



Biotic Communities of Kaibab Plateau, Arizona

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BIOTIC COMMUNITIES OF KAIBAB PLATEAU, ARIZONA*

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BIOTIC COMMUNITIES OF KAIBAB PLATEAU, ARIZONA

I. INTRODUCTION

The recognition of the spatial agreement of many plant and animal communities and their consideration as biotic communities has been a recent development in biological fields. Plant communities have been studied without attention to the animals, but the investigations of terrestrial animal communities without some consideration of plants is practically impossible. Therefore, the necessity for animal ecologists to recognize the importance of plants has given the study of bio-ecology its greatest impetus.

The animal communities of a deciduous forest from the early developmental stages to the climax have been described by Shelford ('13), and the plant and animal communities were shown to be in agreement. In "an associational study of Illinois sand prairie" Vestal ('13) concluded that animals and plants in any terrestrial environment are very intimately related, and the animal and plant communities are coextensive and may be considered together as a biotic "association" (community). The papers of Weese ('24), Blake ('26), Bird ('29), and others have all shown the close relationship of plant and animal communities.

In recent bio-ecological studies there has been a change in methods with greater interest in use of quantitative measurements to improve the quality of field observations. The papers cited are examples of such an approach.

This type of study has dealt in the main with the smaller species present on an area. None of the investigations were concerned with an original fauna in its entirety. The locations of study areas have precluded that.

This paper deals with the results of a study of land communities and their habitats. It is not only concerned with the smaller species, but an attempt is also made to apply quantitative methods of study to a number of large and influent native species. The area studied has been widely advertised because of its larger endemic animals. Also, man, in an attempt to increase the numbers of certain native species here, has greatly modified the biota of the area. The study was undertaken because of interest in the variations in numbers of the large native species.

The terms and concepts of Shelford ('26) have been used following their use by Smith ('28) and Bird ('29). The study concerns larger areas and grosser features, which accounts for not using a number of the terms. One modification of the term "influent" is used in designating those larger animals that have relations of major importance in the biotic balance and in the community, the *Major Influents*. The importance of the animal within the community is the criterion used. It is not limited by year-long residence or seasonal occurrence.

II. PHYSICAL ENVIRONMENT

PHYSIOGRAPHY

This study was conducted on the Kaibab Plateau in Coconino County in extreme northern Arizona. This is located in what is known as the Grand Canyon section of the Colorado Plateau Province. It is unique in being the largest and best-defined of the block plateaus and one of the very few that is bounded on all sides by escarpments and slopes which descend to lower lands. It is enclosed between meridians $111^{\circ} 50'$ and $112^{\circ} 40'$, and parallels $36^{\circ} 5'$ and 37° . (Figs. 1 and 2. The area is included in the Kaibab and Echo Cliffs sheets of the United States Geological Survey. It has a maximum length of sixty miles (95 kilometers) and a maximum width of thirty-five miles (55 km.). The plateau proper consists of approximately 1,152 square miles (2,980 square km.) which are above 6,000 feet (1,830 meters). The highest point has an elevation of 9,200 feet (2,800 m.). On the extreme west side there is an area of nearly 120 square miles (310 square km.) above the upper rim of Kanab Creek, but below the 6,000-foot (1,830 m.) contour. The plateau is bounded on the south by the Grand Canyon of the Colorado River along the region of its greatest magnitude and outstanding scenic grandeur. The elevation of the southern rim of the plateau varies from 8,800 feet (2,680 m.) to slightly less than 6,000 feet (1,830 m.), and is 6,550 (2,000 m.) to 3,800 feet (1,150 m.) above the Colorado River. The canyon rim itself is five to ten miles (8 to 16 km.) back from the river, the area between the rim and river being made of precipitous walls of hard strata several hundred feet thick, with slopes and platforms where the softer strata have receded toward the rim. The most extensive platform is the Esplanade, so named by Dutton ('82), and called "Sand Rocks" by the local cowboys. This has resulted from the weathering back of the Hermit shale, leaving a hard layer of Supai or Permian sandstone exposed. This conspicuous red sandstone, with the great breadth of exposure, is the outstanding feature of the canyon landscape in the western portion of the canyons that border the plateau. It has an elevation of approximately 4,000 feet (1,220 m.).

Kanab Creek Canyon, a miniature Grand Canyon of itself, marks the extreme western boundary of the plateau, its high perpendicular walls forming a natural barrier to movement of most animals. A north and south fault parallel to Kanab Creek, but sixteen miles (26 km.) to the east, marks the approximate west boundary of the higher portions of the plateau. This fault line, north of Snake Gulch (near Ryan), tends toward the east, marking the northwestern boundary of the plateau proper; the plateau ends where this joins the line of escarpment that runs north along

the eastern border. The eastern boundary is marked by a great monoclinical fold, the strata dipping down 2,000 to 3,000 feet (610 to 915 m.) to form the Marble platform. This region is called Houserock Valley.

The surface of the plateau is surprisingly level and although partially dissected, there are no large canyons near the summit. Around the edges are steep,

rugged canyons, and in this region it is the canyons and not the peaks that are the outstanding feature of the topography.

A thick layer of porous Kaibab limestone of Permian age covers the plateau. The presence of this type of terrain accounts for the fact that although higher portions of the plateau receive nearly 30

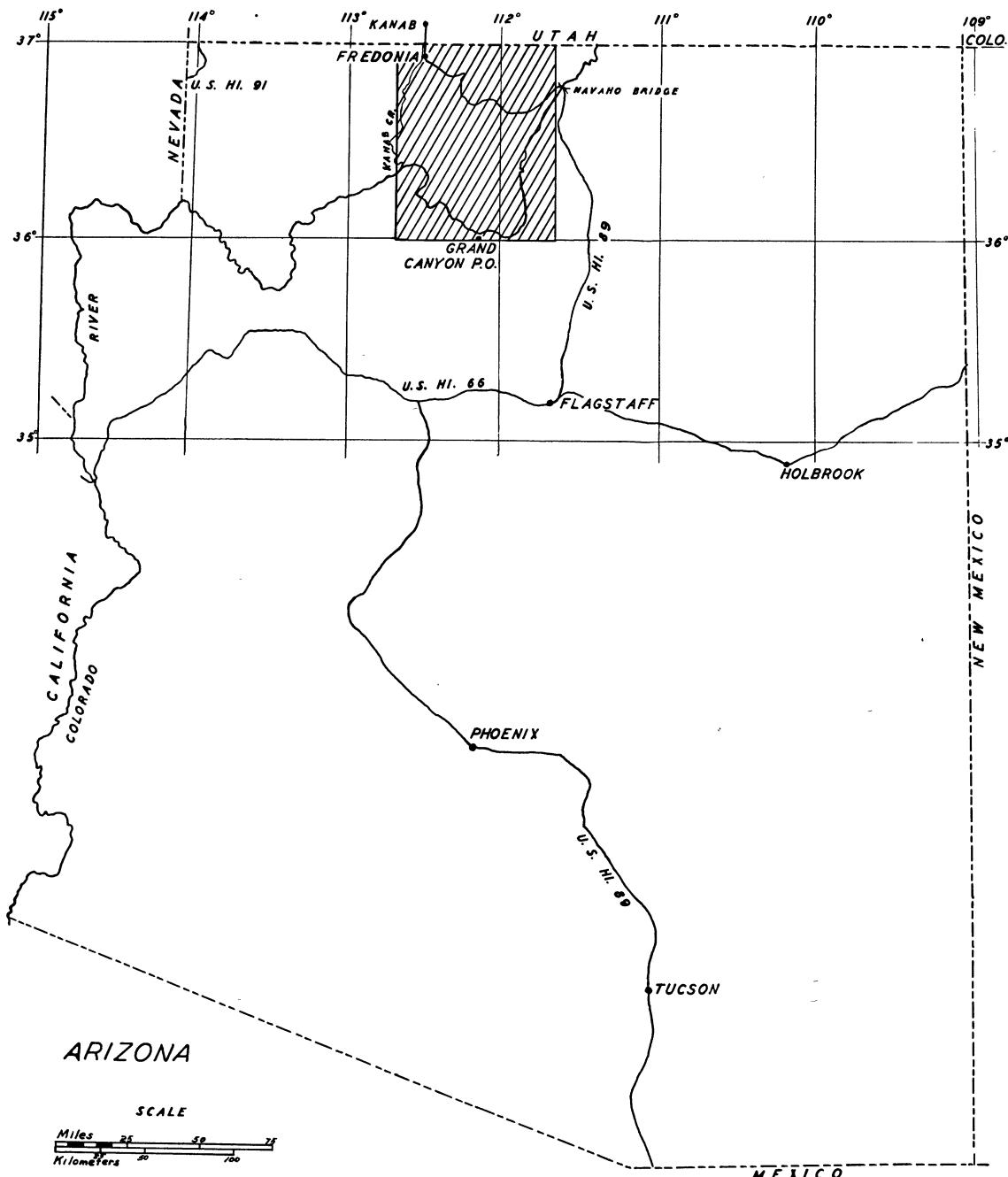


FIG. 1. Outline map of Arizona showing location of Kaibab Plateau and immediately adjacent area (rectangle) in north central part of the state.

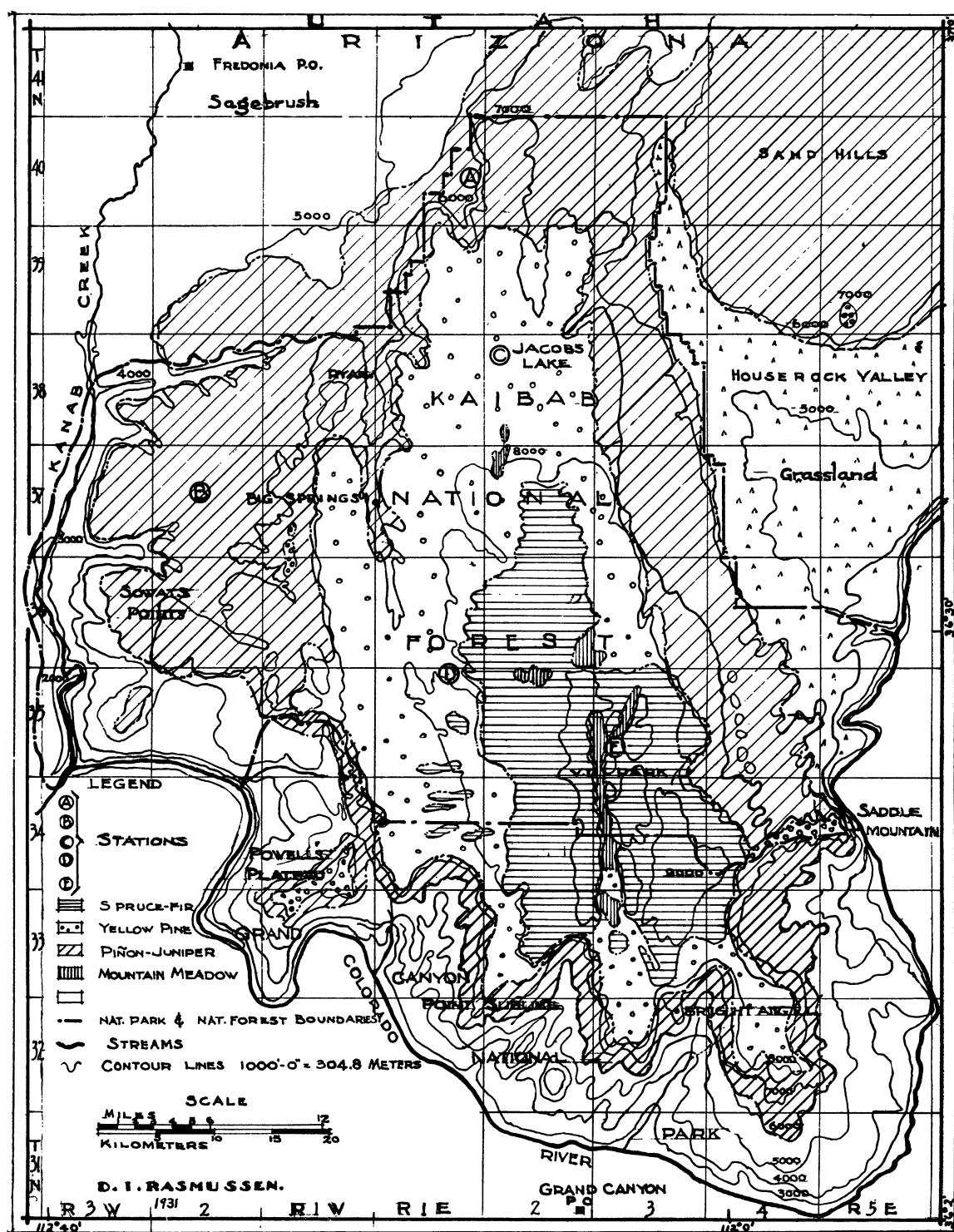


FIG. 2. Map of Kaibab Plateau, Arizona, showing townships, general vegetational types, locations of five study stations (A, B, C, D, E), 1,000-foot (304.8 m.) contours, and Kaibab National Forest and Grand Canyon National Park boundaries.

inches (75 cm.) of precipitation annually, there are no streams. Even after the melting of snow in the spring, or after the heavy rains of late summer, there is no run-off and very rarely erosion caused by running water.

The porous condition of the ground not only prevents run-off, but accounts for the scarcity of springs and bodies of water. A typical form of topography is evident in the presence of "sink holes," circular-shaped areas into which water drains during storms and where it sinks downward. Some few of these sink holes have become sealed by accumulation of fine soils, and the water is retained. Such small ponds of water, of ten to one hundred feet (3 to 30 m.) in diameter, are locally called "lakes." They are practically the sole source of water for all the animals. They are not abundant, and it is often several miles between them.

CLIMATE

The climate of the Kaibab Plateau is decidedly moist in relation to the surrounding region. The only yearly climatological records that exist for the plateau are for the Bright Angel Ranger Station, at an elevation of 8,400 feet (2,560 m.) and situated near the southern tip of the plateau. These records show an average annual precipitation of 26.57 inches (67.48

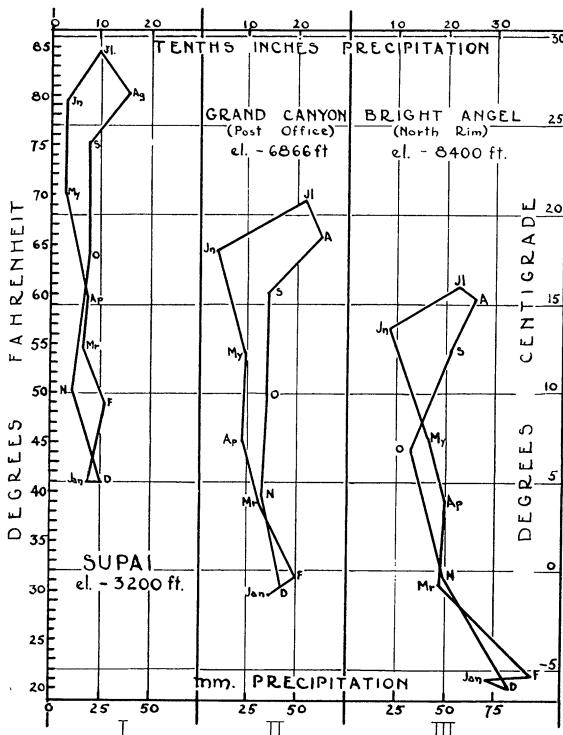


FIG. 3. Climographs of three weather stations located nearest the Kaibab study area. I is Supai, elevation 3,200 feet (975 m.), records 21 years to April, 1923, when it was discontinued. II is Grand Canyon, Arizona, elevation 6,866 feet (2,093 m.), records 28 years to 1937. III is Bright Angel, elevation 8,400 feet (2,560 m.), records 12 years (incomplete), 1925-37.

in.) for the period 1925 to 1936, inclusive. Snows are heavy in winter, often with a depth of eight to ten feet (2.5 to 3 m.) occurring on the higher portions. The typical summer consists of a dry fore-summer, followed by months of greatest rainfall (Fig. 3, III). June is the dry month of the year. May is usually dry, as is early July. Then storms are, as a rule, regular until early September; showers occur several times each week during the afternoon or evening and are often accompanied by violent electrical disturbances. The distribution of the summer showers is spotted, and the regions surrounding the plateau are usually untouched by moisture. On the highest portions of the plateau the precipitation from early October to late April occurs as snow, and snowstorms often occur in May and September. October and November are comparatively dry, and February is the month with the greatest amount of precipitation. Temperature records show only two months, July and August, with a mean temperature over 59° F. (15° C.) and show four months, December to March, inclusive, with a mean temperature below 32° F. (0° C.).

