobula ENDANGERED; wCO: around 6300 ft.
A. perennans Perennial rockcress
A. selbyi Rockcress
Dithyrea wislizenii Sandy soils, dunes.
Spectacle-pod
Draba a. asprella ENDANGERED; nAZ: Coconino, Yavapai Cos., 5000-8000 ft.
D. asprella kaibabensis ENDANGERED; nAZ: Kaibab Plateau, n. rim Grand Canyon.
D. asprella stelligera THREATENED; nAZ: pine woods, 5000-8000 ft.
D. mogollonica THREATENED; nWNM.
Erysimum asperum Western wallflower
Lesquerella intermedia Dry sandy areas.
Bladderpod
L. pruinosa ENDANGERED; swCO: dry hills, 7000 ft.
L. utahensis Dry sandy areas.
Utah bladderpod
Physaria newberryi Newberry twinpod
Sisymbrium kearneyi ENDANGERED; nAZ: Grand Canyon, Mohave Co. only.
Stanleya pinnata Alkali soils containing selenium.
Princesplume
Thlaspi fendleri Fendler pennycress

CRASSULACEAE

Cleome lutea
Yellow beeplant
Echeveria collomae

Sandy soils.

ENDANGERED; cAZ: among rocks, 2000-6000 ft.

SAXIFRAGACEAE

Heuchera versicolor
Alumroot

Cliffs, rock crevices in moist shaded areas.

ROSACEAE

Ivesia sabulosa
Ivesia
Petrophytum caespitosum
Rockmat
Potentilla fissa
Leafy cinquefoil
P. multifoliata

Sandstone crevices.

Rock crevices.

Wooded areas.

THREATENED; nAZ: in washes, 6000-7000 ft.

LEGUMINOSAE

Astragalus ampullaris
Gumbo milkvetch
A. asclepiadoides
Milkweed milkvetch
A. convallarius finitimus
Timber milkvetch
A. cremnophylax
Sentry milkvetch
A. desperatus conspectus
Rimrock milkvetch
A. ensiformis
Pagumpa milkvetch
A. flavus
Yellow milkvetch
A. humistratus
Prostrate locoweed
A. leutoginosus ambiguus

A. lutosus
Dragon milkvetch
A. mollissimus
Thompson's wooly locoweed
A. naturitensis
Naturita milkvetch
A. nuttallianus
Nuttall milkvetch
A. oophorus lonchocalyx
Spindle milkvetch
A. praelongis
Stinking milkvetch
A. shmollae
Schmoll milkvetch
A. scopulorum
Rocky Mountain milkvetch

THREATENED; nAZ, sUT.

Soils containing selenium.

THREATENED; UT: foothills, cliffs.

ENDANGERED; nAZ: s. rim Grand Canyon near El Tovar; fissures in limestone pavement, 7000 ft.

THREATENED; nAZ: near Little Colorado River, 4000-5000 ft.

THREATENED; nAZ, sUT: 4000-5000 ft.

Clay soils.

THREATENED; AZ: sandy soil to 7000 ft.

ENDANGERED; wCO, eUT: dry slopes.

ENDANGERED; swCO: mesas, foothills, 6000-8000 ft.

Dry plains and slopes.

THREATENED; UT: Gravelly foothills in sagebrush and pinyon-juniper.

Clay soils containing selenium.

ENDANGERED; swCO: Mesa Verda, dry mesas in pinyon-juniper, 6000-8000 ft.

LEGUMINOSAE (cont.)

- Astragalus stratiflorus* Escarpment milkvetch THREATENED; nAZ: 6500-7500 ft.
A. thompsonae Thompson milkvetch
A. troglodytus Cliffdweller milkvetch THREATENED; nAZ: 6500-7500 ft.
A. wetherilli Wetherill milkvetch THREATENED; wcCO: 4500-6000 ft.
A. xiphoides Gladiator milkvetch ENDANGERED; nAZ: Navajo Co., desert mesas, sandy soils, 5200 ft.
A. zionis Zion milkvetch ENDANGERED; nAZ, sCO, sUT: rocky slopes, sandstone ledges to 7500 ft.
Dalea fremontii Indigo bush
Hedysarum boreale Northern sweetvetch
Lotus longibracteus Longbract deercllover Rocky, sandy soils.
Lupinus adunctus

L. ammophilus Sand-loving lupine Sandy soils.
L. caudatus Tailcup lupine
L. cutleri Cutler lupine THREATENED; neAZ: about 7000 ft.
L. kingii King lupine
L. pusillus Dwarf lupine Gravel, sand, heavy clay soils.
L. sericeus Silky lupine
Oxytropis obnabiformis ENDANGERED; nwCO, UT: dry sandy soils, 6000-6500 ft.
Peteria thompsonae Thompson peteria THREATENED; sUT: rocky cliffs in sagebrush and pinyon-juniper.
Psoralea castorea Scurfpea Sandy areas at lower elevations.
P. epepsila THREATENED; nAZ, sUT.

GERIANACEAE

- Erodium cicutarium* INTRODUCED; disturbed soils.
Filaree
Geranium marginale THREATENED; CO, UT: foothills.

LINACEAE

Linum lewisii
Lewis flax

EUPHORBIACEAE

Euphorbia albomarginata
Carpetweed
E. fendleri
Fendler carpetweed
E. robusta
Stout spurge

MALVACEAE

Sphaeralcea ambigua
Desert globemallow
S. coccinea
Scarlet globemallow
S. fendleri albescens
Fendler globemallow
S. grossulariaefolia
Gooseberryleaf globemallow
S. parviflora
Globemallow

ENDANGERED; nAZ, sCO: 3000-8000 ft.

VIOLACEAE

Viola canadensis
Canada violet
V. charlestonensis
Charleston mountain violet

Cool, moist canyons.

swUT.

CACTACEAE

Echinocereus engelmanni
Purple torch
E. triglochidiatus
Claret cup
Mammillaria microcarpa
Fishhook cactus
Opuntia basilaris aurea
Utah beavertail
O. chlorotica
Dollarjoint cactus
O. engelmanni
Engelmann prickly-pear
O. erinacea
Grizzlybear prickly-pear
O. polycantha
Plains prickly-pear
O. spinosior
Spiny cholla

CACTACEAE (cont.)

- Sclerocactus glaucus* ENDANGERED; AZ, swCO, UT: 4500-5500 ft.
S. mesa-verdae THREATENED; swCO: dry slopes.
S. whipplei
Fishhook barrel cactus

ONAGRACEAE

- Gaura neomexicana coloradensis* ENDANGERED; swCO: 6000-7000 ft.
Gayophytum nuttallii
Groundsmoke
Oenothera albicaulis
Prairie evening-primrose
O. brevipes
Desert day-primrose
O. caespitosa
White-tufted evening-primrose
O. eastwoodiae
Eastwood evening-primrose
O. flava
Yellow-tufted evening-primrose
O. lavandulaefolia Cracks, fissures in sandstone rimrock.
Lavender-leaved evening-primrose
O. longissima
Tall yellow evening-primrose
O. multijuga Sandy, shaded soil.
Yellow day-primrose
O. pallida
Pale evening-primrose
O. strigosa Sandy soils.
Common evening-primrose
Zauschneria garretti Rocky areas.
Firechalice

UMBELLIFERAE

- Cymopterus basalticus* THREATENED; UT: pinyon-juniper woodland.
C. bulbosus
Onion springparsley
C. fendleri
Chimaya
C. newberryi THREATENED; nAZ, swCO, sUT, NM: foothills
sandy soils in sagebrush and pinyon-juniper.

UMBELLIFERAE

C. purpureus
Wild parsley
Lomatium grayi
Gray's biscuitroot
Oregonia linearifolia
Indian potato
Pseudocymopterus montanus
Mountain false springparsley

Rocky outcrops in lime-rich soils.

PRIMULACEAE

Primula specuicola

THREATENED; nAZ, seUT: n. of Grand Canyon;
canyons beneath cliff overhangs.

APOCYNACEAE

Amsonia peeblesii

THREATENED; nAZ: 4500-6000 ft.

ASCLEPIADACEAE

Asclepias asperula
Rough milkweed
A. cutleri

THREATENED; neAZ, seUT: sand, 5000 ft.

A. speciosa
Showy milkweed
A. subverticola
Poison milkweed
A. tuberosa terminalis
Butterflyweed

CONVULVULACEAE

Convolvus arvensis
Field bindweed

CUSCUTACEAE

Cuscuta cephalanthi
Dodder

POLEMONIACEAE

Collomia grandiflora
Cream phlox
Gilia aggregata
Skyrocket gilia
G. mcvickeerae
G. multiflora
G. scopulorum

THREATENED; UT: Gravelly foothills in
sagebrush and pinyon-juniper.

POLEMOIACEAE (cont.)

- Phlox austromontana*
Desert phlox
P. cluteana THREATENED; neAZ, sUT: 6000-10000 ft.
P. gladiiformis THREATENED; csUT: pinyon-juniper woodland.
P. hoodii
Hood's phlox
P. longifolia Sandy, gravelly soils.
Long-leaved phlox
P. stansburyi
Stansbury phlox

HYDROPHYLLACEAE

- Nama retrorsum* THREATENED; neAZ: sandy areas, 6000-7000 ft.
Phacelia crenulata Dry, gravelly slopes.
Purple scorpionweed
P. curvipes
P. demissa heterotricha THREATENED: nAZ, nwNM, sUT: foothills in
sagebrush or pinyon-juniper.
P. filiformis ENDANGERED; nAZ: Grand Canyon, Kaibab Plateau,
3000-7500 ft.
P. heterophylla
Varileaf phacelia
P. serrata THREATENED; nAZ: 5000-7000 ft.

BORAGINACEAE

- Cryptantha bakeri*
Baker cryptantha
C. confertiflora
Yellow forget-me-not
C. flava
Yellow cryptantha
C. humilis
Low cryptantha
Heliotropium convulvaceum
Morning-glory heliotrope
Lappula redowskii
Common stickseed
Lithospermum incisum
Puccoon
L. multiflorum
Manyflower puccoon
L. ruderale
Wayside gromwell

VERBENACEAE

Verbena bracteata
Bigbract verbena

Distrubed soils.

LABIATAE

Hedeoma nanum
Mock pennyroyal
Marrubium vulgare
Common hoarhound
Moldavica parviflora
Dragonhead

SOLANACEAE

Datura meteloides
Sacred datrua
Physalis fendleri
Fendler groundcherry
Solanum nigrum
Black nightshade
S. triflorum
Cutleaf nightshade

Narcotic.

Dry, rocky banks.

SCROPHULARIACEAE

Castilleja chromosa
Early paintbrush
C. kaibabensis
C. lineariaefolia
Wyoming paintbrush
C. scabrada
Eastwood paintbrush
Cordylanthus parviflorus
Birdbeak
Mimulus cardinalis
Scarlet monkeyflower
M. eastwoodiae
Eastwood monkeyflower
M. floribundus

M. guttatus
Yellow monkeyflower
M. rubellus

Orthocarpus luteus
Owlclover
O. purpureo-albus
Purplewhite owllover
Pedicularis centrantha
Wood betony

THREATENED; nAZ, sUT.

SCROPHULARACEAE (cont.)