Table 1 shows monthly precipitation and temperature records at Bright Angel Ranger Station near

TABLE 1. Climatic data Arizona stations.

El., Elevation in feet; P, Average monthly precipitation from available records; T, mean monthly temperature from available records.

	SUPAI El. 3,200 feet Records 21 years to April 1933 (Station discontinued)	GRAND CANYON		BRIGHT ANGEL El. 8,400 feet Records 12 years (incomplete) 1925-36, inclusive	
		P	T	P	T
January.....	.73	42.2	1.44	29.1	2.88
February.....	1.08	48.0	1.91	32.8	3.76
March.....	.63	54.5	1.28	38.0	1.96
April.....	.71	58.8	.88	45.3	1.94
May.....	.29	69.9	.95	53.4	1.62
June.....	.31	79.3	.39	63.1	.92
July.....	.94	83.0	2.16	68.7	2.26
August.....	1.55	80.8	2.44	66.5	2.63
September.....	.75	75.1	1.35	60.4	2.11
October.....	.75	63.0	1.38	49.5	1.34
November.....	.42	50.4	1.28	39.2	1.92
December.....	.99	42.0	1.61	30.6	3.23
Total precipitation.....	9.15	17.07	26.57
Monthly mean temperature.....	62.3	48.0	40.7

the southern edge of the plateau and the two other nearest weather stations, i.e., Grand Canyon, Arizona, on the south rim of the canyon and Supai, twenty-four miles (38.60 km.) west and south of Grand Canyon postoffice and within the canyon. Figure 3 consists of three climographs based on available climatic data of these three stations. The graphs, in addition to showing the regular seasonal march of temperature and moisture, illustrate the marked differences in monthly precipitation and temperature associated with elevation differences.

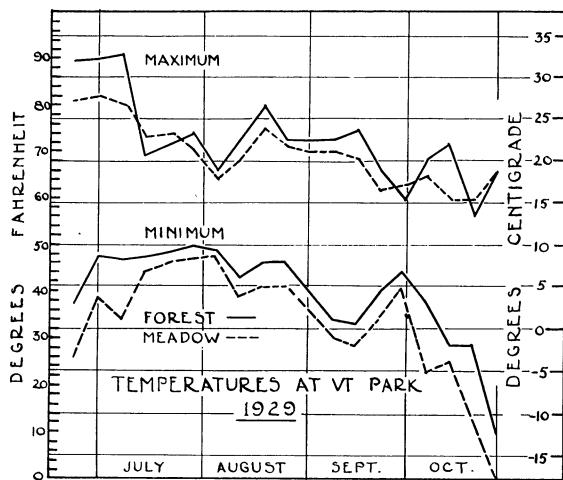


FIG. 4. Weekly maximum and minimum temperatures of spruce-fir forest and meadow, VT Park, 1929.

Figure 4 shows summer temperature records (weekly maximum and minimum) for the summit of the plateau. These previously unpublished data were secured during 1929 at VT Park, elevation 8,900 feet (2,715 m.), by Pauline Mead. They show the temperature range in the open park or meadow and the bordering spruce-fir forest.

III. HISTORY AREA

The individuality and distinctive boundaries of the Kaibab Plateau, usually referred to as just the "Kaibab," have made it an entity in the records and stories of both white men and Indians, and reference to this area is not often confused with any other.

The plateau and the adjoining Grand Canyon have an important part in the legends and stories of the neighboring Indian tribes. The existence of an impassable barrier and the value of a productive hunting-ground in this arid region can well explain the importance with which it has been regarded by these people.

Thus, when the first whites, who were Mormon pioneers from the north, visited the territory in the late 1850's, they found the region famous in Indian tradition and of considerable economic value. The area was the summer home for the Kaibabits, a division of the Piute Indians of southern Utah. The plateau was the fall meeting place for the Piutes, the Navajoes, and often other southwestern tribes. Their primary purpose in assembling was to obtain deer hides or buckskin, which was a main article of commerce. They also came to the plateau to hunt on this neutral hunting-ground, to play games of chance, and to trade with the other tribes. A great deal of the early history of the plateau is reflected in the name "Buckskin Mountain," the name that the first white settlers gave it and by which it is still known locally.

The amount of early hunting on the plateau can only be judged from verbal reports of "old-timers" of the region, both Indians and whites. A number of old residents are very well informed in Indian history and an attempt was made to check various sources of information of this nature.

I am indebted for much of the information concerning early Indian hunting to Mr. Billy Crosby, a local cowboy who speaks the Indian language fluently and is well acquainted with the older Indians. Information was also obtained from Mr. D. A. Riggs, one of the men who assisted Major Powell in the Government Survey of the region in the early 1870's.

The Indians were primarily interested in deer for hides, and although a few were killed in all seasons, the bulk were killed in the fall, when the hides were thickest and best. The Piutes and the Navajoes, especially the latter, have always been great rabbit eaters, and the blacktailed jack rabbit, *Lepus californicus*, was their main source of meat, venison being only of minor importance. The Kaibabits did most of the deer hunting. The total of individuals in the clan averaged only about five hundred Indians, and not more than two hundred of these were men who would take part in hunting. The Navajoes were not especially interested in hunting but bargained for the buckskin of a goodly portion of what the Piutes killed. Crosby estimates that the Piute Indians did not average more than three deer each during the fall hunt, and that in the neighborhood of 100 were killed by them during the summer. He also estimates that the Navajoes did not kill more than a hundred deer in the fall. This would make a total for the maximum kill of 800 deer killed per year by Indian hunting, and perhaps a figure less than that for the average kill. The hides were saved to be tanned; the meat was "jerked," i.e., cut in strips, dried on the ground, and then transported to the lower country to be used as provisions.

The mountain lion was not molested by the Indians, and only occasionally did they kill bobcats or coyotes. The Navajoes never killed coyotes because of a religious taboo.

In 1870, the year following his first descent of the Colorado River, Major John Wesley Powell began the first government exploration of the country north of the Grand Canyon. In the report written in 1875 he says, "The most elevated portion of the country is a central belt, about twenty-five or thirty miles in width and about eighty miles in length. This is called by the Indians Kaibab, or 'mountain lying down,' and we have adopted the name." (Powell, '75, p. 185.) In 1880 and 1881 the region was thoroughly explored and described in detail by Dutton ('82).

"The earliest indicated extensive use of the Kaibab Plateau for livestock was in 1885 and 1886, when 2,000 cattle were placed there." (Mann and Locke, '31). Dutton ('82) comments about wild cattle present on the plateau. These were apparently a small number of feral and semi-wild animals, originally

from herds in surrounding lowlands. "In 1887 and 1889 at least 200,000 sheep and 20,000 cattle and many horses were using the range and surrounding desert," state Mann and Locke ('31); information gained from stockmen indicates that at that time the Kaibab was considered as having an unlimited supply of forage for livestock. The result was that the plateau had its first known overpopulation in excessive herds of cattle, horses, and sheep.

Dutton ('82, p. 137) describes the forest at the time he saw it: "There is a constant succession of parks and glades—dreamy avenues of grass and flowers winding between sylvan walls or spreading out into broad open meadows. From June until September there is a display of wild flowers quite beyond description." These conditions have never been repeated, except in part, since the livestock entered and remained there. The number of livestock that have used the area in recent years, according to available United States Forest Service records, is shown in Figure 5.

On February 20, 1893, by proclamation of President Benjamin Harrison, the Grand Canyon Forest Reserve was created, including the Kaibab Plateau, the Grand Canyon, and the adjoining area on the south rim. On November 28, 1906, President Theodore Roosevelt created the Grand Canyon National Game Preserve, which included approximately the same territory as is now in the Kaibab National Forest and the Grand Canyon National Park north of the Colorado River. He also created the Grand Canyon National Monument by proclamation of January 11, 1908, and by the same means established the name of Kaibab National Forest for the area north of the Grand Canyon, July 21, 1908. By Act of Congress, February 26, 1919, the Grand Canyon National Park was created and made to include approximately the southern fourth of the plateau. In 1927 an additional 46,000 acres (18,600 hectares) was added to the national park from the national forest area. The present area of the national park north of the Colorado River is approximately 346,000 acres (140,100 ha.) and of the Kaibab National Forest, north of the Colorado River, 706,000 acres (285,800 ha.).

DEER HERD

The history of the deer herd since the establishing of the game preserve in 1906, up until the early 1930's, has been a story of conflicting interests, associated with a general misunderstanding of true field conditions.

The story of the population change as interpreted at the present time is: with the creation of the game preserve, the killing of deer was prohibited. At the same time there was a marked decrease in numbers of domestic sheep, grazed on the area. From 1906 to 1923 government hunters were employed in killing predatory mammals. During the period 1906 to 1931, 781 mountain lions, 30 wolves, 4,889 coyotes, and 554 bobcats were trapped or shot (Fig. 5, II). Total

removal 1906 to 1939 inclusive has been 816 mountain lions, 30 wolves, 7,388 coyotes and 863 bobcats. The removal from 1931 to 1939 inclusive has been by hunting lions for sport and coyotes and bobcats for fur. This resulted in extermination of wolves and definite reduction in other species. The decrease in competition for forage, the check on natural enemies and the prevention of killing by man caused an increase in the deer herd in this ideal deer range. The deer's habits and the topography of the country prevented a scattering of deer to adjacent ranges. The increase was allowed to go on without check for sixteen years, until the estimated 4,000 of 1906 had

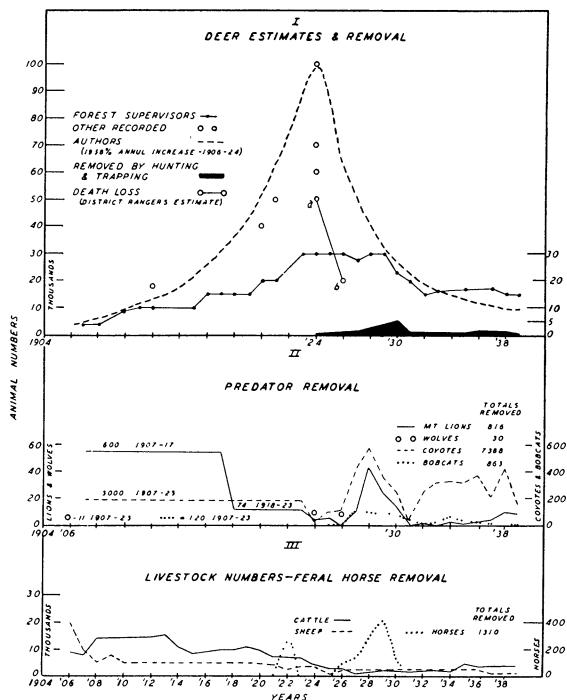


FIG. 5. Estimated numbers of deer and removals; predator removal; livestock numbers and feral horse removal, Kaibab Plateau, Arizona. I shows: forest supervisors' estimates of deer numbers recorded in their annual reports based on general estimates previous to 1930, since 1930 based on organized winter counts; also estimated numbers obtained from reports of men visiting the Kaibab Plateau to make observations on the deer. The death loss of 1924-26, record (line a—b) is based on a report by United States Forest Service Ranger Benjamin Swapp, who was in charge of the area where the deer died. The broken line represents an estimated population trend from 4,000 deer in 1906 to near 100,000 in 1924. This represents an accumulative annual increase of 19.58%. Following 1924 a decrease took place due to the die-off, until there was an estimated 20,000 in 1931, and less than 10,000 in 1939. The shaded portion indicates the total removal from hunting, trapping, and fawn removal during the period. II gives record of predator removal in the period 1906-39. No lions and very few coyotes were removed in 1931, although trapping for fur and hunting of mountain lions for sport has continued since that date. III shows number of livestock permitted on the area from all available Forest Service records and the number of feral or wild horses removed by hunting during the period of 1922-39 inclusive.

become an enormous herd of near 100,000 in 1924. The peak was reached, the range depleted, and the deer population started downhill. There were deaths by thousands from malnutrition and related causes. In 1924 hunting was permitted on the national forest, and an average of near 1,000 deer was removed each year for five years, then 4,400 in 1929, and 5,033 in 1930. During this time the herd decreased to an estimated 20,000. The range had been so severely damaged that 20,000 was an excessive population from the standpoint of condition of forage species. The herd has continued to decrease slowly until an estimated 10,000 were present in 1939.

Figure 5 shows the numbers of large mammals and removals from the Kaibab Plateau for the period 1906 to 1939. I shows the forest supervisor's estimates of deer numbers, recorded estimates of deer numbers from other observers, author's estimate, and hunting removal. The curve extending from 4,000 in 1906 to 100,000 in 1924 equals an annual accumulative increase of 19.58 percent. In the period previous to 1931 a total of 17,844 deer were removed as follows: 13,576 by sportsmen hunting, 1,124 hunting by government employees, 674 by trapping, and 2,470 caught as newly born fawns; 9,372 deer have been removed by sportsmen hunting in the period 1931 to 1939 inclusive.¹ II shows the number of mountain lions, wolves, coyotes, and bobcats removed from the area. III shows the number of sheep and cattle permitted on the area and the number of wild or feral horses killed.

The combination of a national game preserve and a national forest covering the same area and set apart before the creation of the state in which it is located, created a unique situation in administration. The United States Forest Service was in control of the major part of the area and initiated a game management program for their area, although one point in dispute with the State of Arizona (regarding the right to kill deer on that area) was taken to the United States Supreme Court. That Court ruled the Forest Service had the right to remove deer and under this ruling they conducted the so-called "government killing" in December, 1928. Six hundred and seventy-six does and 448 bucks were killed at this time by Forest Service officials following the regular hunt.

The southern end of the plateau is included in the Grand Canyon National Park and neither trapping nor hunting of deer has been allowed on this area. Objections were raised to hunting near the park because the park boundary was not a barrier to deer movement.

Range damage by deer was first recognized by Forest Service officials in 1918 in the Forest Supervisor's report. The first of many investigations was made in April, 1920, by S. B. Locke, then of the United States Forest Service. A memorandum of

this visit is the first definite record of the maladjustments within the area. The problem of overpopulation of deer, however, was entirely new at that time. Knowledge of the habits and life history of deer and their relationship to other animals and to the forage was very meager.

A criticism of lack of knowledge of the Kaibab deer herd was made by Hough ('22), a journalist, in his impression of the Kaibab, and at that time this appeared as a justifiable criticism of both the state and several federal agencies concerned with the area. This was reflected in the very definite difference of opinion between personnel of the agencies as to what the true situation was and what should be done about it.

The necessity of limiting deer numbers was first realized by the Forest Service officials. When the information was made public, a storm of protest arose, mostly based on preconceived prejudices and misunderstandings. The very unusual appearance of many hundreds of these animals in the high meadows during the summer was a sight that could not be duplicated. Interference in any way with this scenic attraction was strongly objected to. Unfortunately, the facts in the matter were not understood nor accepted by all individuals and certain individuals spoke with authority about the area on the basis of a hurried trip along the summit of the plateau in summer. Many thought the reports of conditions to be exaggerated because they were given by a group whose major interest was believed to be the vegetation, and those interested solely in the display value failed to see the complex and far-reaching effect of maintaining such a large herd of deer.

An example of an observer not directly concerned with the controversy, but appreciating the seriousness of the conditions, was contained in a report on the area by George Shiras, III ('24), a naturalist who had wide experience in the study of deer, elk, and moose, and who, concerning a visit to the Kaibab in September, 1923, says, "Never before have I seen such deplorable conditions," and "but one conclusion could be reached, that from 30,000 to 40,000 deer were on the verge of starvation both in their summer and winter range." This statement was verified by the estimated loss of sixty percent of the total herd in the winters of 1924-25 and 1925-26 as estimated by Ranger Benjamin Swapp (Fig. 5, I, line a—b), the individual best acquainted with winter conditions at that time. (Forest Supervisor's Report of 1926.) And at this same time there were very serious objections raised by well-meaning individuals to removal of any of the animals from this area.

Two committees of non-Forest Service men, appointed by the United States Secretary of Agriculture, made investigations in 1924 and again in 1931. They were present for ten days each time, covered the plateau thoroughly and left complete records of conditions. In each case, the seriousness of the situa-

¹ The hunting removal by sportsmen since 1930 has been: 1931, 965; 1932, 640; 1933, 859; 1934, 1,035; 1935, 874; 1936, 1,433; 1937, 1,456; 1938, 1,395; 1939, 715; from United States Forest Service Records.

tion and the depleted conditions of the range were definitely recognized.

It is not believed that the controlled hunting on the National Forest has been the major cause of the great reduction in deer numbers. The greatest decrease took place before this could have been effective. Also, examination of winter ranges definitely indicates that the reduction occurred on the national park portion of the plateau, where no hunting was allowed, as well as on the national forest (Fig. 5).

The Kaibab deer herd has, however, focused attention to the problem of maladjustments in numbers of large native mammals. It can be credited with creating much interest in these problems and influencing the recent establishment in both the National Park Service and Forest Service of administrative divisions to study and act on such problems.

The problem of handling the Kaibab deer herd is not entirely solved at the present time. The existence of the one herd of deer on an area administered by two federal agencies which have distinct objectives and procedures will no doubt always result in certain differences. One of these agencies has as its major objective the preservation of natural conditions on the area under its control and this calls for a program of exclusion of domestic livestock, and protection of all the native animals. Thus no hunting or trapping of either deer, their predators or other animals of the area is permitted. The other agency has as its primary objective the management of the deer herd on the area under its control. This management program is to correlate deer numbers with the forage yield of the range, maintaining of a deer herd for its scenic value, to conduct a program of utilization by sportsman hunting and to correlate some use of the range by livestock with use by deer.

The dividing of the top of the Kaibab Plateau into two independent units from which there is no movement back and forth by the larger animals, either seasonally or year-long, appears to be impossible. On the basis of the present study the boundary established in 1928 between the Grand Canyon National Park and the Kaibab National Forest, although faulty in certain respects, approaches the aim of dividing the area into two fairly independent biological areas.

EXIRPATED AND INTRODUCED MAMMALS

The existence of areas that contain samples of all original fauna and flora are extremely rare, and the Kaibab is no exception in lacking some of the original larger species of animals. A list of names of mammals, birds, reptiles, and amphibians is given in the appendix of this paper.

Formerly the timber wolf occurred in limited numbers. The area appears to be well suited for this animal, but the existence of a small band of less than a dozen individuals was its status for many years. One of the local residents, well acquainted with early conditions, reports that during the early

years of use of the Kaibab by livestock wolves killed a few cattle but they ate many more deer than cattle.

There are only four reported records of bear on the entire plateau in a period of at least eighty-five years, yet bear have always been present and are still found in southern Utah. Of these, three were *Euarctos americanus*, two black and one brown. All were killed on the summit of the plateau. According to reports believed to be authentic, a grizzly bear was killed by an Indian boy in South Canyon on the east side of the plateau about eighty-five years ago. This is the only record of this species reported by either Indians or whites.

The pronghorn antelope was formerly common in the grassland adjoining the plateau, but was exterminated soon after occupation of the area by white men.

Feral or wild horses have always been present on the Kaibab since the area was first used by domestic stock. The early cowboys claim they were not present before that time. Their number has been regularly added to by tame horses turning wild, and a few have been captured each year by cowboys. During the period from 1922 to 1931, 1,310 of these animals were killed on the National Forest in an effort to increase amount of food available for domestic livestock and deer (Fig. 5). In 1931 it was estimated that there were 200 remaining. These are among the most elusive of the wild animals of the plateau.

Feral burros were responsible for damage to native plants within the Grand Canyon, and elimination of several hundred individuals was deemed necessary by the National Park Service during the early 1930's.

Bison have been introduced into Houserock Valley on the east side of the plateau within recent years. The area there appears to be well suited to them, and they are making a rapid increase. There are no reports or records, however, of their former occurrence in this area.

IV. METHODS, SCOPE OF WORK, AND ACKNOWLEDGMENTS

METHODS

The field work on which this study is based was carried on during June, July, and August of 1929, 1930, and in all months of 1931, except January and December. Intensive studies were carried out at five stations in typical plant communities:

- (A)—Piñon-juniper area, north end of plateau, un-browsed by deer.
- (B)—Piñon-juniper area, west side of plateau, very heavily browsed by deer.
- (C)—Yellow pine area, near Jacob's Lake, slightly browsed by deer.
- (D)—Yellow pine area, near Dry Park, very heavily browsed by deer.
- (E)—Spruce-fir area, near VT Park, very heavily browsed by deer.

Major quadrats of 2.50 acres (1 hectare) in area were established at these stations and were used as

bases for comparisons of the plants and animals of various areas. Random quantitative and qualitative samplings were made, supplemented by observations and cruising. The entire plateau was covered in a general reconnaissance in order to understand and correlate the findings of the smaller areas.

Collections of the invertebrate population were made from the ground surface, herbs, shrubs, and trees. In the collections from ground surface a metal cylinder, closed at one end, was used. This was 14.13 inches (36 cm.) in diameter and thus equaled 1/40,000 of an acre, or 1/100,000 of a hectare (King, '27; Bird, '29). In the other strata a sweep net was used. The methods were essentially the same as those of Weese ('24), Smith ('28), Shackleford ('29), and Bird ('29). The unit used here was fifty sweeps of an insect net of 30 cm. in diameter. Thus, a maximum unit collection consisted of fifty sweeps in trees, fifty sweeps in shrubs, fifty sweeps in herbs, and 0.1 m² of ground surface, including the needles and leaves. In the piñon-juniper the trees and shrubs were swept together. In the tabulation of data fifty sweeps were taken as representing the amount of life per square meter in the herb, shrub, and tree strata. Collections were made fortnightly, as nearly as possible. The circuit of the stations, however, exceeded one hundred and fifty miles, which was a limiting factor in this respect.

In the study of vertebrate numbers, considerable difficulty was experienced in arriving at numbers per unit area. A number of the methods reviewed and suggested by Taylor ('30) were used.

Practically each species of mammal called for a different technique in the estimation of population. The smaller nocturnal rodents and some nocturnal carnivores were obtained only by trapping. Golden mantled and antelope ground squirrels and chipmunks were trapped and counted by area counts. Use was made of staked areas and observations in early morning at time of their greatest activity. Presence of woodrats was indicated by the very obvious "rat sign" and trapping was used to check on numbers. The Kaibab woodrats' nests were easily seen and proved a reliable index of the rat population. Jack and cottontail rabbits were counted over large areas, and a number of pellet counts were made in definite small areas to determine relative abundance. Chickaree and Kaibab squirrel numbers were obtained by area counts. Signs of mammals were utilized in determining both relative numbers and distribution.

Many counts were made of Kaibab squirrels observed per mile along the highways and the numerous motor trails in the open stands of yellow pine. These counts showed remarkably uniform results when time of day and weather conditions were comparable. Maximum counts were obtained in very early morning, although evening counts gave very similar results.

Mule deer were seen in numbers of a few to several hundreds of individuals each day. Summer

counts were conducted at various locations in the forests and open meadows or parks of the summer range. Regular morning and evening sex counts of deer visiting the open parks were made. The 1930 and 1931 total of these counts for the VT Park was 13,972 deer tabulated. These counts and the presence of tracks gave definite information on numbers and relative abundance in the various areas at different seasons. The presence of shed antlers gave information concerning distribution of bucks at the season the antlers are shed (usually February) on areas difficult to visit at that time.

Coyotes were often seen, heard, and tracked. Bobcats were tracked and a few individuals observed. Cougars, under natural conditions, were in evidence by "sign" only.

An estimate of the numbers of the more important birds was gained by counting singing males over definite areas. The relative abundance of birds apparently was best shown by use of the unit of time method of Grinnell and Storer ('24), with the modification of a unit of space as suggested by Dice ('30).

Tabulation of animal life of an area to obtain a reliable estimate of numbers involved is fraught with many difficulties. The variations in animal activities, different degrees of shyness, and many other factors are present. Estimates and counts by present methods may be filled with error, yet in population studies the statement, "the more strictly quantitative the work is, the better it is likely to be" (Shelford, '30), should be heeded.

In all censuses the large number of animals that were limited in their distribution by local habitat conditions was kept in mind, and in any area summaries corrections were made for this factor.

Calculations of areas were based on planimeter readings made from a United States Geological Survey map upon which was charted the major plant communities. Total animal numbers were calculated by a similar method.

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I wish to acknowledge the assistance given by the following specialists without whose help and cooperation it would have been impossible to identify the material collected: Dr. R. V. Chamberlin, University of Utah (Chilopoda, Diplopoda, spiders); Dr. A. E. Emerson, University of Chicago (termites); Dr. M. R. Smith, A. and M. College, Mississippi (ants); Dr. Lee H. Townsend, University of Kentucky (ants); Dr. H. H. Ross, University of Illinois (saw-

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V. GENERAL COMMUNITY RELATIONSHIPS

The Kaibab Plateau, although surrounded by mile-deep canyons, desert grassland, or sagebrush plains, is almost entirely covered with trees. It has an extensive pygmy forest (piñon-juniper woodland) of *Pinus edulis*² and *Juniperus utahensis* extending around its edges and occurring at the lower elevations on the plateau summit. Above this is an area of nearly a pure stand of Rocky Mountain yellow pine, *Pinus brachyptera* (yellow pine consociation) extending as a belt around the summit of the plateau. This belt, although narrow at the southeastern border, is from 8 to 15 miles (13 to 25 km.) in width at the north and west sides. A large amount of Rocky Mountain quaking aspen, *Populus aurea*, is present in the upper half of this community.

The highest portions of the plateau are covered with a mixed coniferous forest of spruces, *Picea pungens* and *Picea engelmanni*, and firs, *Abies concolor*, *Abies lasiocarpa*, and *Pseudotsuga taxifolia*, with an interspersion of aspen. This montane forest, although definitely delineated and fairly uniform where it occurs, can hardly be referred to in its entirety as either the Petran montane forest, *Pinus-Pseudotsuga* association, or the Petran subalpine forest, *Picea-Abies* association, of Weaver and Clemens ('29). It contains the characteristic species of both these climaxs.

A series of open parks or meadows occur on the summit of the plateau. These level areas are surrounded by montane forest, but contain only herbs and grasses.

Figure 6 shows the distribution and relative abundance of the dominant tree species on the plateau in relation to their occurrence at different altitudes. This is based on the number of trees with a d.b.h. (diameter breast height) of two inches (5.0 cm.) or over. Shrubs are not included in this comparison as they dominate only in very local situations.

There are, however, a series of discontinuous areas where scrub oak, *Quercus utahensis*, is dominant. These are situated, usually, at the border between the piñon-juniper and yellow pine communities and

an average elevation of 6,800 to 7,000 feet (2,075 to 2,130 m.), on the steeper canyon walls and the plateau border. This Petran chaparral association fragment supports a relatively high population and variety of vertebrates and is considered in the vertebrate distribution study. The presence of the scrub

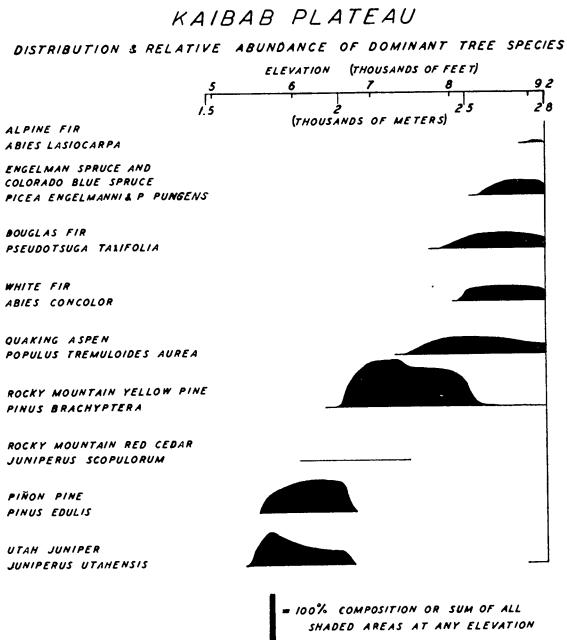


FIG. 6. Distribution and relative abundance of dominant tree species, Kaibab Plateau, Arizona. Total width of all shaded areas at any designated elevation equals 100% or total number of trees present.

oak alone, however, does not explain the distribution of these animals, and there are definite indications that the presence of cliffs, ledges, and steep canyon walls, occurring in much of the area where the oak and associated shrub species are found, is more important in providing favorable habitat conditions than the specific vegetation. Its presence on areas showing a steeper gradient than any other plant community on the Kaibab gives it undue emphasis when considered only from the altitudinal differences.

Table 2 shows a comparison of previous classifications of the vegetation of northern Arizona and plant distribution on the Kaibab Plateau. In the present discussion the forest above the piñon-juniper woodland is collectively referred to as the montane forest, and the distinctions between the yellow pine and mixed coniferous or spruce-fir forests are not considered marked enough to indicate different formations. This is based primarily on the fact that the distribution of the vertebrates on the Kaibab Plateau does not indicate two biotic communities of major importance. The vegetation has certain common characteristics (all is coniferous forest of very similar sized trees); has comparable subclimax stages (presence of aspen and forest parks in both communities);

² See appendix for the complete names of plants.

and the majority of vertebrate species and individuals present are not typical of either community.

Figures 7 and 8 show the distribution of mammals and amphibians and reptiles on the plateau. Table 3 gives the distribution and breeding records of birds.

TABLE 2. Plant communities compared with previous classifications of the vegetation of Northern Arizona.