- Penstemon ambiguus*
Gilia penstemon
- P. barbatus torreyi*
Scarlet bugler
- P. bridgesii*
Bridges penstemon
- P. caespitosus*
Dwarf beardtongue
- P. caespitosus suffruticosus* THREATENED; wCO, seUT: canyons, foothills to 6500 ft.
- P. clutei* ENDANGERED; nAZ: near Sunset Crater only, 7000 ft.
- P. comarrhenus*
Dusty penstemon
- P. eatonii*
Firecracker penstemon
- P. humilis*
Low penstemon
- P. jamesii*
James beardtongue
- P. laevis*
Royal penstemon
- P. pachyphyllus*
Thickleaf penstemon
- P. palmeri*
Palmer penstemon
- P. strictis*
Rocky Mountain penstemon
- P. utahensis*
Utah penstemon
- P. virgatus pseudopus* THREATENED; AZ, NM: Woodlands, meadows, 5000-11,000 ft.
- Wandbloom penstemon
- P. wardii* THREATENED; swUT: dry canyons in pinyon-juniper and ponderosa pine.
- Ward's penstemon
- P. watsonii*
Watson penstemon
- Verbascum thapsus*
Mullein

MARTYNACEAE

- Proboscidea parviflora*
Devil's claw

PLANTAGINACEAE

- Plantago purshii*
Pursh plantain

CUCURBITACEAE

Cucurbita foetidissima
Calabazilla

CAMPANULACEAE

Lobelia cardinalis graminea
Cardinalflower

COMPOSITAE

<i>Achillea millefolium lanulosa</i> Yarrow	Disturbed soils.
<i>Agoseris glauca</i> Mountain-dandelion	Open woods.
<i>Agoseris retrorsa</i> Spearleaf agoseris	
<i>Arnica latifolia</i> Arnica	
<i>Artemisia filifolia</i> Sand sagebrush	
<i>A. ludoviciana</i> Louisiana sagewort	
<i>A. wrightii</i> Wright sagewort	
<i>Aster chilensis</i> Pacific aster	
<i>A. glaucoides pulcher</i> Glaucous aster	
<i>Antennaria parvifolia</i> Small-leaved pussytoes	
<i>Bahia dissecta</i> Wild chrysanthemum	
<i>Baileya multiradiata</i> Desert-marigold	Dry, rocky slopes and ridges.
<i>Balsamorhiza saggitata</i> Arrowleaf balsamroot	
<i>Brickellia californica</i> California bricklebrush	
<i>B. grandiflora</i> Tasselflower bricklebrush	
<i>Chaenactis douglasii</i> Douglas false-yarrow	
<i>Chrysopsis villosa</i> Goldenaster	
<i>Cichorium intybus</i> Chicory	Disturbed soils, agricultural areas.
<i>Cirsium undulatum</i> Thistle	
<i>C. utahense</i> Utah thistle	
<i>C. vulgare</i> Bull thistle	
<i>Crepis intermedia</i> Hawksbeard	
<i>Erigeron divergens</i> Spreading fleabane	
<i>E. eatonii</i> Eaton daisy	
<i>E. flagellaris</i> Whiplash daisy	Sandy soils.

COMPOSITAE (cont.)

- Erigeron pringlei* THREATENED; cAZ: Cliff ledges, crevices, 5000-9000 ft.
- E. pumilis*
Fleabane daisy
- E. religiosus* ENDANGERED; sUT: Zion National Park.
- E. sionis*
Zion daisy Rare; endemic to Zion National Park.
- E. utahensis*
Utah daisy Dry, rocky hillsides.
- Eupatroidium herbaceum*
Thoroughwort Rocky crevices over 5000 ft.
- Galinsoga semicalva percalva* ENDANGERED; neAZ: 5500-8500 ft.
- Haplopappus gracilis*
Iron plant
- H. macronema*
Desert goldenweed
- H. nuttallii*
Nuttall goldenweed
- H. salicinus* ENDANGERED; nwAZ: Grand Canyon National Park, Bright Angel Trail.
THREATENED; nAZ, sUT.
- H. scopulorum*
Three-ribbed goldenweed
- Helenium arizonicum* THREATENED; cAZ; 7000-9000 ft.
- Helianthus annuus*
Common sunflower
- H. petiolaris*
Prairie sunflower
- Hymenopappus filifolius*
Fineleaf hymenopappus
- H. filifolius tomentosus* THREATENED: UT: sagebrush, pinyon-juniper ponderosa pine.
- H. lugens*
- Hymenoxys bigelovii*
Bigelow hymenoxys
- H. cooperii*
Cooper hymenoxys
- H. richardsonii*
Pingue actinea
- H. subintegra*
Kanab bitterweed THREATENED; nAZ: 5500-8000 ft.
- Lactuca scariola*
Wild lettuce
- Machaeranthera bigelovii*
- M. linearis*
Tansy-aster
- Plummera ambigena* ENDANGERED; neAZ: Pinaleno Mountains, Graham Co., 5000-7000 ft.
- Rafinesquia neomexicana*
Desert chicory
- Senecio multilobatus*
Lobeleaf groundsel
- S. mutabilis*
- S. spartioides*
Broom groundsel
- Solidago occidentalis*
Western goldenrod
- S. sparsiflora*
Few-flowered goldenrod

COMPOSITAE (cont.)

<i>Stephanomeria exigua</i> Wire-lettuce	Sandy to clay soils.
<i>Taraxacum officinale</i> Common dandelion	
<i>Thelysperma subnudum</i> Greenthread	Clay soils associated with shales.
<i>Townsendia incana</i> Hoary townsendia	Sandy soils.
<i>Tragopon dubius</i> Salsify	Disturbed soils.
<i>T. pratensis</i> Meadow salsify	

APPENDIX IV

GRASSES OCCURRING IN PINYON-JUNIPER WOODLAND
ON THE COLORADO PLATEAU

GRAMINEAE

- Agropyron desertorum*
Crested wheatgrass
- A. *intermedium*
Intermediate wheatgrass
- A. *smithii* Cool season grass.
Western wheatgrass
- A. *spicatum*
Bluebunch wheatgrass
- Aristida adscensionis*
Sixweeks three-awn
- A. *fendleriana*
Fendler three-awn
- A. *longiseta*
Red three-awn
- Bouteloua aristidoides*
Needle grama
- B. *barbata*
Sixweeks grama
- B. *curtipendula* Warm season grass.
Side-oats grama
- B. *eriopoda* Warm season grass.
Black grama
- B. *gracilis* Warm season grass.
Blue grama
- Bromus carinatus*
California brome
- B. *intermis*
Smooth brome
- B. *japonicus*
Japanese brome
- B. *tectorum*
Cheatgrass brome
- Elymus junceus* Loam, clay.
Russian wildrye
- Festuca arizonica*
Arizona fescue
- F. *idahoensis*
Idaho fescue
- Hilaria belangeri*
Curlymesquite
- Hilaria jamesii* Warm season grass.
Galleta
- Koeleria cristata* Cool season grass.
Prairie junegrass
- K. *gracilis*
- Leucopoa kingii*
- Lycurus phleoides*
Wolftail

GRAMINEAE (cont.)

- Muhlenbergia montana*
Mountain muhly
- M. torreyi*
Ring muhly
- M. wrightii* Warm season grass.
Spike muhly
- Oryzopsis hymenoides*
Indian ricegrass
- Paniculum obtusum*
Vine-mesquite
- Poa fendleriana* Cool season grass.
Mutton bluegrass
- Poa sandbergii*
- Schedonnardus paniculatus*
Tumblegrass
- Sitanion hystrix* Cool season grass.
Bottlebrush squirreltail
- Sporobolus cryptandrus*
Sand dropseed
- S. interruptus* Warm season grass.
Black dropseed
- Stipa columbiana*
Subalpine needlegrass
- S. comata*
Needle-and-thread
- S. thurberiana*
Thurber needlegrass
- Tridens muticus*
Slim tridens
- T. pilosus*
Hairy tridens
- T. pulchellus*
Fluffgrass
- Triticum aestivum*
Bread wheat

APPENDIX V

RIPARIAN PLANTS OF THE COLORADO PLATEAU

CYANOPHYTA (Blue-green Algae)

<i>Anabeana</i> sp.	Small streams, pools.
<i>Lyngbya</i> sp.	"
<i>Merismopedia</i> sp.	"
<i>Oscillatoria</i> sp.	"
<i>Phormidium</i> sp.	"
<i>Rivularia</i> sp.	"
<i>Scytonema</i> sp.	"

CHLOROPHYTA (Green Algae)

<i>Chaetophora</i> sp.	Small streams, pools.
<i>Chara</i> sp.	"
<i>Cladophora glomerata</i>	"
<i>Cocconema</i> sp.	Hanging gardens.
<i>Oedogonium</i> sp.	Small streams, pools.
<i>Scenedesmus</i> sp.	"
<i>Spirogyra</i> sp.	"
<i>Suriella</i> sp.	Hanging gardens
<i>Tribonema bombycina</i>	Small streams, pools.
<i>Ulothrix aequalis</i>	"
<i>U. zonata</i>	"
<i>Vaucheria gemmata</i>	"
<i>V. sessilis</i>	"
<i>Zygnema</i> sp.	"

BACILLARIACEAE (Diatoms)

<i>Cocconema</i> sp.	Small streams, pools.
<i>Cymbella</i> sp.	"
<i>Diatoma</i> sp.	"
<i>Epithemia</i> sp.	"
<i>Gomphonema</i> sp.	"

EQUISETACEAE

<i>Equisetum arvense</i> Common horsetail	Poor soils, wet soils along streams.
<i>E. hymenale</i> Common scouringrush	Wet soil, stream edges.
<i>E. laevigatum</i> Smooth scouringrush	Wet soil, stream edges.

POLYPODIACEAE

<i>Adiantum capillus-veneris</i> Southern maidenhair	Springs, seeps, hanging gardens, 5400-7800 ft.
<i>A. pedatum</i> Birdfoot maidenhair	Uncommon; springs, seeps, hanging gardens, moist, cool canyons.
<i>Asplenium resiliens</i> Little ebony spleenwort	Uncommon; moist, shaded ledges.

POLYPODIACEAE (cont.)

- Asplenium adiantum-nigrum* Rare; seeps, hanging gardens.
Black spleenwort
Cystopteris bulbifera Shaded seeps.
Berry bladderfern
C. fragilis Shaded seeps.
Brittle bladderfern

TYPHACEAE

- Typha angustifolia* In water of deeper ponds, streams.
Narrow-leaved cattail
T. latifolia In water of deeper ponds, streams.
Common cattail

GRAMINEAE

- Agrostis verticellata* In shallower water of ponds, slow streams.
Distichlis spicata In alkaline soil, where seepage leaves salt
Seashore saltgrass deposits.
Phragmites australis Wet soil, shallow water.
Common reed
Puccinellia parishii THREATENED; nAZ: Marshy ground, 5000-6000 ft.
Parish alkaligrass

CYPERACEAE

- Carex aquatilis*
Water sedge
C. aurea
Golden sedge
C. eleocharis
Needleleaf sedge
C. festivella Shallow water, small stream margins.
Ovalhead sedge
C. hystricina
Bottlebrush sedge
C. kelloggii
Kellogg sedge
C. microptera
Smallwing sedge
C. occidentalis Shallow water, small stream margins.
Western sedge
C. rostrata
Beaked sedge
C. specuicola ENDANGERED; nAZ: Coconino Co. (Inscription House).
C. vallicola
Valley sedge
Eleocharis macrostachya
Common spikerush
Scirpus acutus
Tule bulrush
S. americanus
American bulrush
S. microcarpus Shallow water, small stream margins.
Panicled bulrush
S. paludosis Deeper ponds and swamps.
Alkali bulrush
S. validus Deeper ponds and swamps.
Softstem bulrush

LEMNACEAE

Lemna minor Ponds, stagnant water.
Common duckweed

JUNACEAE

Juncus balticus Shallow water, small stream margins.
Wiregrass
J. brunescens Shallow water, stream margins.
Button rush
J. bufonius
Toad rush
J. mexicanus Shallow water, small stream margins
Mexican rush
J. regelli
Regei rush
J. saximontanus-brunescens
Rocky Mountain rush
J. tenuis
Poverty rush
J. torreyi
Torrey rush
J. xiphioides Wet sand.
Swordleaf rush
Luzula parviflora
Woodrush

LILIACEAE

Vagnera amplexicaulis
False solomonseal
V. liliaceae
False solomonseal

ORCHIDACEAE

Epipactis gigantea Streamsides, seeps, hanging gardens.
Helleborine
Habenaria sparsiflora Moist, shaded canyons.
Canyon bog orchid

SALICACEAE

Populus angustifolia Flood plains.
Narrowleaf cottonwood
P. fremontii "
Fremont cottonwood
P. nigra italica "
Lombardi poplar
P. wislizenii "
Rio Grande cottonwood
Salix laevigata "
Red willow
S. lasiandra caudata "
Whiplash willow
D. lasiolepis "
Arroyo willow

Shrub willows:
S. drummondiana "
Drummond willow
S. exigua "
Coyote willow

SALICACEAE (cont.)