(Elevation in feet)

Kaibab Plateau	Clements (1920)	Shreve (1917)	Pearson (1920)	Merriam (1890)
Summit of Plateau				
9200 Mixed coniferous (Spruce-fir) 8200-9200	Sub-alpine forest climax	Alpine summits	Alpine zone above 11,500	Alpine zone above 11,500
MONTANE				
FOREST Yellow pine 6800-8200	Montane forest climax	Northern mesophytic evergreen forest	Engelmann spruce 9500- 11,500	Sub-alpine or timber- line zone 10,500- 11,500
Woodland climax 5500-6800	Woodland climax	Western xerophytic evergreen	Douglas fir 8300-9500	Hudsonian or spruce zone 9200- 10,000
Grassland climax 4000-5500	Sagebrush climax 4500-5500	Grassland climax	Desert grassland climax	Canadian or balsam fir zone 8200-9200
				Neutral or pine zone 7000-8200 (Trans- ition)
				Piñon- juniper 5000-6700
				Piñon zone 6000-7000 (Upper Sonoran)
				Desert area 4000-6000 (Sonoran)

The mule deer (Fig. 7) summers and rears its young in the chaparral, yellow pine, and spruce-fir communities and winters in the piñon-juniper woodland. The selection is not indiscriminate, however, as the yellow pine is preferred by the does at the time fawns are born. Even with the presence of grassland, sage, and desert scrub communities within a short distance of the winter range, there is no marked movement of deer to these areas. The ranges of the coyote, the porcupine, and the most abundant animal of all, the tawny white-footed mouse, are not limited to any plant community or subclimax stage. This is also true of the two most abundant birds, the western chipping sparrow, the red-shafted flicker, and the most abundant reptile, the horned toad. In each case abundance is not uniform and some one or more communities are the regions of greatest abundance, either seasonally or year-long.

KAIBAB PLATEAU

DISTRIBUTION OF MAMMALS

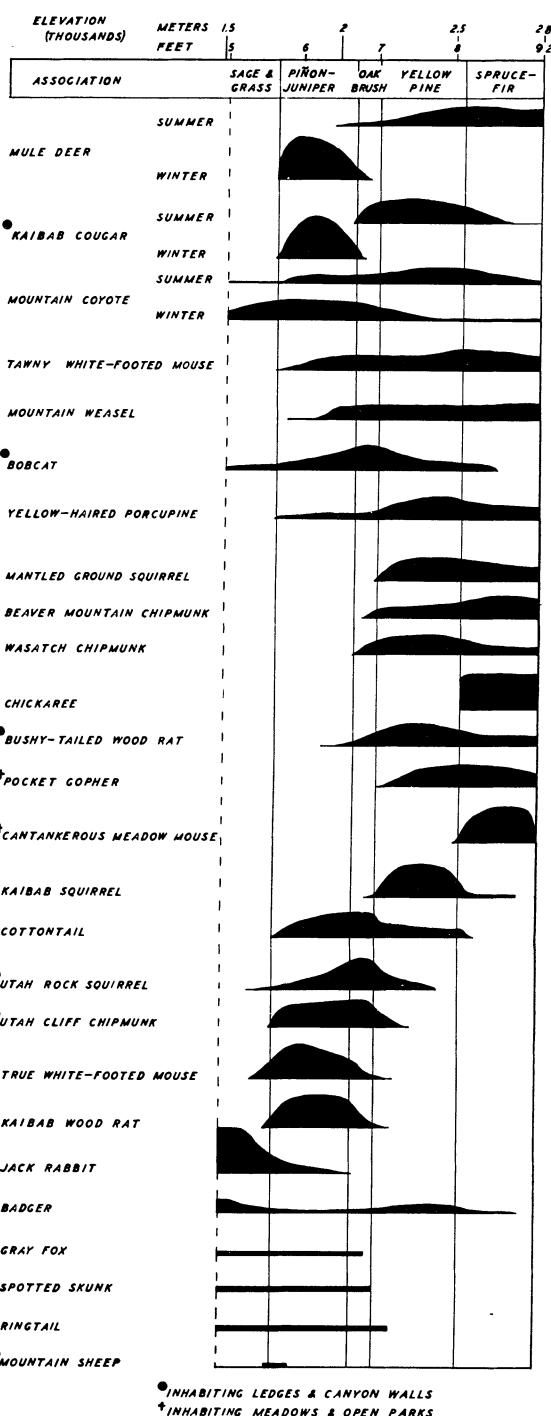


FIG. 7. Distribution of important and abundant mammal species, Kaibab Plateau, Arizona. Shaded areas for each species are of equal size (except four minor species) and represent total population and relative distribution on the plateau.

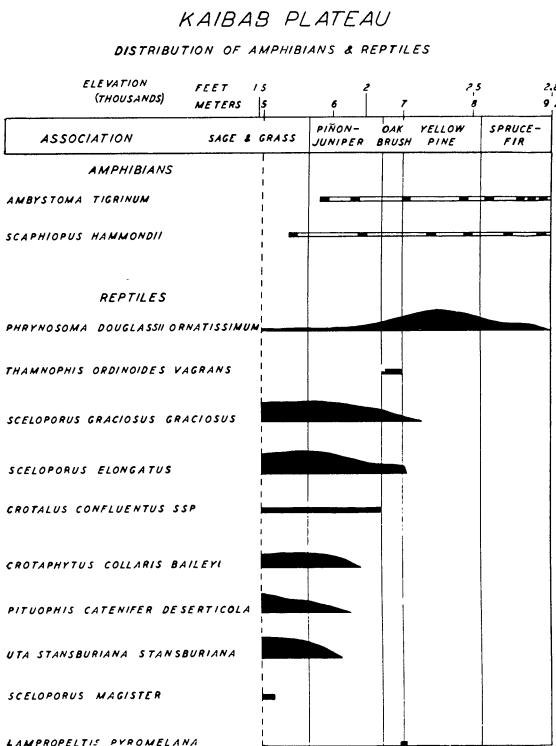


FIG. 8. Distribution of amphibians and reptiles on Kaibab Plateau, Arizona.

In the distribution of many smaller animals, numerous breeding birds and a large number of invertebrates, the plant communities are definitely recognized by the animals. They and the plants make up typical biotic communities of climax and seral rank. These are often greatly influenced by other vertebrates which ordinarily range over more than a single community. Such exceptions and irregularities do not invalidate the concept of a biotic community, but the criteria used in defining plant communities where dominants are sessile and the boundaries usually quite distinct, do not entirely suffice in the case of animals.

A continued, detailed study of plant communities, as such, leads to further divisions and consideration of smaller areas as distinct vegetational units. A study of the distribution of the larger and more influent animals, especially those of major importance (Major Influents) that exist at present only in limited areas and in unsettled regions, leads to the recognition of larger and more extensive units. A study of animal distribution of the Kaibab Plateau raises serious question regarding the rank of certain recognized plant formations as being true biotic formations, i.e., "biomes."

Four major biotic communities are recognized on the plateau, namely:

1. The *Pinus-Juniperus-Neotoma* association of the woodland climax

TABLE 3. Kaibab Plateau birds. Distribution of permanent and summer residents in relation to major plant communities. *, permanent residents; parallel line, abundant or common during breeding season; x, sparse and spotted distribution; N, nesting record; Y, juvenile (too young to have traveled far from nest). Average elevation of lower border of piñon-juniper is 5,500 feet, plateau summit is 9,200 feet.

Elevation	Ave. 5,500 feet (1,675 m.)	Max. 9,200 feet (2,800 m.) →			
Plant Community	Sage-brush	Piñon-Juniper	Oak-brush	Yellow pine	Spruce-fir
Turkey Vulture	x	x	x	x	x
*Western Goshawk	=====	=====	=====	x N x	x x x
*Sharp-shinned Hawk	=====	=====	=====	=====	=====
*Cooper's Hawk	x	x	x	x	x
*Western Red-tailed Hawk	x	=====	N	=====	N N
Swainson's Hawk	x	x x	=====	=====	=====
*Prairie Falcon	x	x	x	x	x
*Ferruginous Rough-leg	x	x	=====	x	=====
*Golden Eagle	x	x	x	x	=====
Desert Sparrow Hawk	=====	=====	=====	=====	=====
*Dusky Grouse	=====	=====	=====	x	Y Y
*Gambel's Quail	x	N x	=====	=====	=====
Band-tailed Pigeon	=====	=====	x x x	=====	=====
Western Mourning Dove	=====	=====	N	=====	=====
*Horned Owl	=====	x x	x	x	x
Nuttall's Poor-will	=====	x	=====	=====	=====
Night Hawk	=====	N	=====	=====	=====
White-throated Swift	x	x	x	x	x
Rufous Hummingbird	=====	=====	x	x	x
Broad-tailed Hummingbird	=====	=====	x	x N x	x x
Black-chinned Hummingbird	x x x	x x	=====	=====	=====
*Red-shafted Flicker	N	=====	=====	N N	N N N
*Lewis Woodpecker	=====	x	=====	x N	x
Natalie's Sapsucker	=====	=====	=====	NNNN	NNNN
*White-breasted Woodpecker	=====	=====	=====	=====	N N N
*Batchelder's Woodpecker	=====	x	x	=====	x
*Alpine Three-toed Woodpecker	=====	=====	=====	=====	x N x N
Ash-throated Flycatcher	*	x	x	x	N x
Wright's Flycatcher	=====	=====	=====	=====	=====
Western Wood Pewee	=====	=====	=====	x x	N
Olive-sided Flycatcher	=====	=====	=====	=====	=====
Violet-green Swallow	=====	=====	=====	N N	N N N
Northern Cliff Swallow	x N x	x NN x	=====	=====	Y
*Long-crested Jay	=====	=====	=====	=====	=====
*Woodhouse's Jay	Y	=====	=====	=====	=====
*American Raven	x	x	=====	x x x	=====
*Piñon Jay	=====	=====	=====	=====	=====
*Clark's Nutcracker	=====	=====	x	x N	x x
*Mountain Chickadee	=====	=====	N	N N	=====
*Gray Titmouse	=====	N N	=====	=====	=====
*Lead-colored Bush-Tit	x x	=====	=====	N N	x x
*Rocky Mountain Nuthatch	=====	=====	=====	=====	=====
*Red-breasted Nuthatch	=====	=====	=====	=====	x x
*Pygmy Nuthatch	=====	=====	=====	N N N	=====

TABLE 3. (Continued)

Elevation.....	Ave. 5,500 feet (1,675 m.)	Max. 9,200 feet (2,800 m.)	→		
Plant Community.....	Sage-brush	Pifon-juniper	Oak-brush	Yellow pine	Spruce-fir
*Rocky Mountain Creeper				x x x	x
Western House Wren.....			N x	N x	
*Cactus Wren.....	x	x x x	x x	x x x	
*Rock Wren.....	x	x N x	x	x	
Sage Thrasher.....	x				
*Western Robin.....		x x x	x x	N	N N N
Audubon's Hermit Thrush.....					N
Chestnut-backed Bluebird.....			x	N N	x
*Mountain Bluebird.....		x N x	N N	x x x	NNNN
Townsend's Solitaire.....				x	x x
Western Gnatcatcher.....			x		N N
Western Ruby-crowned Kinglet.....					
Shrike.....	x	x x	x		
Plumbeous Vireo.....		x x	x x	x Y x	N
Western Warbling Vireo.....				N	N N
Virginia's Warbler.....				x x	
Audubon's Warbler.....				N	
Black-throated Gray Warbler.....		Y Y	x x		
Grace's Warbler.....				x Y x	
Macgillivray's Warbler.....				x	x
Cowbird.....	x	x	x		
Western Tanager.....			x	x x x	x x x
Rocky Mountain Gros-beak.....			Y	x x	
Lazuli Bunting.....	x	x	x		
Western Evening Gros-beak.....					N Y
*Cassin's Purple Finch.....					N
*Pine Grosbeak.....				x	
*Pine Siskin.....				x x x	N
Pale Goldfinch.....					x
Green-backed Goldfinch.....	x	x x	x		
*Crossbill.....				x x	x x x
Green-tailed Towhee.....	x	x x	x x x	x	
*Spurred Towhee.....	x	x			
Western Vesper Sparrow.....			x		
Western Lark Sparrow.....	N	x	x		
Desert Sparrow.....	x				
Northern Sage Sparrow.....	x				
*Red-backed Junco.....				x	N N
Western Chipping Sparrow.....		N	N	N	N
Brewer's Sparrow.....	N	x			
White-crowned Sparrow.....				x	x N x x
*Mountain Song Sparrow ..				x	x

2. The *Pinus brachyptera-Sciurus kaibabensis* association of the montane forest climax
3. The *Picea-Abies-Sciurus fremonti* association of the montane forest climax
4. The *Stipa-Carex-Thomomys* associes or mountain grassland.

Adjacent to the plateau are extensive areas of short-grass grasslands, both on the east and west, Basin sagebrush toward the north and northwest, and canyon desert scrub in the canyons bordering the plateau on the south and southwest.

VI. THE WOODLAND CLIMAX THE *Pinus-Juniperus-Neotoma* ASSOCIATION

GENERAL

The piñon-juniper woodland forms a characteristic association, arranged as a belt below the yellow pine forest, throughout the southern Rocky Mountains. It attains its greatest areas in Utah, Colorado, Nevada, Arizona, and New Mexico. Only a few areas are

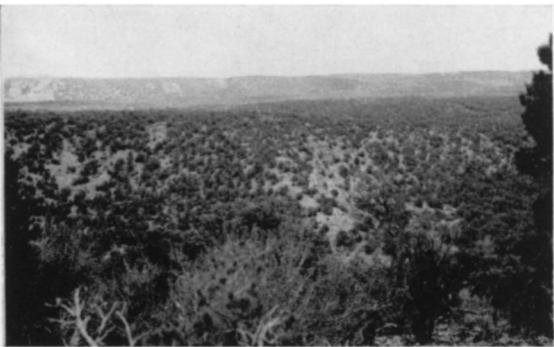


FIG. 9. Characteristic view of the woodland climax (*Pinus-Juniperus-Neotoma* Association).

found north of latitude 44° (Fig. 9). On the Kaibab Plateau this belt is usually found between 5,500 and 6,800 feet (1,675 and 2,075 m.). There is the usual extension of the upper limits on exposed southwestern slopes, occurring often up to 7,250 feet (2,200 m.), and the downward extension on the cool north and northeastern slopes where the upper limits may be 6,500 feet (1,980 m.), the lower limits as far down as 5,000 feet (1,525 m.).

In this woodland or "pigmy forest" the trees do not ordinarily form solid stands, but are scattered with intervening spaces of grass, sage or other shrubs, depending upon location. The trees do not usually attain a height of more than twenty to thirty feet (6-9 m.). They branch from near the ground and are very often nearly as broad as tall. Only in the bottom of draws and toward the upper limit of the association do the trees grow closely enough together to cast a continuous shade.

Throughout the Great Basin and adjacent areas trees of this woodland are usually intermingled with

sagebrush, *Artemesia tridentata*. The sage occupies the more level ground with deep soil and the piñon-juniper occurs on shallow rocky soils and rough, broken country.

On the Kaibab Plateau this association has its greatest width on the north, west, and east slopes, where it varies from four to twelve miles (6-19 km.). Along the south it is confined mainly to the upper slopes within the Grand Canyon and the lower and more exposed portions of the rim. The association is isolated from similar vegetation with exception of the extreme northeast end, where there is a slight break and the same type exists to the northeast. This association fragment covers an area of 435,000 acres (176,000 ha.).

The two stations selected for study in this community were similar in taxonomic composition and appearance, but one, A, was near the north end of the plateau, located on the top of a flat north-south ridge in Section 30, Township 39 N, Range 1 E at 6,000 feet (1,830 m.) elevation; while the second, B, was located towards the western side of the plateau on top of a flat east-west ridge in Section 35, Township 37 N, Range 2 W, at 5,800 feet (1,770 m.) elevation. Their greatest observable difference was that station B and its vicinity had been severely overbrowsed by the deer, while station A was only slightly browsed by them.