<i>Salix geyeriana</i> Geyer willow	Flood plains.
<i>S. lutea</i> Yellow willow	"
<i>S. nigra</i> Black willow	"
<i>S. scouleriana</i> Scouler willow	"

BETULACEAE

<i>Betula occidentalis</i> River birch	Flood plains.
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ULMACEAE

<i>Celtis reticulatus</i> Hackberry	Flood plains.
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RANUNCULACEAE

<i>Aquilegia chrysantha</i> Golden columbine	Seeps, moist banks.
<i>A. micrantha</i> Small-flowered columbine	Hanging gardens.
<i>A. micrantha mancosana</i>	ENDANGERED; swCO: 5000-8000 ft.
<i>A. triternata</i> Cliff columbine	Seeps, wet soil at cliff bases.
<i>Ranunculus cymbalaria</i> Shore buttercup	Small streams, swamp margins, shaded moist canyons, seeps.

CRUCIFERAE

<i>Nasturtium officinale</i> Watercress	Ponds, slow clear streams.
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SAXIFRAGACEAE

<i>Heuchera rubescens</i> Red alumroot	Moist shaded cliffs
<i>H. versicolor</i> Alumroot	"

ROSACEAE

<i>Rosa woodsii</i> Woods rose	Moist stream sites near seeps and springs.
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LEGUMINOSAE

<i>Lupinus latifolius columbianus</i> Columbine lupine	Stream banks.
<i>Robinia neomexicana</i> New Mexico locust	

ANACARDIACEAE

Rhus trilobata Canyon floors, stream banks.
Squawbush

ACERACEAE

Acer grandidentatum Moist canyon bottoms.
Bigtooth maple
A. negundo "
Box elder

TAMARICACEAE

Tamarix gallica Flood plains.
French tamarisk
T. pentandra "
Tamarisk

VIOLACEAE

Viola nephrophylla Moist banks.
Kidney-leaved violet

ONAGRACEAE

Epilobium adenocaulon Stream banks.
Sticky willowherb

OLEACEAE

Fraxinus anomalus
Singleleaf ash
F. velutinus
Velvet ash

SCROPHULARACEAE

Mimulus cardinalis Wet banks, streamsides, seeps.
Scarlet monkeyflower
M. guttatus Shaded canyons, seeps, stream banks.
Yellow monkeyflower
Veronica americana
American speedwell

CAMPANULACEAE

Lobelia cardinalis Hanging gardens, stream banks.
Cardinalflower

COMPOSITAE

Aster hesperius laetivirens Seeps, stream banks.
White-flowered Siskyou aster
Baccharis emoryi Stream banks, flood plains.
Waterwillow
Pluchea sericea Wet flood plains.
Arrowweed

APPENDIX VI

OTHER PLANTS FROM PINYON-JUNIPER WOODLANDS
OF THE COLORADO PLATEAU

CYANOPHYTA (Algae)

Some algal components of desert crusts (cryptogams), in approximate decreasing order of population size:

Microcoleus vaginatus
M. chthonoplastes
Schizothrix creswellii
Schizothrix sp.
Calothrix sp.
Scytonema sp.
Lyngbya sp.
Plectonema golenkinianum
Oscillatoria sp.
Nostoc sp.
Gloeocapsa sp.

SELAGINELLACEAE (Spikemosses)

<i>Selaginella densa</i>	Rocks, gravelly slopes, 5800-10,000 ft.
<i>S. mutica</i>	Rocks, dry cliffs, 4000-7600 ft.
<i>S. underwoodii</i>	On rocks, 5300-9800 ft.
Underwood spikemoss	
<i>S. utahensis</i>	
Utah spikemoss	

EQUISETACEAE (Horsetails)

<i>Equisetum arvense</i>	Poor soils.
Common horsetail	

COMMELINACEAE (Spiderworts)

<i>Tradescantia occidentalis</i>	Sandy areas.
Spiderwort	

POLYPODIACEAE (Ferns)

<i>Asplenium serpentrionale</i>	On rocks, 5000-8200 ft.
Forked spleenwort	
<i>A. trichomanes</i>	Rocks, cliff crevices, 5000-8700 ft.
Maidenhair spleenwort	
<i>Athyrium cyclosorum</i>	Woods, fields, thickets, 5500-9500 ft.
Ladyfern	
<i>Cheilanthes covillei</i>	Dry, shaded rocks, beneath dry ledges, 5500-8500 ft.
Coville lipfern	
<i>C. eatoni</i>	Rocky areas, crevices.
Eaton lipfern	
<i>C. feei</i>	Dry, shaded rocks, beneath dry ledges, 5500-8500 ft.
Slender lipfern	

POLYPODIACEAE (cont.)

<i>Cheilanthes fendleri</i> Fendler lipfern	Shaded rocks and ledges, 5000-7500 ft.
<i>Cryptogramma acrostichoides</i> American rockbrake	Among rocks, especially rock slides, 7000-12,000 ft.
<i>Pellaea glabella</i> Purple cliffbrake	Dry rock crevices
<i>P. truncata</i> Spiny cliffbrake	Dry rock crevices.
<i>P. suksdorfiana</i> Suksdorfs cliffbrake	Cliffs, rock crevices.
<i>Pityrogramma triangularis</i> Goldfern	RARE; dry crevices in pinyon-juniper and ponderosa pine areas.
<i>Polypodium herperium</i> Western polypody	Dry rocks of shaded canyon sides.
<i>Pteridium aquilinum pubescens</i> Bracken	Open woods, dry to moist slopes, canyons, 5500-9100 ft.
<i>Woodsia scopulina</i> Rocky Mountain woodsia	Rocks, crevices, 5000-10,000 ft.
<i>W. mexicana</i>	

APPENDIX VII

KEY FOR APPENDICES VIII-XI

ar arid
br brushy
de dense
ed edges

op open
ov over
sa semiarid
un under

Ag Agricultural areas
Bu Bushland, brushy areas
Ca Canyons
Cf Coniferous forest
Cl Cliffs
Cn Cavity-nester
Ct Cattails
Cv Caves
De Desert
Dw Deciduous woodland
Fh Foothill slopes
Gb Underground burrow
Gr Grassland
Gs Gravelly soil
Ht Hollow trees
Lo Logs (hollow logs),
boards
Ma Marshes
Ms Mesas, plateaus
Mt Mountains

Gg On ground
Pj Pinyon-juniper woodland
Po Ponderosa pine
Pp Permanent ponds, lakes
Ps Permanent streams, rivers
Rc Rock crevices
Ri Riparian woodland
Ro Rocky areas (rocks)
Sa Sagebrush
Sc Scrubland
Sh Shrub or bush
Ss Sandy soil
Ta Tanks in arid country
Tp Temporary ponds
Tr Tree, trees
Ts Temporary streams
Ur Urban areas
Wa Near water
Wi In water

APPENDIX VIII

MAMMALS OCCURRING IN PINYON-JUNIPER WOODLAND
OF THE COLORADO PLATEAU

	DISTRIB.	HABITAT	DEN, BURROW	COMMENTS
Or.	MARSUPALIA Fam. Didelphidae <i>Didelphis virginiana</i> Opossum	Ag, Ri	Ht, used dens	Range expanding
Or.	INSECTIVORA Fam. Soricidae <i>Sorex merriami leucogenus</i> Merriam's shrew <i>Notiosorex crawfordi</i> Desert shrew	AZ, NM AZ, CO AZ, NM, sCO ar, opPj, opDw, Sa, Gr Sa, Ri, Gr, opPj		
Or.	CHIROPTERA Fam. Vespertilionidae <i>Eptesicus fuscus</i> Big brown bat <i>Euderma maculatum</i> Spotted bat <i>Antrozous p. pallidus</i> Pallid bat Fam. Molossidae <i>Tadarida brasiliensis</i> Mexican Freetailed bat <i>Tadarida macrotis</i> Big freetailed bat	All AZ, NM, UT AZ, CO, NM, UT AZ, CO, NM, UT DeGr, Pj DeGr, Pj	Cv, Rc, Ht Cv Cv, Rc, Tr Cv Rc, Cv	Endangered; very rare
Or.	LAGOMORPHA Fam. Leporidae <i>Sylvilagus nuttalli pinetus</i> Mountain cottontail	All deBu, deSc, Pj, Ro, C1	Og	

	DIST.	HABITAT	DEN, BURROW	COMMENTS
<i>Sylvilagus auduboni warreni</i>	ATI	Gr, Sa, edPj, Ca, Ms	Og, abandoned Gb	
Desert cottontail	CO, NM, UT	opGr, Sa, edPj		
<i>Lepus townsendii</i>	ATI	Gr, Sa, De, Pj, edPo		
White-tailed jackrabbit				
<i>Lepus californicus</i>				
Black-tailed jackrabbit				
Or. RODENTIA				
Fam. Sciuridae				
<i>Eutamias minimus</i>	ATI	Sa, Sc, Bu, Dw, Pj, Cf		
Least chipmunk	AZ, CO, UT	RoFh, Pj		
<i>Eutamias dorsalis utahensis</i>	neAZ, CO, nNM	opPj, opCf, Ro, BuFh		
Cliff chipmunk	NM	upper Pj	Gb near boulder	
<i>Eutamias q. quadrivittatus</i>	AZ, CO, NM, UT	saMs, Gs, opPj, Ss	Gb, unTr, unRo	
Colorado chipmunk				
<i>Marmota flaviventris</i>	AZ, CO, NM, UT	asSs, opBu, Gs, De, opPj	Gb, unSh, unRo	
Yellow-bellied marmot				
<i>Ammospermophilus leucurus</i>	AZ, CO, NM, UT	Ro, RoCa, RoFh	Gb, unRo, Ht	
White-tailed antelope ground squirrel				
<i>Spermophilus spilosoma</i>	AZ, CO, NM, UT	opBu, opPj; sloping ground	Gb (colonial)	
Spotted ground squirrel				
<i>Spermophilus variegatus</i>	AZ, CO, NM, UT	edPj, Po	Tr	
Rock squirrel				
<i>Cynomys gunnisoni</i>	AZ, CO, NM, seUT	saGr, Bu, opPj, Ss	unSh	
Gunnison prairie dog				
<i>Sciurus aberti</i>	AZ, CO, NM, UT	Gr, Ss, opPj, Sa	unSh	
Abert's squirrel				
Fam. Heteromyidae				
<i>Pergnathus flavus</i>	AZ, UT	Fh, GsunSs, Bu, opPj		
Silky pocket mouse				
<i>Pergnathus apache</i>	AZ, UT	saMs, Sc, Pj	unSh	
Apache pocket mouse				
<i>Pergnathus longimembris</i>	nAZ, UT	DeCa, RoFh, Gs, Rs		
Little pocket mouse				
<i>Pergnathus parvus</i>				
Great Basin pocket mouse				
<i>Pergnathus formosus</i>				
Long-tailed pocket mouse				n of Colorado Riv.