VEGETATION

The dominant plants are the two trees, the piñon, *Pinus edulis*, and cedar or juniper, *Juniperus utahensis*. These occur in a fairly even ratio over large areas. The piñon, however, reached its maximum development at a slightly higher elevation than the juniper. Near the upper limits of the association these characteristic trees become less abundant, but of good size, and then gradually give way to the first of the yellow pine. Some local areas have a narrow portion of Petran chaparral, oak-brush climax, forming a belt between the two major forest communities.

Considerable variation is shown in the vegetation of the understory in this association. Blue grama grass, *Bouteloua gracilis*, is the most abundant and widespread of the plants, forming in many places practically the only other abundant plant besides the dominant trees. It attains its greatest abundance in the lower half of the association. This is especially true of the eastern borders, where the piñon-juniper is bordered by an area of grassland, in which *B. gracilis* is the dominant plant. This relationship differs from the distribution of the same species in the region near Flagstaff, Arizona, where Hanson ('24) reports "*B. gracilis* was near its limit of xerophytism in the lower part of this (piñon-juniper) association." Towards the north the most important dominant is sagebrush. Finger-like projections extend up into the piñon-juniper community from the plains below. The sagebrush is gradually

replaced until it is practically absent at the upper limits of the community.

Cliffrose, *Cowania stansburiana*, is abundant and generally distributed throughout the association. Although ordinarily a shrub, showing considerable branching and spreading, and growing from five to ten feet high (1.5-3 m.), it is not uncommon on the Kaibab for it to form small trees from fifteen to twenty feet (4.6-6.1 m.) in height. There is some extension of this species into the yellow pine, but maximum development is in the piñon-juniper. It is of extreme importance because it is the most important single winter deer food. Some areas have not been damaged by severe browsing. Others, for example, on Sowats Points at the extreme western edge, where Cowania was the most abundant of all the shrubs and trees, have been so badly overbrowsed that at the time of study only 10 to 20 percent of these plants had survived, and most of the growing portions of these individuals were beyond the reach of the deer (Fig. 10).



FIG. 10. (a) Picture of dead *Cowania stansburiana* and highlined *Juniperus utahensis* (right) within the piñon-juniper community. Results of over-utilization by deer. (b) Closer view of dead Cowania.

Subdominant shrubs of general occurrence are: *Amelanchier alnifolia*, *Quercus utahensis*, *Ephedra viridis*, *Yucca baccata*, and *Chrysothamnus* sp.

Subdominant shrubs of local importance are: *Purshia tridentata*, *Cercocarpus ledifolius*, *Artemesia nova*, *Fallugia paradoxa*, *Coleogyne ramosissima*, *Quercus turbinella*, *Atriplex confertifolia*, *Opuntia basilaris*, and *Forsellesia* sp.

Subdominant herbs and grasses are: *Gilia*, *Artemesia mexicana*, *Solidago petradoria*, *Pentstemon* spp., *Calochortus nuttallii*, *Sphaeralcea marginata*, *Oreocarya* sp., *Hymenopappus lugens*, *Erodium cicutarium*, *Oryzopsis hymenoides*, and *Sporobolus* sp.

Table 4 gives sample counts showing number of the larger plants per 1/20 acre (1/50 ha.), on basis of sample plots in the lower, middle and upper portions of the association. The counts were made near station A at the northern end of the plateau.

TABLE 4. Showing the number of larger plants per 1/20 acre (1/50 ha.) within the piñon-juniper woodland. Sample plots located near the lower middle and upper portions of the community. Percentage of cover refers to estimated amount of herbaceous cover on the ground.

	<i>Lower</i>	<i>Middle</i>	<i>Upper</i>
<i>Pinus edulis</i>	9	15	8
<i>Juniperus utahensis</i>	11	10	6
<i>Cowania stansburiana</i>	3	7	11
<i>Ephedra viridis</i>	4	0	0
<i>Odostemon fremontii</i>	1	0	0
<i>Opuntia acanthocarpa</i>	1	0	0
<i>Opuntia basilaris</i> ?.....	4	1	0
<i>Yucca baccata</i>	1	4	0
<i>Artemesia tridentata</i>	67	16	7
<i>Echinocereus coccineus</i>	1	1	0
<i>Amelanchier alnifolia</i> ?.....	0	2	4
<i>Quercus utahensis</i>	0	1	13
<i>Gutierrezia sarothrae</i>	5% cover	20% cover	10% cover
<i>Bouteloua gracilis</i>	30% cover	10% cover	5% cover

MAMMALS

The native mammals of major importance, major influents, within the piñon-juniper formation are limited only rarely to this definite plant community in their year-long and breeding distribution. They are the Rocky Mountain Mule Deer, Mountain Lion, Mountain Coyote, and Plateau Bobcat. Figure 7 shows the distributions of more common vertebrates on the area.

The most important animal of herbivorous habits, and the animal the region is famous for, is the Rocky Mountain Mule Deer. All parts of the plateau are visited by this animal, and during the three years of intensive study the numbers of deer on the plateau were estimated at: 1929, 30,000; 1930, 25,000; and 1931, 20,000.

The entire herd spends the winter and shows greatest concentration of the year within the piñon-juniper association. The peculiarities of homing habit or unknown stimuli during the fall migration cause the deer to return year after year to certain favorite localities.

They fail to distribute themselves evenly over the desirable range. The result is that some of these localities are nearly destitute of suitable food, while other areas available, but out of the main line of drift, have an abundance of food and are hardly touched. This is in agreement with Clepper ('31, p. 21) who says of the white-tailed deer, found in Pennsylvania, "They are very loath to seek out new feeding grounds. . . . Will remain and live in . . . region on a starvation diet rather than seek out new feeding areas even within a few miles of their home range." And it is in disagreement with Russell ('32, p. 39), who in speaking of the western mule deer, says, "Availability of desirable food is the most important controlling factor in determining range to be occupied by deer at all times."

Deer on the Kaibab Plateau scatter with considerable extension of range to seldom used areas in the late fall and early winter. Later, however, migrations to the concentrated regions take place with all but a few individuals, even from seemingly more desirable areas. The presence of food does not explain the difference, nor does any other obvious reason. The activity, however, is the same year after year.

The deer start entering the piñon-juniper in late September, and by late October a large percentage has usually migrated. In this downward movement there are well-defined migration routes or drift trails, which are very evident following early winter snowstorms. Migrating deer find shelter during severe storms and move as the storm clears or lessens. After an early heavy snowstorm the entire herd goes down on the winter range and subsequent storms will hold it there. However, if the weather clears up, there may be considerable upward movement again until the country becomes entirely snowbound. In spring the upward movement follows closely the clearing of the ground of snow and the availability of forage plants above the piñon-juniper. The majority of animals leave the piñon-juniper within a few days. On the west side of the Kaibab this movement averages near the fifteenth to the twenty-fifth of April.

Censuses of deer numbers were made by riding over winter range and actually counting individuals on sample areas and estimating the total numbers on the basis of area covered. Systematic winter counts to determine total deer numbers on the Kaibab were inaugurated in February, 1930, and have been continued since that time. A count made in February, 1931, by representatives of the United States Forest Service and Park Service, the Arizona State Game Department, and the author, resulted in the actual counting of 2,700 head. A sample area count was made the afternoon of February 23, 1931, in what is called the "Jump-up Pasture," a broad point extending toward Kanab Creek, with an area of 5,000 acres (2,000 ha.). It is bounded by perpendicular cliffs of several hundred feet, except at the north end, which joins the plateau proper. Eight riders counted 436 deer of various ages on this area

or one deer per 11.5 acres (4.65 ha.). This was believed to represent near two thirds of all deer on the area. Assuming that the count represented 66.6%, there was a population of 654 deer or one deer per 7.6 acres (3.1 ha.) or 84 deer per section. This is not an unreasonable estimate if one judges the efficiency of careful range counts of cattle in the southwest. Usually such counts show only 75 to 85 percent of the animals that are secured in the drive-off in the fall.

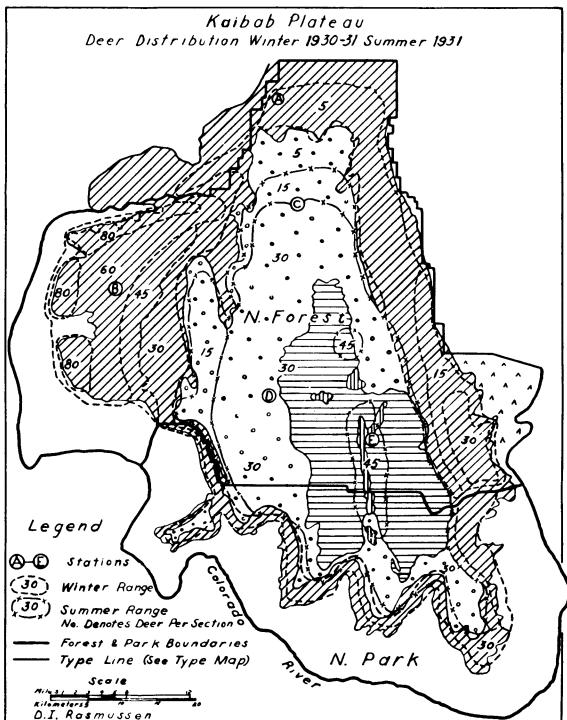


FIG. 11. Numbers and distribution of mule deer on Kaibab Plateau, Arizona. Winter 1930-1931, summer 1931. Numbers within regular broken lines signify numbers per section (640 acres, 260 hectares) in late winter. Numbers within lines broken by crosses signify numbers per section in midsummer. Types are same as on type map, Figure 2.

Figure 11 shows the late winter and mid-summer distribution of deer on the plateau. For the most preferred west-side winter range this figure shows the concentration is approximately 8 acres (3.24 ha.) per deer or 80 deer per section. On the average winter range there are 45 to 60 deer per section or 11.7 to 14.2 acres (4.7 to 5.75 ha.) per deer. In the past the concentration over the entire area is believed to have been four to five times as great.

On the basis of the condition of the vegetation and presence of remains of dead deer it is estimated that at the peak, deer numbers were as abundant as one per acre over several thousand acres of very productive winter range on the points bordering Kanab Creek. This resulted in killing out or "high-lining" of nearly all available forage, including the

unpalatable species, such as piñon pine. On winters following this severe use there was only 5-10 percent as much forage available for deer as on similar but unbrowsed or moderately browsed areas. Marked reduction in winter carrying capacities occurred over all of the heavily used areas, although not as severe as on the above-mentioned area.

The area of the northern end of the plateau and along the eastern border to Kane supports a few deer. Late winter investigations showed that there were about five or fewer deer per section, or 128 acres (52 ha.) per deer. In the late fall and early winter (Oct. 1-Jan. 1) the area often supports three to four times this number.

A concentration area is present on the east side of the plateau in the neighborhood of South Canyon and the north slope of Saddle Mountain. This is of interest in the history of the Kaibab deer, because on December 16, 1924, a small area of this range was to furnish not less than 3,000 or more than 8,000 head of deer for the celebrated deer drive across the Colorado River, these to be delivered at the south rim of the Grand Canyon at the cost of \$2.50 per deer. At that time deer were extremely abundant and many thousands were observed ahead of the 125 whites and Indians who were to act as drivers at the beginning of the so-called drive, but these were all back of them at the finish. In the winter of 1930-31 deer were not nearly as numerous on the east side as on the western border of the plateau. The maximum east-side winter concentration in 1931 was about 30 deer per section. On this east-side area the die-off of deer was even more complete, and the peak preceded the great mortality on the west side by a year. The east-side range has recovered from the severe damage of several years ago, and the 1931 deer numbers were not in excess of the grazing capacity.

The remaining portion of the piñon-juniper consists of a relatively very narrow strip along under the rim of Grand Canyon. The unevenness of the rim itself, with all canyons and points, greatly increases the length of this strip. The distance along the rim, including the rim of Powell's Plateau, from Saddle Mountain to Big Saddle above the Crazy Jug, is approximately 100 miles (161 km.). Deer from the top of the plateau move over the rim in small numbers all the way along. There is concentration in the neighborhood of Point Sublime and Powell's Plateau, with resulting heavy damage to browse there. It is impractical to count the numbers of deer occupying this strip of country, and estimates must be very general. There is an estimated 1,500 to 2,000 head during the winter of 1930-31 along this entire strip. This area is within the Grand Canyon National Park. The decrease in number of deer in the past years on certain areas, notably Point Sublime and Powell's Plateau, has been similar to that of those within the National Forest.

In the piñon-juniper woodland the deer show considerable choice of forage plants. They have some

very definite choice species, but do not feed entirely on any one species for even a day. Browse makes up the bulk of the food, and cliffrose, *Cowania stansburiana*, juniper, *Juniperus utahensis*, and sagebrush, *Artemisia tridentata*, are the main browse plants that are utilized. Figure 18 shows the year-long food habits of the mule deer and gives comparative amounts of the various species eaten at the time of this study.

The deer influence the community by browsing on a great majority of plant species present. A reasonable number of deer fit into the biotic make-up of the association without greatly hindering the growth or favoring the increase of any one species. It is even believed that browsing stimulates growth of certain species and that shrubs may produce more growth if browsed moderately than if totally protected. Such an example is given for Cowania on the Kaibab by Dayton ('31). Examination of such plants in the field, however, shows that those portions of the plant showing increased amount of growth as a result of browsing do not produce seed.

The excessive numbers of deer have thinned out the shrubbery and favored the growth of certain grasses and herbs which they do not usually select as food. These plants are favored by the increase of space and the decrease of shade and root competition. In certain Kaibab areas the whole aspect of the range is changed by a decrease in shrub species and increase in grasses resulting from deer usage. It is even logical, on the basis of the observable facts, to see where it would be possible for deer to turn a woodland containing abundant browse into an area resembling a savannah and by continuous use hold an area in a subclimax state.

The cougar, mountain lion, puma, or panther, as it is variously called, is known in the territory of the Kaibab Plateau simply as "lion." This region has long been famous as a lion country, which implies that lions are fairly numerous and generally distributed. But even when abundant, they are very rarely seen except when trapped or hunted with dogs. The number present in former times is impossible to ascertain due to their secretive habits. The number that has been removed is startling, and yet there is a good representation left at the present time. Forest Supervisor Mann has made a careful check-up on records of past removals. Previous to 1931, 781 were taken. "Uncle Jim" Owens, the pioneer in the hunting of mountain lions with dogs, claims to have killed or captured at least 600 from 1906 to 1918 on the Kaibab (Mann and Loeke, '31). Since 1923, when the last federal government hunter was employed in the Kaibab, hunting of lions has been for sport and trophies under special permits.

During the study period the total lion population on the plateau, which includes the National Park and the National Forest north of the canyon, is estimated as fifty individuals. The range of these animals is limited and quite definite, and even with the great amount of hunting, certain comparatively small

areas are and always have been good lion country. The lions limit themselves in the main to the canyon rim, where they have a safe retreat and yet are near locations where deer are found. Only occasionally are individuals found up on top of the plateau. Past reports seem to show this always to have been the condition.

They are primarily deer-eaters, and their pressure on a herd of deer is enormous. Grinnell ('24) estimates that a mountain lion kills a deer a week within the region of the Yosemite. In addition to personal observations, interviews gave further information on this subject. "Uncle Jim" Owens, in 1930, after tracking down over 600 lions mostly on the Kaibab Plateau, said very definitely that the "lion feeds on a fresh kill of deer, colt, or calf, as the case may be, three times a week." Jack Butler, interviewed in the years 1929, 1930, and 1931, is a trapper and guide and an extremely careful observer. He has captured over 150 lions on the Kaibab and believes that each adult Kaibab lion averages two deer every week. Butler trails the lions with dogs, and thus locates all kills that a lion has made or visited. He also reports examples of one lion's tracks leading to two kills both less than a day old. Maximum kills by lions could certainly be expected under conditions of deer abundance similar to those existing on the Kaibab.