	DISTRIB.	HABITAT	DEN, BURROW	COMMENTS
<i>Petrognathus intermedius</i>	AZ, NM, UT	RoFh, old lava flows		
Rock pocket mouse				
<i>Dipodomys microps</i>	AZ, UT	opRoFh, Sc, Pj		
Great Basin kangaroo rat				
Fam. Castoridae				
<i>Castor canadensis</i>	AZ, CO, NM, UT	Ps, Ri		Stream bank, lodge, behind dam
Beaver				
Fam. Cricetidae				
<i>Reithrodontomys megalotis</i>	AZ, CO, NM, UT	RoCa, DeMt, Cl, Pj	Ro, unRo	
Western harvest mouse				
<i>Petomyscus crinitus</i>	AZ, MN, sUT	opDe, Ss, RoFh, Pj	Gb, Ro	
Canyon mouse				
<i>Petomyscus eremicus</i>	All	Ro, Pj, Po, Cf, Sa, Gr, Ag, Me, Ri	Gb, Tr	
Cactus mouse				
<i>Petomyscus maniculatus</i>	AZ, CO, NM, UT	RoMs, RoCa, Pj	unRo, Rc	
Deer mouse				
<i>Petomyscus boylei</i>	AZ, CO, NM, UT	Ro, Bu, Pj	Tr, Ht, Ro	
Brush mouse				
<i>Petomyscus truei</i>	AZ, CO, NM, UT	Ro, Cl, Ca, Fh, Dw, Pj, Po		
Pinyon mouse				
<i>Petomyscus difficilis</i>	AZ, CO, NM, UT	saGr, saSc, saBu, Sa, opPj	Gb	
Rock mouse				
<i>Onychomys leucogaster</i>	All	De-Cf	Gb, unTr, unRo	
Northern grasshopper mouse				
<i>Neotoma albigula</i>	AZ, CO, NM, seUT	SaSc, opBu, RoFh, Pj	unRo, Og	
White-throated woodrat				
<i>Neotoma lepida</i>	AZ, NM, sUT	RoPj, Rc		
Desert woodrat				
<i>Neotoma stephensi</i>	AZ, CO, NM, seUT	Cf, Pj, Dw, Ro	Rc, unLo	
Stephen's woodrat				
<i>Neotoma mexicana</i>	AZ, CO, NM, UT	SaSc, Cf, Pj, Ro	Rc, Lo, Cv	
Mexican woodrat				
<i>Neotoma cinerea</i>				
Bushy-tailed woodrat				

<i>Microtus longicaudus</i>	All	Me, edSa, edPj	Gb	
Long-tailed vole				
<i>Microtus mexicanus</i>	AZ, swCO, NM	Me, Gr, Po, Cf, opPj	Gb	
Mexican vole	SUT			
Fam. Muridae	All	Ur, Ag		
<i>Mus musculus</i>				
House mouse				
Fam. Erethizontidae	UT, nAZ, CO	Ri, Cf, BuGr, Ro	Ro, Gb, Ht, Cv	
<i>Erethizon dorsatum</i>	NM			
Porcupine				
Or. CARNIVORA				
Fam. Canidae				
<i>Canis latrans</i>	All	Wide tolerance	Gb	
Coyote				
<i>Vulpes macrotis</i>	All	opSs, Gr, Sa, opPj	Gb	
Kit fox				
<i>Vulpes velox</i>	CO, NM, UT	opGr	Gb	ENDANGERED
Swift fox				
<i>Urocyon cinereoargenteus</i>	All	Bu, Dw, Pj	Ht, Lo, unRo, Gb	
Gray fox				
Fam. Ursidae				
<i>Ursus americanus amblyceps</i>	All	Mt, Cf, Pj, Po		
Black bear				
Fam. Procyonidae				
<i>Bassariscus astutus</i>	AZ, wCO, NM, UT	RoBu, Dw, Pj, Fh, Cl, Ca, Wa	Cv, Rc, Cl, Ht, unRo	
Ringtail				
Fam. Mustelidae				
<i>Mustela frenata</i>	All	wide tolerance; Cf, opPj, Dw, Bu, Ro, Wa	Gb, unLo, unRo	
Long-tailed weasel				
<i>Taxidea taxus</i>	All	De, Gr, Dw, Bu, Pj, Sc, Po, Cf, Ms, Mt, Ca	Gb	
Badger				
<i>Mephitis mephitis</i>	All	Dw, Gr, opPj, Ri, Wa	Gb, Ro, unLo	
Striped skunk				

	DISTRIB.	HABITAT	DEN, BURROW	COMMENTS
<i>Conepatus mesoleucus</i>	AZ, CO, NM	FhCa, Gr, Dw, Pj, Bu, Ro	Rc	
Hog-nosed skunk				
Fam. Felidae				
<i>Felis concolor</i>	All	Mt, Ca		
Mountain lion				
<i>Lynx rufus</i>	All	RoDe-Cf, Ca, Fh, Mt	Rc, Lo	
Bobcat				
Or. ARTIODACTYLA				
Fam. Cervidae				
<i>Cervus elaphus canadensis</i>	All	Winters in Pj		
Elk				
<i>Odocoileus hemionus</i>	All	DeSc-Mt		
Mule deer				
Fam. Antilocapridae				
<i>Antilocapra americana</i>	All	saGr, Sc, De, Sa		
Pronghorn				
Fam. Bovidae				
<i>Bison bison</i>	UT	opGr, opMe, edPj		Henry Mts., uses Pj for cover
Bison				
<i>Ovis canadensis nelsoni</i>	AZ, NM, UT	RoCa, RoFh, RoMt		
Desert bighorn sheep				

APPENDIX IX

BIRDS OCCURRING IN PINYON-JUNIPER WOODLANDS
OF THE COLORADO PLATEAU

KEYS:

SEASONAL OCCURRENCE STATUS

- P Permanent resident A Abundant
S Summer resident C Common
W Winter resident U Uncommon
T Transient R Rare
 T Threatened
 E Endangered

	SEASONAL OCCURRENCE	STATUS	HABITAT	NEST
Or. FALCONIFORMES				
Fam. Cathartidae				
<i>Cathartes aura teter</i>	S	U	Ag, De, Gr, Sa, Sc, Bu, Dw, Pj, Mt	Og, Dv, Lo, Ht
Turkey vulture				
Fam. Accipitridae				
<i>Circus cyaneus hudsonius</i>	P	U	As, Gr, Me, Bu, opDw, opPj, opRi, Cl, Ma	Og
Marsh hawk				
<i>Buteo lagopus sanctijohannis</i>	W	U	Gr, Me, opPj, Tr, Og	
Rough-legged hawk				
<i>Buteo jamaicensis</i>	S, T	U	Pj, Ri, Tr, Fh, Ms, Sc, Me, Ag, De, Gr, Sa, Sc, Bu	Cl, Tr, Fh, Mt
Red-tailed hawk				
<i>Buteo regalis</i>	S	U	Ag, Cl, Sa, Sc, Pj	Og, Tr
Ferruginous hawk				

SEASONAL OCCURRENCE	STATUS	HABITAT	NEST
<i>Buteo swainsoni</i>	U	Tr, Me, Sc, Cl, Ag, De, Gr, Pj,	Tr
Swainson's hawk		Sa	
<i>Aquila chrysaetos canadensis</i>	U	De-Mt	Cl, Cv, Tr
Golden eagle			
<i>Haliaeetus leucocephalus</i>	R, E	Ri, Pp, Ps	
Bald eagle			
<i>Falco mexicanus</i>	U	Ag, De, Bu, Gr, Sc, Pj, Dw, Fh, Me, Ms	Cl
Prairie falcon			
<i>Falco peregrinus tundrius</i>	R, E	De-Mt, Pp, Ca, Cl, Fh, Ms	
Peregrine falcon			
<i>Falco s. sparverius</i>	U	De-opCf, Ag, Ur, Sa, Sc, Bu, Ri, Tr, Fh, Me, Pj, Dw	Cl, Ht, Cn
American kestrel			
Or. GALLIFORMES			
Fam. <u>Meleagrididae</u>			
<i>Meleagris gallopavo</i>	R	Dw, Pj, Po, Cf	Og, unSh, unLo
Turkey			
Fam. <u>Tetraonidae</u>			
<i>Centrocercus urophasianus</i>	U	SaSc, Pj	Og
Sage grouse			
Fam. <u>Phasianidae</u>			
<i>Alectoris chukar</i>	U	Pj, Bu, Cl	Og, Bu
Chukar			
Or. COLUMBIFORMES			
Fam. <u>Columbidae</u>			
<i>Zenaidura macroura marginella</i>	S, T	De, arGr, Pp, Ps, Tp, Ts, Ta, arPj	Sh, Tr
Mourning dove	C		

SEASONAL OCCURRENCE	STATUS	HABITAT	NEST
Or. STRIGIFORMES			
Fam. <i>Strigidae</i>			
<i>Bubo virginianus</i>	P	deDw, dePj, deRi, deCf, Mt, Ca, Cl	Og, Cl, Tr
Great horned owl			
<i>Asio otus tuftsi</i>	P	deDw, dePj, deRi, deCf	Tr
Long-eared owl			
<i>Strix occidentalis</i>	P	Pj, Ri, Cf, Ca, Cl, Tr	Tr, Cl, Cn
Spotted owl			
<i>Aegolius a. acadicus</i>	P	dePj, Ri, Cf, Sa, Bu	Ht, Cn
Saw-whet owl			
<i>Glaucidium gnoma californicum</i>	P	Ri, Pj, Po, Cf, Ca	Ht, Cn
Pygmy owl			
Or. CAPRIMULGIFORMES			
Fam. <i>Caprimulgidae</i>			
<i>Phalaenoptilus n. nuttallii</i>	S	De, saGr, saBu, Ca, Ri	Og
Poor-will			
<i>Chordeiles minor</i>	S	Gr, opDw, opPj, Bu, Me, Og, Tr, Ro, opCfed	Og, Rs, Ag
Common nighthawk			
<i>Chordeiles acutipennis</i>	S	De, arGr, arBu, arDw, arPj, Og, Sh	Og
Lesser nighthawk			
Or. APODIFORMES			
Fam. <i>Apodidae</i>			
<i>Aeronautes saxatilis</i>	S	Mt, Ca, Fh, Cl	Cl, Rc, Cv
White-throated swift			
Fam. <i>Trochilidae</i>			
<i>Selasphorus p. platycercus</i>	S	Fh, Mt, Ag, Cl, Sa, Pj, Bu, Me, Cf, Ri	Sh
Broad-tailed hummingbird			
<i>Archilochus alexandri</i>	S	Fh, Pj, Ag, Cl, Sa, Bu	Tr
Black-chinned hummingbird			