Lion kills were located throughout the period of the field study and were easily identified. Usually the lion had devoured all the flesh and organs except the paunch and the digestive tract. In those kills that had been only partially eaten, the viscera had, as a rule, been taken. A lion may or may not return to its kill to feed again, regardless of the fact that it usually covers the carcass with needles, limbs, or even rocks.

No evidence was found of lions utilizing any appreciable numbers of smaller rodents or birds. This, no doubt, happens, but not to any great extent on this area. The professional lion-hunters of the plateau are sure that the smaller vertebrates contribute very little to the animal's total diet. They do occasionally kill and eat porcupines in this area. Young horses are killed and eaten, and local cowboys say it is nearly impossible for either a tame or wild mare to raise a colt near the lion areas. One valuable horse weighing 800 pounds (365 kg.) was killed by lions near Powell's Plateau during the summer of 1930.

In the examination of numerous kills and reports of many others there was no evidence recognized that the deer killed by lions represented anything other than a cross-section of the adult herd of the areas the lion hunted. There appeared to be some preference shown for mature bucks, but this could be indicative of the areas the lions hunted.

The mountain lions are found with the piñon-juniper during the period when the deer are present. In late winter tracks and "kills" were found in various parts of the community. These were usually

within local areas that are recognized as lion country. One well-defined area of some 70 square miles (180 km.²), including South Canyon on the eastern edge of the plateau and containing a great amount of rough country, cliffs, and ledges, supports 8 to 10 lions. According to best available information, the number here has never been in great excess of this. Butler reported knowing of two litters of kittens in this area in the summer of 1931, but believes them to be the only new ones during the year. When lions are hunted out of this area, as has been done several times in the past, other lions are definitely known to have moved in from the outside.

The cougar has a very definite place in the biotic relations of the piñon-juniper community, if by its abundance and its pressure on deer, deer numbers are influenced. As herbivores, the deer exercise the greatest direct influence on the native plant species of the woodland association and apparently influence, directly or indirectly, the majority of organisms present.

During the period of study the coyote was as abundant over the Kaibab as in any time in the past, and apparently had increased in recent years in spite of consistent trapping. Coyotes are present within the piñon-juniper throughout the year. The summer population is the lowest per township (23,040 acres; 9,325 ha.), estimated at 20 to 25 as compared to 30 to 40 per township in the higher portions of the plateau. In the fall, there is a considerable downward movement of the coyote population and a marked increase during the winter in this community. This is true of areas of deer abundance as well as areas where deer are scarce or lacking.

In the late fall of 1931 several individuals could be seen by close observations during one day's ride. Tracks and droppings were in evidence in great numbers and numerous individuals were heard. A series of coyote droppings collected in mid-winter showed primarily deer hair and bones with some rabbit fur, remains of *Peromyscus* and a small amount of grass. Another series of droppings from late summer consisted primarily of vegetable matter, juniper berries, service berries, prickly pears, grass, and rodent remains. Within this community the coyote's main year-long food is the small rodents that are found here.

During the time deer are present, there is use of them as food, but hair in the droppings and evidence of their having eaten deer does not of necessity mean the coyote is responsible for killing. In February 1931, however, many dead deer were found, and a great number had not been disturbed by carnivores; while numerous others showed definite evidence of having been killed by coyotes. A preference for meat of its own killing or freshly killed meat, was clearly indicated.

The generally conceded increase in coyote numbers on the plateau has possibly been affected by an increased supply of weak and dead deer available in the mid-winter, normally a season of food scarcity.

However, evidence also points to an increase in coyote numbers following extermination of the wolves.

It is estimated that there was a total 1931 coyote population of 1,000 animals. Trapping in recent years has been done almost entirely in winter for the fur, with an average annual removal of two to three hundred animals. A small amount of poison for coyote control was placed out on the plateau in October 1925. A number of coyotes and some valuable dogs were destroyed. No poison had been used previously nor has it been used since that time.

The plateau wildcat or bobcat is a fairly common resident of the association. Its nocturnal and retiring habits do not make its presence very obvious. In suitable habitats its round, small tracks are usually in evidence. Its breeding distribution is local and it often is confined to areas of cliffs and ledges. It is distributed entirely around the edge of the plateau, and reaches its greatest numbers in this association and in the lower portions of the yellow pine. In total numbers it does not equal the coyote, estimates of numbers for the plateau and surrounding canyons being near 500.

Its food consists primarily of small rodents and some birds. Bobcats perhaps take some fawns, but exact evidence is scarce. They have no trouble in killing sheep and are accused of taking heavy toll of lambs in the near-by region.

Its usual residence is in what is also the favorite haunts of certain white-footed mice, the woodrat, and cottontail rabbits. These rodents are eaten by the bobcats and are believed to constitute the bulk of its food. Its outstanding influence takes the form of pressure on the rodent population.

Influent mammals of this community are the:

Kaibab Woodrat	Black Hills Cottontail
True's White-footed Mouse	Utah Rock Squirrel
Tawny White-footed Mouse	Yellow-haired Porcupine
Utah Cliff Chipmunk	Arizona Gray Fox
Jack Rabbit	

The Kaibab woodrat is characteristic of the piñon-juniper distribution, and is fairly common over the area. It makes use of cliffs and rocky slopes when such are available, but is also distributed where these conditions are not present. Here the characteristic nest may be placed about the stump of a juniper or piñon, under the protection of the spiny leaves of yucca or in a rocky outerropping. One was found occupying the shelter provided by the dry hide of a dead cow, as it remained stretched over the skeleton. The nests are made up of all that a "pack rat" collects.

A pack rat nest near Slide Reservoir, examined October 1931, was taken apart following the trapping of the occupant. The record of material was as follows: bulk approximately ten bushels (350 liters); 85% sticks and twigs of piñon, juniper, and holly-grape, and some miscellaneous plant species; 5% empty piñon cones; 4% a great variety of bones of cattle, horse, deer, rabbit; 2% rocks; 1% cactus (*Opuntia*); 1% mushrooms; and 2% deer hide and

hair. The deer hair was plentiful throughout the nest. The nest also contained about one-half pound (225 grams) of piñon nuts, and a small collection of juniper and hollygrape berries.

It seems that this animal is well adapted in habits of living and food relation in this association. It has a wide range in choice of foods. Among those usually taken is the piñon nut, which it stores in great quantities during years when they are abundant. It is fond of juniper berries, fruits and seeds of a variety of plants, herbaceous growth in summer, and in winter it was observed to have eaten considerable quantity of the heavy leaves of *Yucca baccata*.

Some careful area counts were made. In level portions of the piñon-juniper the occupied houses were estimated to be one per one and one-fourth acre (two per ha.). As a rule a single rat was found in a nest. They are active throughout the year and although they store foods, they use these materials only in supplementing what they obtain by foraging about.

True's white-footed mouse is perhaps the most abundant mammal species within the piñon-juniper. They are most common in regions where cliffs and broken country provide suitable breeding localities. They are not limited to such areas, and mice droppings are seen about hollow stumps and fallen trees of piñon and juniper throughout the woodland. They are strictly nocturnal and were present wherever camp was made or traps were set among piñons and juniper. They are found in the same localities and mingle with the tawny white-footed mouse. Because of this their food habits are difficult to determine specifically. Their appetite for grain of all kinds is very marked. In natural conditions juniper berries, grass, and herb seeds appear to be the main diet. They are two or three times more abundant at this lower elevation than is the tawny species.

Estimation of area populations of mice are difficult to determine. The seasonal difference is perhaps over 200 percent, and the entire population is subject to periods of great abundance following favorable conditions. Mice in general appeared to be more abundant in this community than in others studied. These mice are active all year although the main breeding season is believed to be early summer. A female containing four embryos was taken in October, 1931. An estimate of twelve to fifteen *Peromyscus* per acre was made on the basis of trapping a series of measured areas (October, 1931).

The cliff chipmunk is present throughout the community, but is another species preferring a habitat consisting of cliffs and ledges. They are not as abundant as the chipmunks of the upper forests, but are seen wherever desirable habitat conditions exist. They are very adept at climbing cliffs and trees and feed upon a variety of available foods—piñon nuts, juniper berries, acorns, fruit of the cactus, and seeds of composites. They are active almost year-long, with some inactivity during more severe weather, when they are dependent on their stores of food.

The blacktailed jack rabbit is abundant in the area

surrounding the Kaibab Plateau, and extends upward with the sagebrush through the piñon-juniper to the yellow pine. It is a very characteristic mammal of the western deserts and semi-deserts, and ranges over a number of plant communities. It is abundant enough in the area to have considerable influence on the association because of its voracious feeding habits. Vorhies and Taylor ('33) have shown in the closely related species, *Lepus californicus eremicus* (Allen), that 12 rabbits ordinarily eat as much as one sheep. There is some difference in their distribution, according to the amount of sagebrush present. This is interesting in view of the fact that this rabbit's diet on the study area was primarily grass, but presence of sage limits distribution.

At study stations A and B the rabbit populations were very similar, although a few more were present at B, the heavily grazed area. The three years, 1929-30-31, showed no great variations in numbers that were obvious in general census. In this area there has been no conspicuous peak of abundance or scarcity within the past decade. Where conditions were favorable for the species, repeated counts of rabbits showed a population of one per ten acres (4 ha.). Over the entire association the average would be nearly one rabbit per twenty-five acres (ten ha.). This is much lower density than in the near-by sagebrush desert.

The cottontail rabbit is found throughout the association in small numbers, but is not so abundant as the jack rabbit. It is ordinarily seen in the local situation of brush slopes.

The rock squirrel is local in distribution according to the rocks and canyon walls, but is most abundant at the upper edge of the piñon-juniper, oak brush, and steep, rocky hillsides, where there are often several per acre. Under the rim of Grand Canyon they range upward to 8,000 feet (2,440 m.) on the exposed rocky sides, which support a growth of scrub oaks and similar vegetation.

The porcupine is found in small numbers in this association. There appeared to be an increase in numbers during fall and winter. Individuals, droppings, and tracks were observed that would indicate a limited downward migration from higher elevations in this season. The piñon is their main food in this community, but some Cowania showed evidence of porcupine attack. They are rare and show no uniformity in distribution.

Three mammals of minor influence, mainly because of the scarcity of numbers, but found in this association are the gray fox, ringtailed cat, and the little spotted skunk. Several fox are trapped each year, but nowhere is it abundant enough to be of great ecologic importance. This animal ranges below the piñon-juniper and is occasionally trapped in the rougher, lower country. It is usually an animal of the broken foothills.

The ringtailed cat is limited in distribution by canyon walls and ledges, but is occasionally encountered by tracks or trapping. They range above and below

the association where suitable localities occur. They are never very abundant and four or five has usually been the annual catch on the plateau.

The skunk occurs in small numbers within the Grand Canyon. The absence of streams on the summit of the Kaibab appears to be a factor influencing their rareness. Occasionally one is found on the plateau, two were trapped at the upper limits of the piñon-juniper near Big Springs Ranger Station in 1931.

BIRDS

The birds of this association are more abundant per unit area of climax woodland than in the true, unbroken climax of any other major association on the Kaibab. (The greatest bird concentration of the plateau, however, is along the park and meadow boundaries of the higher elevations.) The seasonal and stratal societies of birds and invertebrates are well defined. The stratification is not as conspicuous as in other forest associations due to the very scattered arrangement of the dominant trees, which usually do not exceed 15 to 20 feet (4.6 to 6.1 m.) in height.

Counts of breeding pairs of birds by repeated counts of singing males during May, 1931, showed as many as eight birds on five acres (2 ha.). The large number of birds on this area is surprising because it is usually three to five miles (4.8 to 8.0 km.) air-line to the nearest permanent water, and because in late May and June this association very often lacks any measurable amount of precipitation. The scarcity of water and absence of subclimax vegetational stages are believed to be the cause of absence of a number of birds often listed as the commonest species at comparable elevations near-by.

Most abundant resident birds are:

Gray Titmouse	Red-shafted Flicker
Woodhouse's Jay	Piñon Jay
Western Red-tailed Hawk	Lead-colored Bush-tit
Golden Eagle	Rock Wren

The gray titmouse is limited practically year-long to this association, being the least migratory of the native species. It forages about the smaller limbs and twigs of trees and larger shrubs. Observations in the field proved that the abundant leaf-hoppers were eaten in great numbers in summer, along with a large assortment of other small forms. In winter, when no insects are active, they continued to forage in the same niche; the food then must, of necessity, be mainly dormant insects. They utilize plant material to some extent, but the relative percentage is unknown.

The Woodhouse's jay is also present year-long in this association and the oak brush belt. There is some movement to lower country in colder weather. This jay's food is a combination of vegetable and animal material. It forages in general over all strata, a considerable portion of its food being collected from the ground.

The western red-tailed hawk, although present over the entire plateau, is of influence here because of its year-long residence. In summer it is not abundant, there being only one pair per section. In winter this number is doubled. Its soaring habits make it conspicuous at all times. The jack rabbits, cottontails, and mice appear to be its main winter foods. This is varied with other rodents in summer.

The golden eagle nests and is present year-long in the rough, rugged country that abounds all about the plateau. In summer it is occasionally seen well up on the higher elevations, but is usually in the rocky box canyons to the south and west. It is seen foraging over the level country ten to twenty miles (16 to 32 km.) back from the canyon. In winter there is a decided upward movement and numbers are seen on the plateau. It is not adverse to the use of dead deer, and in past winters these have provided easy food. This has resulted in a great influx of golden eagles to the west portions of the Kaibab each winter. One reliable observer counted eighteen of these large birds in a limited area, December, 1929. This is unusual, but individuals are usually present in some numbers throughout the range.

The red-shafted flicker appears in all wooded portions of the plateau. The abundant ants provide the bulk of their food in open seasons. There is a downward migration in the fall and an increase of their numbers in the piñon-juniper during winter.

The piñon jay occurs very irregularly according to the success of the piñon nut crop, which is very indefinite and spasmodic. Flocks are often seen. They were abundant in the fall of 1931, the time at which the Kaibab had its first good piñon crop in three years.

The lead-colored bush-tit is present. Flocks of this diminutive bird are seen in this association, but not elsewhere.

The rock wren ranges throughout the association with a very marked preference for the exposed rocky slopes and ridges.

Open season or summer resident birds of importance are:

Western Chipping Sparrow	Night Hawk
Black-throated Gray Warbler	Northern Cliff Swallow
Rocky Mountain Grosbeak	Western Lark Sparrow
Western Mourning Dove	Desert Sparrow

The western chipping sparrow is found in all parts of the plateau, except in the deep forests of yellow pine and spruce-fir. It usually occurs along borders of woods and more open portions. In the piñon-juniper this type of niche is common throughout the climax, due to its open orchard-like arrangement, and the chipping sparrow is found throughout the area. In numbers it is the most abundant bird during the time it is present in this association. It usually forages on the ground; and although a sparrow, it has been shown that animal matter makes up sixty-two percent of its food (Bailey, '28).

The black-throated gray warbler is a common bird that occurs throughout the community but they are less abundant nearer the lower limits. They forage in the crowns and mid-branches of the trees, and individuals are rarely seen on or near the ground. The Rocky Mountain grosbeak is a very characteristic and common bird of this community.

Other abundant open season birds are the western mourning dove, which occurs commonly but is limited by distance from water; the night hawk, which is seen regularly throughout the association, its activity being confined to evening, night, and early morning; and the northern cliff swallow, which occurs locally according to available nesting sites.

At the lower edges of the piñon-juniper, where there is considerable amounts of sagebrush, the very typical western lark sparrow, the desert sparrow, and an occasional sage thrasher occur.

The common winter resident birds are:

Shufeldt's Junco	Rocky Mountain Nuthatch
Pink-sided Junco	Mountain Bluebird
Gray-headed Junco	Western Robin
Red-backed Junco	Long-crested Jay

The most abundant birds found during the winter season in this association are the juncos. The red-backed junco, which breeds in the upper portions of the mountain, is present in winter along with Shufeldt's junco, with perhaps individuals of the pink-sided junco and the gray-headed junco. Flocks of juncos were observed in the snow-covered foothills in flocks of twenty-five to one hundred individuals in the winter of 1930-31. Both the "black heads" and the "gray heads" were present. The former exceeded the latter in numbers of three to one. They are active on the ground, and their food consists of all available plant seeds, grasses, herbs and shrubs.

The Rocky Mountain nuthatch is present year-long, but not in any great numbers. However, in fall and winter there is a downward migration, and solitary individuals were found throughout the piñon-juniper. In this association during mid-winter they forage almost entirely on the trunks and larger limbs, as they do on the spruces, firs and pines in summer.

Other more common winter residents include birds of the higher elevations—the mountain bluebird, the western robin, and at times considerable numbers of long-crested jays, which descend to this association from the montane forests above. During the winter the bluebird and robin also range lower than the piñon-juniper; the jay's distribution is limited by its lower border.

REPTILES

Reptiles found here are:

Short-horned Horned Toad	Western Collared Lizard
Sagebrush Swift	Great Basin Rattlesnake
Blue-bellied Lizard	Grand Canyon Rattlesnake
Brown-shouldered Uta	Great Basin Gopher Snake

The upper limits of the piñon-juniper mark the range in which reptiles are present in any numbers and have any marked influence on the community.

One reptile, the horned toad, is found in small numbers in this association and becomes more abundant in the open yellow pine forests. This is the only reptile that occurs in any numbers above the piñon-juniper.

The sagebrush swift is the most common reptile, occurring up to the upper limits of the piñon-juniper. Some counts were made where it averaged six to eight per acre. Its food consists of terrestrial arthropods with a wide range of selection, ants being among those more often eaten because of their great abundance and accessibility. The two lizards, the blue-bellied and the brown-shouldered Uta, were both present in the lower and more open regions. The distribution of both species is local. The western collared lizard is present, but limited in its distribution to the rocky slopes and ledges, attaining its highest vertical distribution along the rim of the Grand Canyon.

The rattlesnakes are found in limited numbers along the rocky canyons extending upward from Kanab Creek and Grand Canyon and rarely on the rocky, exposed points.

The Great Basin gopher snake is found in the sagebrush and grassland regions at the base of the plateau, and individuals are found in the lower limits of the association, where the sage makes up a conspicuous part of the community.

INVERTEBRATES

The invertebrate population was studied by regular quantitative collections. In this community the fifty sweeps of the shrubs included trees as well, and ratio of sweeps were: piñon eighteen, juniper sixteen, Cowania twelve, scrub oak two, and sage two. (This selection of plant species was based on the approximate amount of green vegetation of each species present at stations.) For the herbs the sweepings were practically limited to Gutierrezia and Bouteloua, the only abundant species.

The total population averaged about .20 million per acre (.50 million per ha.) and had its first maxima in the early estival period, late May, with a decline during the dry late estival period. A second lesser maxima was found in the serotinal period, following the rainy season. This second maxima was the result, primarily, of increase of the herb and ground strata population (Fig. 12).

Eighty-three species of invertebrates were collected quantitatively in this community; of these 37 were taken only once. Of the total number of individuals the groupings were as follows: 25% spiders, 13% Chermidae, 12% Formicidae, 8% other Hymenoptera (mostly Ichneumonidae), 10% Diptera, 9% Cicadellidae, 6% Hemiptera, 5% Coleoptera, 3% Orthoptera, and 9% others.

The most abundant invertebrates are the immature of the crab spider, *Misumemops asperatus*; the chermid, *Paratrhoza cockerelli* (Sule.); and the ant, *Formica fusca* var. *subaenescens*. All three were taken from tree-shrub and herb strata. The spider

and chermid were most abundant on the trees and shrubs. The ant was present in the ground collections as well. Complete names of Formicidae and Orthoptera are given in the appendix.

In the shrub and tree strata the following were most abundant species: immature spiders of genera *Dendryphantes* and *Oxyopes*; two leaf-hoppers, *Cicadellidae*; chermid, *Psyllia brevistigmata acuta* Crawford; a beetle of genus *Anthonomus*; and a fly of family *Cecidomyiidae*.

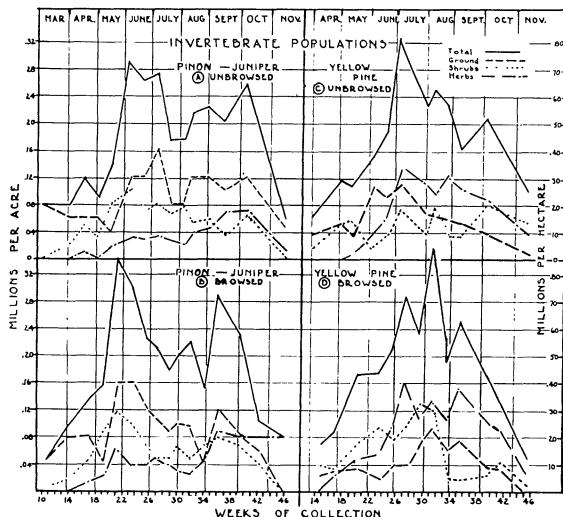


FIG. 12. Graph showing invertebrate population of four stations as indicated by quantitative collections made in 1931. A = Station A, unbrowsed area of piñon-juniper, north end of the plateau; B = Station B, area of piñon-juniper, heavily browsed, on west side of plateau; C = Station C, unbrowsed yellow pine, near Jacob's Lake; D = Station D, heavily browsed yellow pine, west side of the plateau.

In the herb strata the beetle *Monoxia* spp., found on the Gutierrezia, was the most abundant species. The banded-winged locusts, *Trimerotropis inconspicua*, *T. cincta*, and *T. cyaneipennis* were present. Their usual resting place was the bare ground in the spaces between the trees. They foraged, however, on both grasses and shrubs. In July, 1931, there was considerable local damage to cliffrose, sage, and grass on the western portion of the association by Orthoptera. This occurred in the area of greatest winter concentration of deer and most severely damaged deer range. *Trimerotropis cincta* was collected from Cowania as a possible causative agent.

On the ground surface ants predominated. In addition, the large black *F. fusca* var. *subaenescens*, as listed above, the *Leptothorax texanus*, and the very dark red *Myrmica scabrinodis* var. were found on vegetation and ground. The very small *Monomorium minimum*, and the odoriferous *Crematogaster lineolata* were found about fallen logs, tree trunks, and under rocks. Nests of *Camponotus maculatus vicinus* var. *luteangulus* were found under rocks, but no activity of this species was noted in midday. In the

very open sites, most evident in sagebrush areas toward the lower parts of the association, were the mounds and individual burrows of the mound-building prairie ant, *Pogonomyrmex occidentalis*.

The termite, *Reticulitermes tumiceps* Banks, was found making galleries in both piñon and juniper wood, where dead limbs rested on the ground. The piñon seemed to be the favorite, however, and practically all pieces of any size were infested. A tenebrionid, *Eleodes* sp. and the carabid, *Cymindis blanda* Casey, were common. The poison spider, *Latrodectus mactans* (Fabricius) was found in the association under rocks on exposed ridges and was fairly common. An asilid, *Osprioncerus abdominalia* (Say), and a cicada, *Platypedia putnami* (Uhler) were characteristic species of this community.

The general collections did not show any great differences in insect infestation due to deer browsing. As a check for difference in insect infestation due to severe browsing, a separate series of collections were made. Two stations, A of a little browsed range and B of severely browsed range, were used. In addition, two other stations B₁ of moderately browsed but healthy shrubs, and B₂, an area of the most severe damage to the shrubs. These last two were also on the west-side winter range area, near Station B.

TABLE 5. Results of counts of invertebrates on 20 m.² (1,000 sweeps) taken over a period of four collections. May-June, 1931.

Station	Damage by Browsing	Total Insects	Total Insects per 20 m ²
A.....	None	462	23.1
B.....	Severe	494	24.7
B ₁	Moderate	552	27.6
B ₂	Extreme	348	17.4
Average	464	23.2

The more abundant species were nearly the same at all four stations. The increase at station B₁ consisted primarily of Cicadellidae, Chermidae, and spiders. These groups were much less abundant at station B₂. There was a marked increase of insect numbers associated with the presence of a greater number and more compact arrangement of leafy shoots, a condition which results from moderate browsing in numerous shrubs. On the other extreme, where Cowania and juniper were low in vitality as a result of overbrowsing and had a minimum of shoots and new green vegetation, the number of insects were definitely less than average.

Further study of the species present will, no doubt, show some very definite changes in the species concerned, and very likely, an increase in the more important insects that attack the woody portions of the trees and shrubs, due to their weakened condition. The infestation of Orthoptera in July, 1931, was practically limited to severely browsed areas and was general over these areas. The damage was accentuated by the fact that the amount of new growth of browse here was only a fraction (estimated at

less than 10%) of the new growth present on slightly browsed areas.

Thus, an equal loss of vegetation on the two areas due to insect attack could be of minor importance with the normal plants, but very serious in the case of the heavily browsed areas.

The invertebrate population curves of the two stations within the piñon-juniper differ slightly (Fig. 12). The agreement in the main peaks and the ratio of animals of different strata to each other is marked. Station A is so located that seasonal changes are a little later than at station B. This is shown by the peak of abundance of invertebrates occurring slightly later at station A.

The total population reaches a higher peak on the severely browsed areas, but the difference in numbers is not great enough to be significant. The increase of animals of the herb strata of station B over animals of the same strata in unbrowsed plot of station A is the major difference. This is possibly due to the favoring of plants of herb strata where browsing has removed a great amount of the parts of shrubs and trees that shade the lower strata.

Invertebrate populations at both stations agree in their main characteristics, and the following conclusions can be drawn about the numbers of invertebrates in the piñon-juniper community that was studied:

- (1) Ground stratum averages slightly more animals per acre than any other stratum.
- (2) Shrub and tree strata average more per acre than herb and grass strata.
- (3) There are two maxima during the season, the first in late May and the second and lesser maximum in September.
- (4) The total invertebrate population is much less than populations of deciduous forests of Illinois, as shown by studies of Smith ('28) and Weese ('24), or of aspen parkland, as shown by Bird ('29).

VII. THE MONTANE FOREST CLIMAX

THE *Pinus brachyptera-Sciurus kaibabensis* ASSOCIATION

GENERAL

The most extensive and typical true forest of western United States is that composed of yellow pine, *Pinus brachyptera* and *Pinus ponderosa* Doug. It is the most important economic tree of several southwestern states and occurs in pure stands in all far western states, in the Black Hills of South Dakota, in portions of western Canada, and in the mountains of Mexico.

The Kaibab Plateau has been greatly advertised because of its yellow pine forest, one of the nation's finest and largest undisturbed stands. On the plateau it is dominant between 6,800 and 8,200 feet (2,075 and 2,500 m.), extending downward to 6,500 feet (1,980 m.) on cold slopes and upward to 8,800 feet (2,680 m.) on certain exposed slopes and the canyon

rim. It forms a belt of varying width about the plateau, being extremely narrow at the eastern border, but from eight to twelve miles (13 to 19 km.) wide at the west and north ends. The total area of yellow pine forest is approximately 245,000 acres (99,200 ha.). The summit of Powell's Plateau, an area of 2,500 acres (1,000 ha.) of this forest, is within the canyon and is separated from the main forest.

The forest itself is decidedly open. The trees are unusually large and mature, growing in groups or widely spaced so that the sunlight reaches the ground in almost all parts of the forest. The understory is usually free from shrubs or smaller trees and little fallen timber is present throughout the forest. The open nature is attested by the fact that one can drive a car for miles through the primitive forest. The limitations are matters of topography, not vegetation. This yellow pine forest is completely isolated from similar plant communities either by the Grand Canyon or twenty to thirty miles of piñon-juniper woodland and sagebrush.

The two stations selected in this community were similar in vegetational composition but differed in degree of browsing by deer (Fig. 2). Station C was located toward the northern end of the plateau, near Jacob's Lake Ranger Station, in Section 36, Township 38 N, Range 2 E, at 7,800 feet (2,380 m.) elevation. Here deer were often seen, but the vegetation was not damaged by them to any great degree. Station D was located a mile west of Dry Park Ranger Station, in Section 12, Township 35 N, Range 1 E, at 8,000 feet (2,440 m.) elevation. This is west of the highest portion of the plateau, in a region where deer at the time of study were extremely abundant during the summer, with increased numbers in the spring and fall. The range is very severely browsed, so much so that the seedling yellow pine are at a standstill because of deer pressure.

VEGETATION

The dominant plant is the western yellow pine, *Pinus brachyptera*. Other plants act as dominants in small areas but the climax consists of a pure stand of yellow pine (Fig. 13).

The trees range in size to over one hundred feet (30 m.) in height, and three to four feet (.9 to 1.2 m.) in diameter. Counts of trees on sample plots in the mature forest showed an average of only forty to fifty-five per acre with a d.b.h. of six inches and over. The younger trees occur regularly in small groups of similar age class, often 200 to 400 per acre.

With the exception of the yellow pine no tree or shrub occurs uniformly throughout the community in numbers that make it of great ecological importance. *Ceanothus fendleri* is a characteristic and quite uniformly distributed shrub, never having formed any very conspicuous part of the vegetation. It is more limited at the present time than previously due to the close browsing it has been subjected to by deer.

Robinia neomexicana is usually found in the lower portions of this community. It is rather common, often making up small stands among the yellow pine, and is frequently found in mixed patches with *Quercus utahensis*. For the entire forest the small and inconspicuous *Odostemon repens* is perhaps the most abundant shrub. *Arctostaphylos patula*, one of the very few shrubs unpalatable to the deer, occurs locally. This plant forms a conspicuous understory in the yellow pine on the Walhalla Plateau, at the extreme southeast portion of the plateau. Other shrubs that are found here are: *Chrysothamnus parryi*, *Sambucus caerulea*, *Ribes inebrians*, and *Seriocarpa glabrescens*.

Symporicarpos sp. occurs in upper portions of the community. Much of this species has been killed by the deer, and the remaining plants show that they have been closely clipped for years. Raspberry, *Rubus* sp., was formerly present and reported as common, but this species is now extremely rare. This is a known example of deer eliminating a desirable plant species; how many others have been destroyed in this manner is unknown.

At the lower border of the yellow pine association a number of trees and shrubs that are typical of the oak belt and of the piñon-juniper are often found

growing under the yellow pine. *Quercus utahensis* is the most common shrub; it occurs as scattered individuals and makes up small colonies. *Cowania stansburiana* and *Amelanchier alnifolia* are abundant in certain localities. *Juniperus scopulorum*, *Pinus edulis*, and more rarely *Juniperus utahensis* occur as lone individuals or in small groupings in local situations. Hanson ('24) has shown that these shrubs and trees act as a seral stage in the primary xerosere of the yellow pine, and this appears to be the condition in the lower portions of the association of the Kaibab Plateau.

In the upper half of the community and extending downward in the cooler slopes and draws are stands of quaking aspen, *Populus aurea*. In the Southwest aspens are usually not present in any great numbers as low as the yellow pine. The aspen attains its maximum development above the yellow pine, but areas and scattered groups are present in many parts of the association. This species apparently forms a primary seral stage in the forest succession near the upper border of the community but it is also found in a variety of local situations.