SEASONAL OCCURRENCE	STATUS	HABITAT	NEST
<i>Selasphorus rufus</i> Rufous hummingbird	S	Pj, Po, Cf	Tr, Sh
Or. PICIFORMES			
Fam. Picidae			
<i>Colaptes a. auratus</i> Common flicker	P	Ag, Pj, Ri, Po, Cf, Fh, Mt	Tr, Ht, Cn
<i>Dendrocopos villosus</i> Hairy woodpecker	P	Dw, Pj, Ri	Cn, RiTr, Tr
<i>Dendrocopos pubescens leucurus</i> Downy woodpecker	P	opDw, opPj, Ri	Cn, Tr
Or. PASSERIFORMES			
Fam. Tyranidae			
<i>Tyrannus verticalis</i> Western kingbird	S, T	Ag, Pj (lower)	Tr, Sh
<i>Tyrannus vociferans</i> Cassin's kingbird	S, T	Pj	Tr
<i>Miarchus cinerascens</i> Ash-throated flycatcher	S	De, Fh, Dw, Pj	Cn
<i>Sayornis saya</i> Say's phoebe	S, T	arDw, arPj, Sa	Cv, Cl, Ro
<i>Empidonax wrightii</i> Gray flycatcher	S	Sa, Pj	Tr
<i>Empidonax difficilis</i> Western flycatcher	S	Pj, Bu, Ri, Po, Cf	Tr
Fam. Hirundinidae			
<i>Tachycineta thalassina</i> Violet-green swallow	S	Ag, Sa, Bu, Me, Pj, Po, Cf, Ri, Cl, Ca	Cl, Rc, Ht, Cn
Fam. Corvidae			
<i>Aphelocoma coerulescens</i> Scrub jay	P	Bu, Sc, Pj	Tr
<i>Gymnorhinus cyanocephalus</i> Pinyon jay	P	Pj	Tr

SEASONAL OCCURRENCE	STATUS	HABITAT	NEST	
<i>Pica pica</i>	P	U	Ag, Bu, Gr, Sa, Sc, Dw, Pj, Fh, Ms, Ri	Tr
Black-billed magpie				
<i>Nucifraga columbiana</i>	P	U	Mt, Cf, Po, dePj (upper)	Tr
Clark's nutcracker				
<i>Corvus corax</i>	P	C	De, Fh, Ms, Mt, Sa, Dw, Pj, Cf, Cl, Ca	Cl
Common raven				
<i>Corvus brachyrhynchos</i>	P	U	Ag, Sa, Bu, Dw, Pj, Gr, Cf	Tr
Common crow				
Fam. Paridae				
<i>Parus gambeli</i>	P	U	Bu, Pj, Po, Cf, Ri, Mt	Cn, Tr
Mountain chickadee				
<i>Parus inornatus</i>	P	U	opBu, opDw, opPj, Fh	Cn
Plain titmouse				
<i>Psaltriparus minimus</i>	P	U	Sa, Dw, Pj, Fh, Ri	Tr
Common bushtit				
Fam. Sittidae				
<i>Sitta carolinensis</i>	P	U	Bu, Pj, Po, Cf	Cn, Tr
White-breasted nuthatch				
Fam. Troglodytidae				
<i>Troglodytes troglodytes</i>	W, T	U	Bu, Pj, Ri, Fh, Wa	Tr, Sh
Winter wren				
<i>Thryomanes bewickii</i>	S, T	U	deBu, deSc, Sa, dePj	Cn, Ht, Lo
Bewick's wren				
<i>Salpinctes obsoletus</i>	S	U	Pj, Fh, Ms, Ro, Cl	Rc, Ht, Lo
Rock wren				
<i>Catherpes mexicanus</i>	P	U-C	Pj, Dw, Ri, Ca, Cl, Wa	Cl
Canyon wren				
Fam. Turdidae				
<i>Turdus migratorius</i>	S, T	U	edPj, edCf, Sa, Me, Gr, edDw	Tr
Robin				
<i>Sialia mexicana</i>	S	U	Bu, Pj, Po	Sh, Tr, Cn
Western bluebird				

SEASONAL OCCURRENCE	STATUS	HABITAT	NEST	
<i>Sialia currucoides</i> Mountain bluebird	S, T	U	Ag, Sa, Bu, Pj, Po, Cf	Tr, Cn
Fam. <u>Sylviidae</u> <i>Polioptila caerulea</i> Blue-gray gnatcatcher	S	U	Sa, Bu, Pj	
Fam. <u>Bombycillidae</u> <i>Bombycilla cedrorum</i> Cedar waxwing	W, T	U	Pj	Bu, Tr
Fam. <u>Laniidae</u> <i>Lanius excubitor</i> Northern shrike	W	U	Sa, Dw, Pj, Po	Tr
<i>Lanius ludovicianus</i> Loggerhead shrike	S, T	U	Sa, Pj	Sh, Tr
Fam. <u>Sturnidae</u> <i>Sturnus vulgaris</i> Starling	P	U	Wide tolerance	Ma, Tr
Fam. <u>Vireonidae</u> <i>Vireo vicinior</i> Gray vireo	S	U	Pj	
<i>Vireo solitarius</i> Solitary vireo	S	U	Me, Bu, Pj, Po	
Fam. <u>Parulidae</u> <i>Dendroica nigrescens</i> Black-throated gray warbler	S	U	Sc, Bu, Pj, Dw, Cf	Tr
Fam. <u>Icteridae</u> <i>Icterus parisorum</i> Scott's oriole	S	ROU	saGr, Bu, Dw, Pj, Ca, Ro	Sh
Fam. <u>Thraupidae</u> <i>Piranga ludoviciana</i> Western tanager	S	U	Bu, opDw, opPj, Ri, Po, Fh, Mt	Tr
Fam. <u>Fringillidae</u> <i>Carpodacus mexicanus</i> House finch	S, T	C	Ag, Sa, Me, Bu, Pj, Ri	

SEASONAL OCCURRENCE	STATUS	HABITAT	NEST
<i>Acanthis flammea</i>	T	Ag, Gr, Me, Bu, Pj, Po, Cf	
Common redpoll			
<i>Spinus pinus</i>	S, T	Bu, Pj, Po, Cf	Tr
Pine siskin			
<i>Pipilo erythrophthalmus</i>	S, T	Sc, Bu, Me, Pj, Ri	
Rufous-sided towhee			
<i>Chondestes grammacus</i>	S, T	Ag, Sa, Bu, Pj	Og, Sh
Lark sparrow			
<i>Junco h. hyemalis</i>	W	Pj, Po, Cf	
Dark-eyed junco			
<i>Spizella passerina</i>	S	Gr, Bu, opPj, opDw, Sa, Me, Ri, Cf	
Chipping sparrow			
<i>Spizella breweri</i>	S	Sa, Sc, saPj, saDw, Fh	Sh
Brewer's sparrow			
<i>Spizella atrogularis</i>	S	Pj	Tr
Black-chinned sparrow			

REPTILES OCCURRING IN PINYON-JUNIPER WOODLANDS
OF THE COLORADO PLATEAU

	DISTRIB.	HABITAT	COMMENTS
Or. CHELONIA Fam. Kinosternidae <i>Kinosternon sonoriense</i> Sonora mud turtle	AZ, SUT	Dw, Pj, Po, Cf, Pp, Tp, Ta, Wi	
Fam. Emydidae <i>Chrysemys picta bellii</i> Western painted turtle	wCO, NM, SUT	Ma, Pp	
Or. SQUAMATA, Subor. SAURIA Fam. Lguanidae <i>Crotaphytus collaris baileyi</i> Western collared lizard <i>Crotaphytus collaris auriceps</i> Yellow-headed collared lizard	nAZ, wCO, nwNM, SUT nAZ, SUT	De, Gr, opPj, arRo, Ca, Fh Upper Colorado, Green River Basins	Protected by Colorado state law
<i>Gambelia w. wislizeni</i> Long-nosed leopard lizard <i>Gambelia wislizeni punctatus</i>	AZ, swCO, nwNM, SUT nAZ, wCO, nwNM, SUT n-cAZ, swUT	Ss, Rs, Ro, Sc, Bu, Dw, Pj Fh, Ro, Bu, Ca, Cr, unLo, unRo	Upper Colorado River Basin only
<i>Sceloporus magister unifornis</i> Yellow-backed spiny lizard <i>Sceloporus magister cephalo- flavus</i> Orange-headed spiny lizard <i>Sceloporus undulatus elongatus</i> Northern plateau lizard <i>Sceloporus undulatus tristi- chus</i> Southern plateau lizard	neAZ, swCO, nwNM, seUT nwAZ, wCO, nwNM, eUT neAZ, nwNM, seUT	Ca, RoFh RoPj	

	DISTRIB.	HABITAT	COMMENTS
<i>Sceloporus g. graciosus</i>	All	Sa, De, Bu, Dw, Pj, Po, Cf, Gs	
Northern sagebrush lizard			
<i>Uta stansburiana stejnegeri</i>	AZ, NM, swUT	Ss, Gs, Ro, De, Gr, opSc, opPj, Fh	
Desert side-blotched lizard			
<i>Uta s. stansburiana</i>	nAZ, wCO, nwNM, UT	Gs, De, Gs, Sc, Bu, opPj	
Brown-shouldered lizard			
<i>Urosaurus ornatus wrightii</i>	nAZ, nwNM, wCO	Ro, Ca, CI	
Northern tree lizard			
<i>Phrynosoma douglassi hernandesi</i>	AZ, wCO, nNM, seUT	Mt, Ms, Pj, Po	
Mountain short-horned lizard			
Fam. Xantusiidae			
<i>Xantusia vigilis utahensis</i>	seUT	unLo, unSh, unRo	Restricted to Henry Mts., Utah
Utah night lizard			
Fam. Scincidae			
<i>Eumeces obsoletus</i>	AZ, NM	unLo, UNRo, Rc, Gb, DeGr, Dw, Pj, saCa, Mt, Ms, Wa	
Great Plains skink			
<i>Eumeces skiltonianus utahensis</i>	nAZ, wUT	Dw, Pj, Gr, Me, Sa, unRo, unLo, RoRi	
Great Basin skink			
<i>Eumeces gilberti arizonensis</i>	AZ	Wa, Ps, Ts, Dw, Pj, Ro, Lo	Extreme sw edge of Colorado Plateau
Arizona skink			
Fam. Teiidae			
<i>Cnemidophorus velox</i>	neAZ, swCO, nwNM, seUT	Dw, Pj, Po, Fh, Wa, Ps, Ts	
Plateau whiptail			
<i>Cnemidophorus tigris septentrionalis</i>	nAZ, wCO, nwNM, SUT	De-Po, saGr, opPj, opDw, Ss	
Northern whiptail			
<i>Cnemidophorus exsanguis</i>	AZ, NM	De-Po, RoFh, Ss, Ca	
Chihuahua whiptail			
Or. SQUAMATA, Subor. SERPENTES			
Fam. Colubridae			
<i>Coluber constrictor morroni</i>	nwAZ, wCCO, NM, UT	opDw, opPj, Bu, Me, Ag, Ri, Ro, Lo, Wa	THREATENED in NM: no legal protection
Western yellow-bellied racer			

DISTRIB.	HABITAT	COMMENTS
<i>Masticophis flagellum piceus</i> Red racer	De, Gr, Bu, Dw, Pj, Ag	
<i>Masticophis t. taeniatus</i> Desert striped whipsnake	Gr, opBu, opPj, Ms, Ca, Mt, Wa	
<i>Elaphe guttata emoryi</i> Great Plains rat snake	Ps, RoFh, Pj, Cf, unRo, unLo, Gb	
<i>Arizona elegans philipi</i> Painted desert glossy snake	opGr, opBu, opPj, Ss, Ro, Gb	
<i>Pituophis melanoleucus affinis</i> Sonora gopher snake	Gr, opBu, De, Ag, Pj, Dw, Cf, Mt, Ms, unRo, unLo	
<i>Pituophis melanoleucus deserticola</i> Great Basin gopher snake	AZ, NM, extr. sCO extr. wCO, UT	
<i>Lampropeltis getulus californica</i> California kingsnake	nwAZ, sUT	
<i>Lampropeltis p. pyromelana</i> Arizona mountain kingsnake	AZ	San Francisco Mts., AZ
<i>Lampropeltis pyromelana inyalabius</i> Utah mountain kingsnake	nAZ, UT	THREATENED in UT
<i>Lampropeltis triangulum celaemops</i> New Mexican milk snake	opDw, opPj, opCf, opRi, RoFh, Gr, Ag, Ss, unRo, unLo	
<i>Lampropeltis triangulum taylori</i> Utah milk snake	Dw, Pj, Cf, RoFh, unRo, unLo	THREATENED in NM
<i>Thamnophis rufo punctatus</i> Narrow-headed garter snake	Ri, Pj, Dw, Po, Ps, Wa	Almost strictly aquatic

	DISTRIB.	HABITAT	COMMENTS
<i>Thamnophis elegans vagrans</i>	All	Gr, Bu, Pj, Cf, Ps, Ts, Wa	
Wandering garter snake			
<i>Thamnophis c. cyrtopsis</i>	cAZ, sCO, NM, seUT	Fh, Mt, Wa	
Black-necked garter snake			
<i>Sonora semiannulata gloydi</i>	nwAZ, swUT	Ss, Ri, Ms, RoFh, unRo	THREATENED in UT
Grand Canyon ground snake			
<i>Tantilla planiceps utahensis</i>	nwAZ, wCO, sUT	unRo, unLo, Ro	Protected in Colorado
Utah black-headed snake			
<i>Trimorphodon biscutatus</i>	nwAZ	De, arGr, Pj, Dw, Po, RoCa, RoFh	
<i>Lytrophanes</i>			
Baja California lyre snake			
<i>Hypsiglena torquata ochro-</i>	AZ, wNM, sUT	Ro, Ss, unRo, unLo	
<i>rhynchus</i>			
Fam. Viperidae,			
Subf. Crotalinae			
<i>Crotalus m. molossus</i>	cAZ, wcNM	Cf, Pj, Mt, Ms, Ro, Ca	
Northern Black-tailed rattlesnake			
<i>Crotalus viridis concolor</i>	wCO, eUT	Sc, Pj, Ca, Cl, Ro, Fh, Ms, Rc, Ss	
Midget faded rattlesnake			
<i>Crotalus viridis nuntius</i>	neAZ, swCO, nwNM, sUT	Sc, Pj, Ca, Cl, Ro, Fh, Ms, Rc, Ss	
Hopi rattlesnake			
<i>Crotalus viridis abyssus</i>	AZ	Sc, Pj, Ca, Ro, Fh, Rc	Restricted to Grand Canyon; protected
Grand Canyon rattlesnake			
<i>Crotalus viridis cerberus</i>	cAZ, extr. wNM	Sc, Bu, Dw, Pj, Ro, Fh	Protected in NM; rare
Arizona black rattlesnake			

APPENDIX XI
 AMPHIBIANS OCCURRING IN PINYON-JUNIPER WOODLANDS
 OF THE COLORADO PLATEAU

	DISTRIB.	HABITAT	COMMENTS
Or. CAUDATA			
Fam. Ambystomidae			
<i>Ambystoma tigrinum utahensis</i> Utah tiger salamander	nAZ, wCO, nwNM, UT	Pp, Ps, Wi. Adults: Rc, Lo, Gb	
Or. SALIENTA			
Fam. Ranidae			
<i>Rana catesbeiana</i> Bullfrog	All	Pp, Ps, Ma, Ct, Wa, Wi	
<i>Rana pipiens</i> Leopard frog	All	Ma, Me, Ps, Pp, Ts, Tp, Ri, Ct	
Fam. Hylidae			
<i>Hyla arenicolor</i> Canyon tree frog	All	Ta, Ca, Ps, Pp, Ts, Tp, Ri, Wa	
<i>Pseudacris t. triseriata</i> Western chorus frog	AZ, NM	Bu, Og, Ri	
<i>Pseudacris t. maculata</i>	CO, nNM, UT	Wa, Pp, Ps, Me	
Fam. Pelobatidae			
<i>Scaphiopus inermontanus</i> Great Basin spadefoot toad	nAZ, Co, NM, UT	Sa, Gr, Pj, Gb, Ca, Ps, Ts, Ta	
Fam. Bufonidae			
<i>Bufo w. woodhousei</i> Rocky Mountain toad	All	Sa, Gr, Ri, Dw, Pj, Ss	
<i>Bufo punctatus</i> Red-spotted toad	All	Ca, opGr, Ri, Ro, Rc	

APPENDIX XII

BIRDS OCCURRING IN RIPARIAN HABITATS
ON THE COLORADO PLATEAU

Note: Use same key as Appendix IX

	SEASONAL OCCURRENCE	STATUS	HABITAT
<i>Gavia immer</i> Common Loon	T*W	U	Open water
<i>Aechmophorus occidentalis</i> Western grebe	T	R	Open water
<i>Podiceps caspicus</i> Eared grebe	T*	U	Open water
<i>Podilymbus podiceps</i> Pied-billed grebe	T*	U	Open water
<i>Pelecanus erythrorhynchos</i> White pelican	T	U	Open water
<i>Phalacrocorax auritus</i> Double-crested cormorant	T	U	Open water
<i>Olor columbianus</i> Whistling swan	T*	R	Open water
<i>Branta canadensis</i> Canada goose	S,T	C	Open water
<i>Chen hyperborea</i> Snow goose	T*	U	Open water
<i>Anas platyrhynchos</i> Mallard	T,W	U	Open water

* Hypothetical (from Behle 1960)

SEASONAL OCCURRENCE	STATUS	HABITAT	
<i>Anas acuta</i>	T,W	U	Open water
Pintail			
<i>Anas strepera</i>	T,W	U	Open water
Gadwall			
<i>Mareca americana</i>	T	U	Open water
American widgeon			
<i>Anas clypeata</i>	T	U	Open water
Shoveler			
<i>Anas discors</i>	T	U	Open water
Blue-winged teal			
<i>Anas cyanoptera</i>	T	U	Open water
Cinnamon teal			
<i>Anas carolinensis</i>	T,W	C	Open water
Green-winged teal			
<i>Aythya americana</i>	T*	U	Open water
Redhead			
<i>Aythya valisneria</i>	T	U	Open water
Canvasback			
<i>Aythya affinis</i>	T	U	Open water
Lesser scaup			
<i>Bucephala clangula</i>	T	U	Open water
Common goldeneye			
<i>Bucephala albeola</i>	T*	U	Open water
Bufflehead			
<i>Oxyura jamaicensis</i>	T*	U	Open water
Ruddy duck			
<i>Mergus merganser</i>	T*W	U	Open water
Common merganser			
<i>Mergus serrator</i>	T*	U	Open water
Red-breasted merganser			

SEASONAL OCCURRENCE	STATUS	HABITAT	
<i>Accipiter gentilis</i> Goshawk	T*	R	River bank vegetation
<i>Accipiter cooperi</i> Cooper's hawk	P	U	River bank vegetation
<i>Accipiter striatus</i> Sharp-shinned hawk	P*	U	River bank vegetation
<i>Circus cyaneus</i> Marsh hawk	P*	U	River bank vegetation, terraces, marshes
<i>Buteo regalis</i> Ferruginous hawk	P*	C	River bank vegetation
<i>Buteo jamaicensis</i> Red-tailed hawk	P	A	River bank vegetation
<i>Buteo swainsoni</i> Swainson's hawk	S	R	River bank vegetation
<i>Haliaeetus leucocephalus</i> Bald eagle	W	U	River bank vegetation
<i>Falco peregrinus</i> Peregrine falcon	T	R	Over rivers, lakes
<i>Falco columbarius</i> Merlin	T	R	River bank vegetation
<i>Falco sparverius</i> American kestrel	P	C	River bank vegetation
<i>Leucophoxy thula</i> Snowy egret	T	U	Bars
<i>Ardea herodias</i> Great blue heron	S,T	C	Bars, river bank vegetation
<i>Nycticorax nycticorax</i> Black-crowned night heron	T	U	Bars, river bank vegetation
<i>Botaurus lentiginosus</i> American bittern	T*	U	Bars, river bank vegetation
<i>Plegadis chihii</i> White-faced ibis	T	U	Bars, river bank vegetation

SEASONAL OCCURRENCE	STATUS	HABITAT
<i>Rallus limicola</i>	T*	Marshes
Virginia rail		
<i>Porzana carolina</i>	T*	Marshes
Sora		
<i>Fulica americana</i>	S	River bank vegetation, marshes
American coot		
<i>Recurvirostra americana</i>	T*	Bars
American avocet		
<i>Charadrius vociferus</i>	P	Bars, river bank vegetation
Killdeer		
<i>Numenius americanus</i>	T*	Bars, river bank vegetation
Long-billed curlew		
<i>Tringa solitaria</i>	T*	Bars
Solitary sandpiper		
<i>Actitis macularia</i>	S,T	Marshes
Spotted sandpiper		
<i>Catoptrophorus semipalmatus</i>	T*	Bars
Willet		
<i>Totanus melanoleucus</i>	T*	Bars
Greater yellowlegs		
<i>Totanus flavipes</i>	T*	Bars
Lesser yellowlegs		
<i>Limnodromus scolopaceus</i>	T*	Bars
Long-billed dowitcher		
<i>Erolia bairdii</i>	T*	Bars
Baird's sandpiper		
<i>Erolia minutilla</i>	T*	Bars
Least sandpiper		
<i>Ereunetes mauri</i>	T*	Bars
Western sandpiper		
<i>Steganopus tricolor</i>	T*	Bars
Wilson's phalarope		
<i>Capella gallinago</i>	T*	Marshes
Common snipe		

SEASONAL OCCURRENCE	STATUS	HABITAT
<i>Larus californicus</i>	U	Over rivers, lakes; bars
California gull		
<i>Larus delawarensis</i>	U	Over rivers, lakes; bars
Ring-billed gull		
<i>Larus pipixcan</i>	U	Over rivers, lakes; bars
Franklin's gull		
<i>Larus philadelphia</i>	U	Over rivers, lakes; bars
Bonaparte's gull		
<i>Chlidonias niger</i>	U	Over rivers, lakes; bars
Black tern		
<i>Coccyzus americanus</i>	R	River bank vegetation
Yellow-billed cuckoo		
<i>Tyto alba</i>	U	River bank vegetation
Barn owl		
<i>Otus asio</i>	U	River bank vegetation
Screech owl		
<i>Bubo virginianus</i>	U	River bank vegetation
Great horned owl		
<i>Asio otus</i>	U	River bank vegetation
Long-eared owl		
<i>Strix occidentalis</i>	U-R	River bank vegetation
Spotted owl		
<i>Aegolius acadicus</i>	R	River bank vegetation
Saw-whet owl		
<i>Selasphorus platycercus</i>	C	River bank vegetation, terraces
Broad-tailed hummingbird		
<i>Stellula calliope</i>	U	River bank vegetation, terraces
Calliope hummingbird		
<i>Archilochus alexandri</i>	C	Over rivers, lakes; river bank vegetation; terraces
Black-chinned hummingbird		
<i>Calypte socata</i>	U	River bank vegetation, terraces
Costa's hummingbird		
<i>Selasphorus rufus</i>	C	River bank vegetation, terraces
Rufous hummingbird		

SEASONAL OCCURRENCE	STATUS	HABITAT
<i>Colaptes cafer</i>	P	River bank vegetation
Red-shafted flicker		
<i>Sphyrapicus varius</i>	W	River bank vegetation
Yellow-bellied sapsucker		
<i>Sphyrapicus thyroideus</i>	T*	River bank vegetation
Williamson's sapsucker		
<i>Dendrocopos pubescens</i>	T*	River bank vegetation
Downy woodpecker		
<i>Tyrannus verticalis</i>	S	River bank vegetation
Western kingbird		
<i>Tyrannus vociferans</i>	S	River bank vegetation
Cassin's kingbird		
<i>Myiarchus cinetascens</i>	S	River bank vegetation, terraces
Ash-throated flycatcher		
<i>Sayornis nigricans</i>	S*	River bank vegetation, terraces
Black phoebe		
<i>Empidonax trailii</i>	T*	River bank vegetation
Traill's flycatcher		
<i>Empidonax oberholseri</i>	T*	River bank vegetation
Dusky flycatcher		
<i>Empidonax wrightii</i>	T*	River bank vegetation
Gray flycatcher		
<i>Empidonax difficilis</i>	T	River bank vegetation
Western flycatcher		
<i>Contopus sordidulus</i>	T,S*	River bank vegetation
Western wood peewee		
<i>Nuttallornis borealis</i>	T	River bank vegetation
Olive-sided flycatcher		
<i>Eremophila alpestris</i>	P	Terraces
Horned lark		
<i>Hirundo rustica</i>	T*	Over rivers, river bank vegetation
Barn swallow		

SEASONAL OCCURRENCE STATUS HABITAT

<i>Petrochelidon pyrrhonata</i> Cliff swallow	S	C	Over rivers, lakes
<i>Tachycineta thalassina</i> Violet-green swallow	S	C	Over rivers, lakes; river bank vegetation, terraces
<i>Iridoprocne bicolor</i> Tree swallow	T*	U	Over rivers, lakes; river bank vegetation
<i>Riparia riparia</i> Bank swallow	T*	U	Over rivers, lakes; river bank vegetation
<i>Stelgidopteryx ruficollis</i> Rough-winged swallow	T, S*	U	Over rivers, lakes; river bank vegetation
<i>Aphelocoma coerulescens</i> Scrub jay	P	U	River bank vegetation
<i>Parus atricapillus</i> Black-capped chickadee	W*	U	River bank vegetation
<i>Parus gambeli</i> Mountain chickadee	W	U	River bank vegetation
<i>Psaltriparus minimus</i> Common bushtit	P*	U	River bank vegetation
<i>Cinclus mexicanus</i> Dipper	P	C	Clear streams
<i>Sitta carolinensis</i> White-breasted nuthatch	W*	U	River bank vegetation
<i>Sitta canadensis</i> Red-breasted nuthatch	W*	U	River bank vegetation
<i>Certhia familiaris</i> Brown creeper	W	U	River bank vegetation
<i>Troglodytes aedon</i> House wren	W*	U	River bank vegetation
<i>Telmatodytes palustris</i> Long-billed marsh wren	T*	U	Marshes
<i>Dumetella carolinensis</i> Catbird	S	U	River bank vegetation
<i>Turdus migratorius</i> Robin	P	C	River bank vegetation

SEASONAL OCCURRENCE	STATUS	HABITAT
<i>Myadestes townsendi</i>	W*	River bank vegetation
Townsend's solitaire		
<i>Catharus g. guttatus</i>	T*	River bank vegetation
Hermit thrush		
<i>Catharus guttatus ustulata</i>	T*	River bank vegetation
Swainson's thrush		
<i>Sialia mexicana</i>	T*	River bank vegetation
Western bluebird		
<i>Polioptila caerulea</i>	S	Over rivers, lakes; river bank vegetation; terraces
Blue-gray gnatcatcher		
<i>Regulus satrapa</i>	W*	River bank vegetation
Golden-crowned kinglet		
<i>Regulus calendula</i>	W*	River bank vegetation
Ruby-crowned kinglet		
<i>Bombicilla cedrorum</i>	T*	River bank vegetation
Cedar waxwing		
<i>Phainopepla nitens</i>	S*	River bank vegetation
Phainopepla		
<i>Sturnus vulgaris</i>	P*	River bank vegetation
Starling		
<i>Vireo solitarius</i>	T	River bank vegetation
Solitary vireo		
<i>Vireo gilvus</i>	S*	River bank vegetation
Warbling vireo		
<i>Vermivora celata</i>	T	River bank vegetation
Orange-crowned warbler		
<i>Vermivora ruficapilla</i>	T*	River bank vegetation
Nashville warbler		
<i>Vermivora virginiae</i>	T*	River bank vegetation
Virginia's warbler		
<i>Vermivora luciae</i>	S	River bank vegetation
Lucy's warbler		
<i>Dendroica petechia</i>	S	River bank vegetation
Yellow warbler		
<i>Dendroica coronata</i>	T*	River bank vegetation
Audubon's warbler		

SEASONAL OCCURRENCE	STATUS	HABITAT
<i>Dendroica townsendi</i>	T*	River bank vegetation
Townsend's warbler		
<i>Seiurus noveboracensis</i>	T*	River bank vegetation
Northern waterthrush		
<i>Geothlypis trichas</i>	S	River bank vegetation
Yellowthroat		
<i>Icteria virens</i>	S	River bank vegetation
Yellow-breasted chat		
<i>Oporornis tolmiei</i>	T*	River bank vegetation
MacGillivray's warbler		
<i>Wilsonia pusilla</i>	T*	River bank vegetation
Wilson's warbler		
<i>Passer domesticus</i>	P*	River bank vegetation
House sparrow		
<i>Dolichonyx oryzivorus</i>	T*	River bank vegetation
Bobolink		
<i>Xanthocephalus xanthocephalus</i>	T	River bank vegetation
Yellow-headed blackbird		
<i>Agelaius phoeniceus</i>	T,S*	River bank vegetation, marshes
Red-winged blackbird		
<i>Euphagus cyanocephalus</i>	T	River bank vegetation, terraces
Brewer's blackbird		
<i>Lothrus ater</i>	T	River bank vegetation
Brown-headed cowbird		
<i>Icterus parisorum</i>	S*	River bank vegetation
Scott's oriole		
<i>Icterus galbula bullocki</i>	S	River bank vegetation
Bullock's oriole		
<i>Piranga ludoviciana</i>	T	River bank vegetation
Western tanager		
<i>Pheucticus melanocephalus</i>	T,S*	River bank vegetation
Black-headed grosbeak		

SEASONAL OCCURRENCE	STATUS	HABITAT
<i>Giraca caerulea</i>	S	River bank vegetation, terraces
Blue grosbeak		
<i>Passerina amoena</i>	S	River bank vegetation
Lazuli bunting		
<i>Carpodacus cassinii</i>	T*	River bank vegetation
Cassin's finch		
<i>Carpodacus mexicanus</i>	S	River bank vegetation
House finch		
<i>Spinus pinus</i>	T,W*	River bank vegetation
Pine siskin		
<i>Spinus tristis</i>	P	River bank vegetation
American goldfinch		
<i>Spinus psaltria</i>	P	River bank vegetation
Lesser goldfinch		
<i>Chlorura chlorura</i>	T*	River bank vegetation
Green-tailed towhee		
<i>Pipilo erythrophthalmus</i>	P	River bank vegetation
Rufous-sided towhee		
<i>Passerculus sandwichensis</i>	T*	River bank vegetation
Savannah sparrow		
<i>Poocetes gramineus</i>	T*	River bank vegetation
Vesper sparrow		
<i>Chondestes grammacus</i>	S	River bank vegetation, terraces
Lark sparrow		
<i>Junco h. hyemalis</i>	W*	River bank vegetation
Slate-colored junco		
<i>Junco hyemalis oregonus</i>	W	River bank vegetation
Oregon junco		
<i>Junco caniceps</i>	T*	River bank vegetation
Gray-headed junco		
<i>Spizella atotrea</i>	W*	River bank vegetation
Tree sparrow		
<i>Zonotrichia querula</i>	W*	River bank vegetation
Harris' sparrow		
<i>Zonotrichia leucophrys</i>	W	River bank vegetation
White-crowned sparrow		

SEASONAL OCCURRENCE	STATUS	HABITAT
<i>Passerella iliaca</i> Fox sparrow	U	River bank vegetation
<i>Melospiza lincolni</i> Lincoln's sparrow	U	River bank vegetation
<i>Melospiza melodia</i> Song sparrow	C	River bank vegetation

APPENDIX XIII
MAJOR PERENNIAL PLANT SPECIES ON AND ADJACENT
TO THE COLORADO PLATEAU
(from West et al. 1975)

KEY

1. WYOMING BASIN South slope Owl Creek Mtns., Fremont Co., central WY; 1750m (5800 ft.).
2. UPPER BASIN AND RANGE Duckwater watershed, west slope Duckwater Mtns., Nye Co., east-central NV; 2040m (6650 ft.)
3. WESTERN LOWER BASIN AND RANGE Pine Canyon, Lincoln Co., southeast NV; 2080m (6720 ft.).
4. WESTERN LOWER BASIN AND RANGE Southeast slope, Pine Valley Mtns., Washinton Co., southwest UT; 1385m (4550 ft.).
5. WESTERN COLORADO PLATEAU Fishtail Mesa, Grand Canyon National Park, northwest AZ; 1880m (6150 ft.).
6. EASTERN COLORADO PLATEAU Long Mesa, Mesa Verde National Park, southwest CO; 2160m (7600 ft.).
7. EASTERN COLORADO PLATEAU Upland sand site, No Man's Mesa, Kane Co., southeast UT; 1820m (6000 ft.).
8. SOUTHEAST COLORADO PLATEAU San Augustin Plain, Catron Co., west-central New Mexico; 2100m (7400 ft.).
9. EASTERN LOWER BASIN AND RANGE Hills site, Ft. Stanton Coop. Range Res. Sta., Lincoln Co., south-central New Mexico; 1960m (6500 ft.).

APPENDIX XIII
(cont.)

	1	2	3	4	5	6	7	8	9
<u>TREES</u>									
<i>Juniperus osteosperma</i>	x	x	x	x	x	x	x	x	
<i>Juniperus monosperma</i>								x	x
<i>Pinus edulis</i>					x	x	x		
<i>Pinus monophylla</i>		x	x	x				x	x
<i>Quercus grisea</i>								x	
<u>SHRUBS</u>									
<i>Amelanchier pallida</i>			x			x			
<i>Amelanchier utahensis</i>							x		
<i>Arctostaphylos patula</i>							x		
<i>Arctostaphylos pungens</i>							x		
<i>Artemisia bigelovii</i>					x				
<i>Artemisia nova</i>		x							
<i>Artemisia tridentata</i>	x		x	x	x		x		
<i>Ceanothus greggii</i>							x		
<i>Cercocarpus montanus</i>						x			
<i>Chrysothamnus viscidiflorus</i>		x					x		
<i>Coleogyne ramosissima</i>					x				
<i>Cowania mexicana</i>					x				
<i>Ephedra viridis</i>							x		
<i>Fallugia paradoxa</i>					x			x	
<i>Fendlera rupicola</i>					x	x			
<i>Garrya flavescens</i>							x		

1 2 3 4 5 6 7 8 9

SHRUBS (cont.)

<i>Purshia tridentata</i>		x	x	x		x			
<i>Quercus gambelii</i>			x				x		
<i>Quercus turbinella</i>				x					
<i>Quercus undulata</i>								x	
<i>Shepardia rotundifolia</i>					x		x		
<i>Symphoricarpos oreophilus</i>							x		
<i>Tetradymia canescens</i>							x		

SUCCULENTS

<i>Opuntia polycantha</i>	x				x	x	x		
<i>Opuntia spinosior</i>					x				
<i>Yucca baccata</i>				x	x	x			

FORBS

<i>Arabis pendulina</i>							x		
<i>Astragalus spp.</i>		x	x						
<i>Eriogonum caespitosum</i>			x						
<i>Eriogonum ovaliflorum</i>							x		
<i>Hymenoxys bigelovii</i>							x		

GRASSES

<i>Agropyron smithii</i>							x		
<i>Agropyron spicatum</i>	x	x							
<i>Bouteloua curtipendula</i>									x
<i>Bouteloua gracilis</i>								x	
<i>Bouteloua hirsula</i>								x	x

	1	2	3	4	5	6	7	8	9
<u>GRASSES (cont.)</u>									
<i>Eragrostis erosa</i>									x
<i>Hilaria jamesii</i>					x				
<i>Koeleria cristata</i>	x		x				x		
<i>Lycurus phleoides</i>									x
<i>Muhlenbergia pauciflora</i>									x
<i>Muhlenbergia torreyi</i>							x		
<i>Oryzopsis hymenoides</i>		x			x	x	x		
<i>Poa fendleriana</i>						x	x		
<i>Poa longigula</i>					x				
<i>Poa sandbergi</i>	x	x							
<i>Sitanion hystrix</i>		x	x			x			
<i>Stipa comata</i>							x		
<i>Stipa speciosa</i>					x				
<i>Stipa thurberiana</i>		x							


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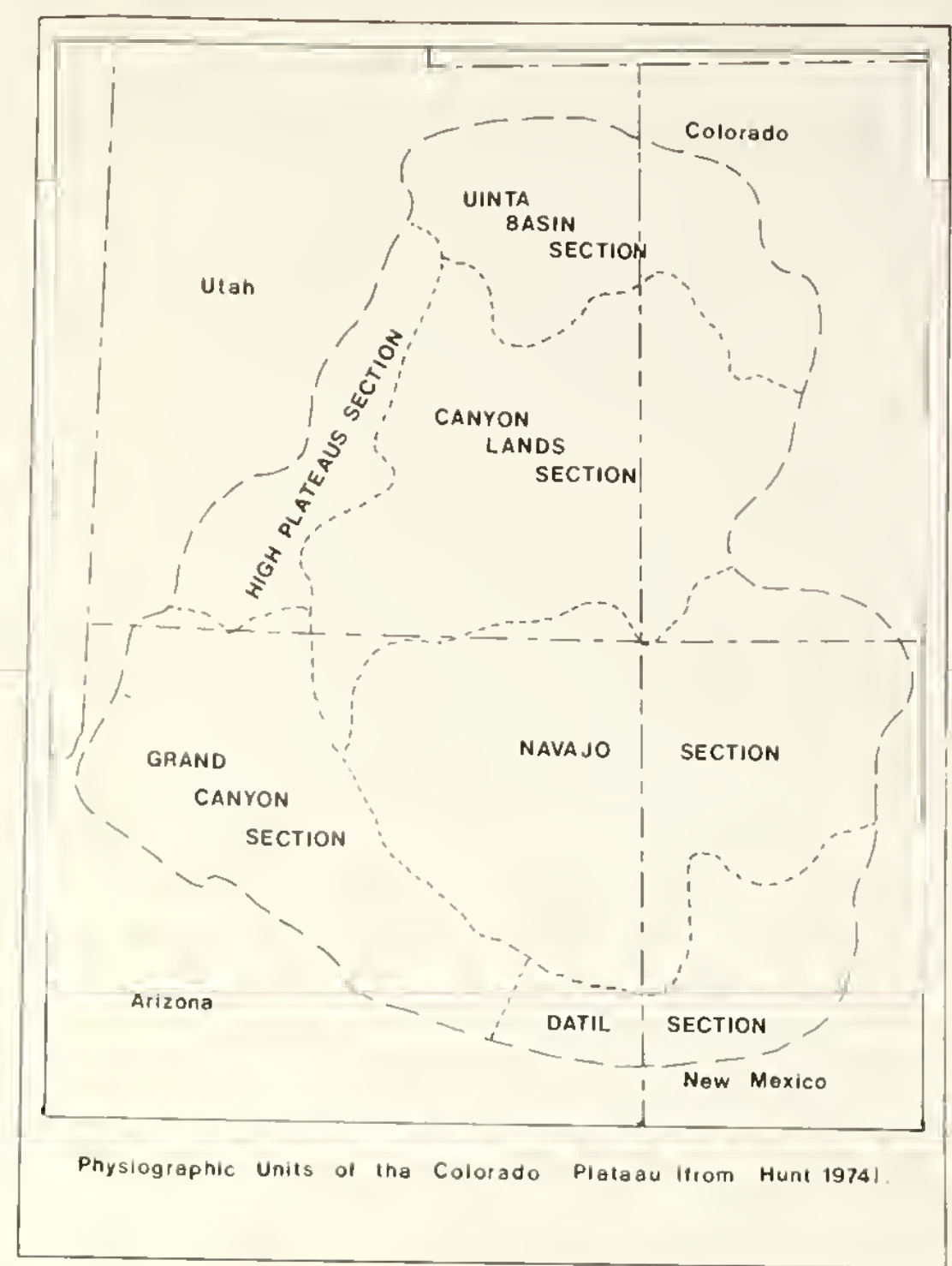
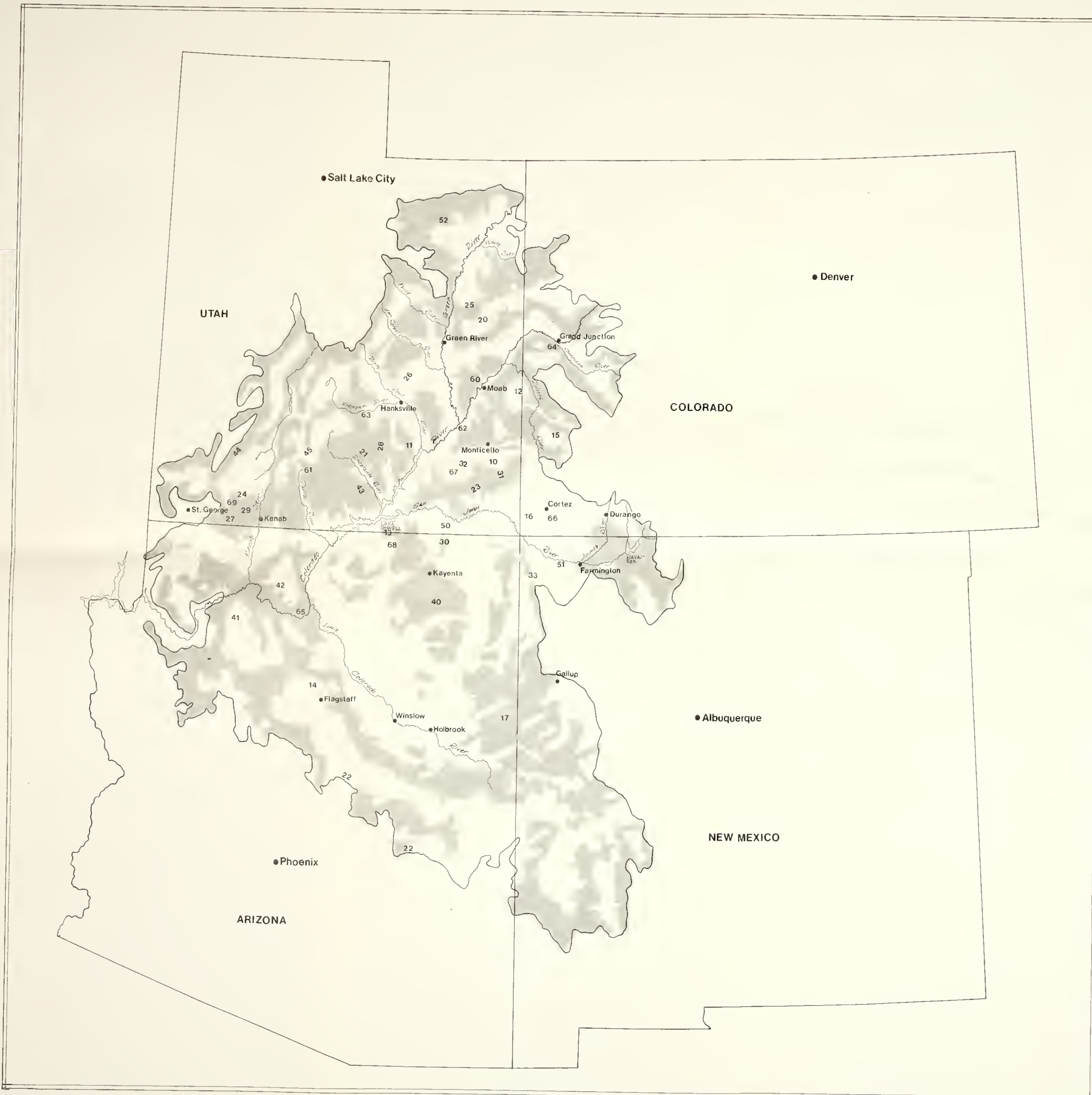
Characteristics of Pinyon-
lands on the Colorado Plateau...

Number	Division	Date Ret'd

DSC 1279-3a (Feb. 1977)



Colorado




 PINYON - JUNIPER WOODLAND

KEY TO PHYSIOGRAPHIC FEATURES AND LANDMARKS:

- | | |
|------------------------------|--------------------------------|
| 10 - Abajo Mountains | 40 - Black Mesa |
| 11 - Henry Mountains | 41 - Coconino Plateau |
| 12 - La Sal Mountains | 42 - Kaibab Plateau |
| 13 - Navajo Mountain | 43 - Kaiparowits Plateau |
| 14 - San Francisco Mountains | 44 - Markagunt Plateau |
| 15 - San Miguel Mountains | 45 - Paunsagunt Plateau |
| 16 - Ute Mountain | |
| 17 - White Mountains | 50 - Monument Valley |
| | 51 - San Juan Basin |
| | 52 - Uinta Basin |
| 20 - Buok Cliffs | 60 - Arches Nat. Park |
| 21 - Circle Cliffs Upwarp | 61 - Bryce Canyon Nat. Park |
| 22 - Mogollon Rim | 62 - Canyonlands Nat. Park |
| 23 - Monument Upwarp | 63 - Capitol Reef Nat. Park |
| 24 - Pink Cliffs | 64 - Colorado Nat. Mon. |
| 25 - Roan Cliffs | 65 - Grand Canyon Nat. Park |
| 26 - San Rafael Swell | 66 - Mesa Verde Nat. Park |
| 27 - Vermilion Cliffs | 67 - Natural Bridges Nat. Mon. |
| 28 - Waterpocket Fold | 68 - Navajo Nat. Mon. |
| 29 - White Cliffs | 69 - Zion Nat. Park |
| 30 - Agatha Peak | |
| 31 - Comb Ridge | |
| 32 - Elk Ridge | |
| 33 - Shiprock | |

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**POTENTIAL OCCURRENCE OF PINYON - JUNIPER WOODLANDS
 ON THE COLORADO PLATEAU**
 (from Küchler 1964)
 SCALE 1:3,168,000

 STATUTE MILES