In the greater portion of the forest the natural succession does not show a series of stages of tree or shrub species, and with the exception of changes



FIG. 13. (a) Typical scene in the montane forest climax (*Pinus brachyptera-Sciurus kaibabensis* Association).
(b) Yellow pine bushy growth resulting from repeated heavy browsing by deer.

in herbaceous species the dominants are the same, yellow pine following yellow pine on areas of burns or "bug" kills.

The grasses, *Muhlenbergia montana*, *Blepharoneuron tricholepis*, and *Sitanion hystrix* are common herbaceous elements of the climax yellow pine forest. A conspicuous yellow Carex grows among the pine needles and directly under the trees throughout the community. A number of lupines are found here, a common one being *Lupinus barbiger*. Other common herbs are *Potentilla* sp., *Erigeron divergens*, *Solidago* sp., *Castilleja* sp., *Lotus wrightii*, *Artemisia gnaphalodes*, *Astragalus* spp., *Eriogonum* spp., and *Antennaria* sp.

The mistletoe, *Razoumofskya cryptopoda*, is parasitic on the yellow pine, usually forming conspicuous abnormal growths on the lower limbs of the mature trees. It is abundant throughout the forest, 10 to 20% of the older trees showing some sign of it. In some few cases death results from it.

MAMMALS

The major influents of this association are the same as the other forest communities of the plateau, namely the Mule Deer, Mountain Lion, and Mountain Coyote.

Although not a year-long resident in this association, the mule deer, due to its decided influence during the time it is present, is the most important animal species.

The major part of the deer herd enters this community in middle and late April. A number migrate on upward as conditions permit, reaching the summit and the regions of the mountain meadows at VT Park late in May. Thus during May the majority of the deer are in the yellow pine. During June, July, and August they are throughout the montane coniferous forest in both yellow pine and the spruce-fir communities. Again in September and October, depending to a great degree on weather conditions, the yellow pine is the area of maximum concentration of deer numbers.

There appears to be a segregation of sexes soon after the deer enter the montane forest, and this is evident throughout the summer. The bucks are in a majority at the upper and the extreme lower portions of the summer range; the does predominate in the intermediate region. Does without fawns act much as bucks do and are often associated with them. The bucks are sometimes seen singly, but are usually in small groups of two to five. The composition of these groups is not uniform, containing old, young, or both old and young animals. During fawning season, late June and early July, breeding does are most abundant in the upper portions of the yellow pine belt, where they are seen singly or in groups of two and three.

Summer population in the more concentrated areas amounts to 30 deer per section. For the entire yellow pine forest the average is near 20 to 30 per section (1931 data) (Fig. 11). The home range of a doe

with a fawn or fawns seldom exceeds two miles (3.2 km.) in radius. It is believed that with abundant available water this would be much less. Does without fawns and bucks frequently range four or five miles (6.4 or 8.0 km.) from water. The extreme northern part, north of Jacob's Lake, has few deer during this season (5 per section, 1931).

The early spring migration follows so closely the melting of the snow that the growth of early herbaceous species is merely beginning when the deer first arrive in this community, and as a result the yellow pine is heavily utilized as food.

During the summer the deer feed mostly on the herbs and the few shrubs that are present, and eat only a small amount of yellow pine. In the fall an increase of the amount of yellow pine eaten is shown. From a standpoint of damage to the trees, the spring browsing is by far the most severe. Terminal buds and shoots are eaten, and the result is that the majority of the smaller trees within reach of the deer had made little growth for the decade preceding 1931. The leaders on these small trees within the fenced-enclosure plots that have been in existence for four and five years (1931) in areas of heavy deer damage show an annual growth of six to eleven inches (15 to 28 cm.), as compared with an inch or less for trees in the open.

Contrary to the general belief that the winter range is the only area of overbrowsing, examination of forage plants on the summer range shows this to be also severely damaged. The three choice summer browse species, *Rubus*, *Symporicarpus*, and *Ceanothus*, have been greatly reduced in numbers and size of growth. No young aspens are present that are less than ten or fifteen years old (1931). Certain legumes are reported to have entirely disappeared. The blame for overgrazing of the herbaceous species should not be entirely attributed to deer, as the whole mountain has been subjected to severe overgrazing in the past by domestic livestock and wild horses. However, marked reduction of the browse species and the damage to the trees can be attributed primarily to the deer.

The maximum summer concentration of the mountain lion is in the yellow pine forest in those areas that are near the canyon rim or suitable rough country. They follow the deer herd in their migration, in and out of this community. The numbers, range, and peculiarities have been discussed under the animals of the piñon-juniper association.

Coyotes are present throughout the association year-long, their distribution is fairly uniform, with an estimated population in summer of 35 to 40 per township and only 10 to 15 per township in winter.

The downward movement of deer is a well-defined migration along certain main routes; whereas, in the case of the coyote, it is merely random descent, taking place all about the plateau, the intensity depending upon the severity of the winter.

The coyote's winter diet, while present in this community, is primarily the small rodents that are active at that time of the year, namely, the white-footed

mouse, woodrat, and the cottontail, but they are known to eat almost anything available in the line of animal life, as well as fruits, berries, and vegetation. In the open season the two species of chipmunks, and for a shorter period the mantled ground squirrel, form an important part of their diet. They kill some adult deer in the summer but there is no heavy loss except in the case of fawns from a month to three months old. There seem to be two factors contributing to the heavy killing of fawns, namely: (1) the coyote's ability to locate fawns by scent and (2) their ability to catch them. Very young fawns are not killed as often as older ones are. Experiments with dogs and man fail to show any detectable odor in fawns less than a month or six weeks old.¹ This fact is also seemingly borne out by the method of systematic hunting by sight and sound which a doe uses in locating her fawn after being separated from it. At about six weeks of age the fawns develop the characteristic odor of deer, strong enough to be detected by man upon handling them. Coyotes on three separate occasions were observed trailing fawns by scent, shortly after the average fawn was six weeks old, and numerous kills were located. This predation was highest for a period of about one month, and then decreased. The decrease in numbers killed later in the summer appears to be explained by the ability of the fawn to take care of itself. The coyote appears to eliminate a number of the weaker and more undesirable adult deer during the summer as indicated by the kills examined. This selection should not always be interpreted as betterment, as the inability to escape can be associated with age as well as comparative vigor or undue advantage. An example of undue advantage is given by Hall (1925). He records the killing by a coyote of a Kaibab doe deer while giving birth to a fawn. Groups of coyotes were observed running relays on prime full-grown deer and successfully killing the animal.

The pressure the coyotes exercise on the deer herd is difficult to determine. The Secretary of Agriculture Investigation Committee of 1931 recommended non-hunting of the coyotes, as well as other predators, on the forest. This recommendation is perhaps not as significant in the case of coyotes as other predators, because in point of numbers they have been holding their own and are believed to be increasing over the region.

These observations over a period of three years show the independence of deer and coyote migration and the varying seasonal pressure of coyotes on the deer herd. The number of deer killed per year per coyote can only be approximated. Droppings show deer hair in a higher percentage of cases in deer range, but their habit of eating others' kills and returning to a carcass many times would emphasize the evidence of deer eaten. From this study recent increases in coyote numbers are believed to be due, in part to additional available winter food in form of deer. Also, the number of deer killed per coyote

¹ Two thousand four hundred and seventy were caught to be hand-reared in the years 1925 to 1931.

appears to be higher in areas of deer concentration. If true, this could possibly be due to habit as well as availability. There is need, however, of a critical study of the deer-coyote relationship to evaluate these various factors.

Influent mammals of this community are:

Kaibab Squirrel	Tawny White-footed Mouse
Wasatch and Beaver	Colorado Bushy-tailed Woodrat
Mountain Chipmunks	Plateau Bobcat
Say's Mantled Ground Squirrel	Utah Rock Squirrel
Yellow-haired Porcupine	Black Hills Cottontail

The Kaibab squirrel, a climax influent, is the plateau's most interesting animal, inasmuch as this large, tassel-eared squirrel is absolutely unique, being found only in the yellow pine of the Kaibab Plateau. Its range is not entirely limited to the pure pine forest, as scattered trees of yellow pine occur upward to the top of the plateau, and occasional squirrels are encountered wherever these trees exist (Fig. 14).

The squirrel is a resident animal, active throughout the year. The distribution is remarkably uniform over the area of yellow pine. On the basis of counts at various times of day and in all seasons of 1931, an estimate was made of six to eight squirrels per section throughout the pure stand of forest. Three areas, one near Jacob's Lake, one near the western border of the yellow pine, and a smaller area near Bright Angel camp grounds, gave relatively higher

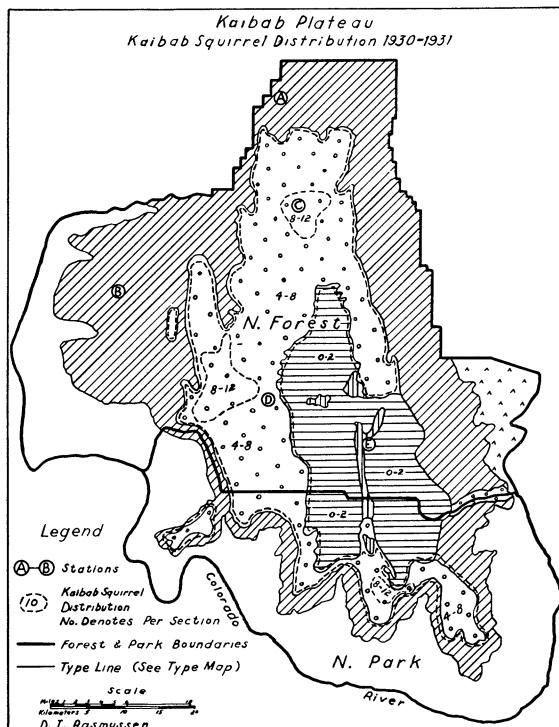


FIG. 14. Distribution and numbers per section (640 acres, 260 ha.) of Kaibab squirrel (*Sciurus kaibabensis* Merriam), Kaibab Plateau, Arizona, 1930-31. Types are same as on type map, Fig. 2.

counts, and it was estimated eight to twelve squirrels were present per section (640 acres, 260 ha.) in these areas. No definite reason (except perhaps additional food in form of camp ground scraps at Jacob's Lake and Bright Angel camp) could be determined for this concentration.

On the basis of mapped vegetation areas there are 387 sections of yellow pine forest and 172 sections of forest above the yellow pine. An average population of seven squirrels per section for pure yellow pine forest and one per section for mixed forest would give a total of 2,900 animals. Interestingly enough, this includes all individuals of a species that are existing in a fairly original situation.

This squirrel has a very restricted diet, feeding almost entirely on the year-old cambium and bark of the terminal shoots of yellow pine (Fig. 15). During



FIG. 15. Main food items of the Kaibab squirrel (*Sciurus kaibabensis*). Bottom row: remnants of 3 green pine cones left by squirrels after feeding on them. Center row: peeled, year-old twigs from which squirrels had removed the cambium and bark. Top row: discarded terminal tufts of pine needles, current years' growth; all *Pinus brachyptera*.

summer it eats a number of the green pine cones, a small amount of herbage, and occasionally some fungi. Its importance in forest biotics is not very great. At times they do considerable damage to certain selected trees; and in exceptional cases, remains of several hundred twigs may be present on the ground, under a tree, with enough foliage removed to reduce materially the total leaf surface. They have no part or interest in the gathering and storing of food, seeds or otherwise, and so are of no importance in that respect.

No interrelation between shrubs and squirrel numbers could be determined either as food or shelter and under these conditions no effect on squirrel numbers could be shown by the overbrowsing. The number of squirrels in 1931 was at a higher figure than in the preceding four years. There has seemingly been a small increase of numbers for four or five years. The only other information on changes in numbers is the report by the Forest Supervisor in 1919 of a decrease. He says, "Squirrels seem to have suffered considerable loss last winter (1918-19), cause of which is not known" (Kaibab National Forest Reports 1905-39).

Two chipmunks are present throughout this community, and although they are more abundant along the forest edge and in rock habitats, there are numbers of them throughout the open yellow pine forest. They climb readily and forage in trees and bushes as well as on the forest floor. The small Wasatch chipmunk is perhaps the most abundant species; the difference, however, is not great, as the slightly larger Beaver mountain chipmunk is also very abundant. The numbers caught in traps near station C at Jacob's Lake show nearly a fifty-fifty ratio. Within the unbroken forest, however, the Wasatch chipmunk appears as the more abundant species. The attempt at exact estimates of chipmunk numbers is very difficult. The rapidity with which they assemble at available food, such as grain or scraps from camp, is hard to explain on the basis of what appears as an average population of three to five per acre. This estimate is based on trapping and observation in undisturbed localities.

The activity of the chipmunks appears to be a matter of direct response to weather. Some few were abroad in the yellow pine before the snow was entirely gone in early April (1931) and two were seen on a warm hillside at 8,200 feet (2,500 m.) elevation as late as the first week of November. The time when they are most active above ground and the greatest number are in evidence is from the middle of April until early October, but late storms in spring or early fall storms limit this activity. The young ones appear above ground near the middle of June.

The mantled ground squirrel is found throughout the montane forest above the piñon-juniper. Although a ground squirrel of the forested areas, it is not found in deep forest but prefers forest edges and open areas. They are most abundant at the upper edge of the yellow pine, and decrease in numbers to some degree in the higher forests and toward the lower edge of the pine forest.

Their usual abode is a burrow of their own digging or a nest under rocks or fallen trees, although in a number of places they were observed occupying the burrows made by the pocket gopher, which were well out in the mountain meadows.

The season of activity is very short in this species. In 1931 near station D, at Dry Park Ranger Station the mantled ground squirrel was first observed above ground on May 16. They were active and numerous all summer; the numbers were augmented two or three times with the appearance of the young above the ground about the first of August. Their activity continued until a thinning out of numbers was shown in early September, and the last individuals, the season's young, were last seen on September 26. The animals transported a large amount of food to their burrows but differed markedly from chipmunks in that they became extremely fat late in summer.

The food of both chipmunks and ground squirrels appeared to be very similar, consisting of most of the available seeds of herbaceous plants, especially grasses and composites. Their diet also included some green vegetation and anything available in the

line of berries and seeds of trees. Figure 7 shows the evident relative abundance of the species and distribution of the three species.

The porcupine is a widely distributed influent, resident and active year-long in the entire coniferous forest of the plateau, in the spruce-fir, the yellow pine, and the piñon-juniper communities. It shows a preference for yellow pine, and on many areas fifteen to twenty-five percent of the trees have signs of porcupine damage. South and southwestern slopes and trees of less than average vigor seem to be preferred. The damage is serious when the trees are small and the cambium is removed completely from around the trunk, causing the top to die; or when the tree is but a seedling and is completely girdled causing death to the tree.

Porcupines did not feed on conifers to any great extent during summer. From observation of these animals along forest roads, in mountain meadows and parks, and from more than a score of stomach analyses, the summer food shows a preponderance of netted-veined leaf material.

The almost total independence a porcupine shows in its wanderings on the ground away from any tree or retreat and the infrequency of evidence of their being killed by natural predators, appear as proof of the animal's ability to take care of itself. Coyotes ate with relish porcupines that were killed by man and there was evidence that on rare occasions they feasted on a fresh kill of their own. Cougars more than coyotes left evidence of having killed and eaten porcupines.

Numerous porcupine females were killed and examined. All pregnant females had but a single embryo. On the evening of May 9, 1931, five female porcupines were killed near VT Park. Two showed definite signs of having given birth to a single young a short time before. The left horn of the uterus was swollen and inflamed and milk was present in the four most pectoral teats. The other three each contained a single fully-developed young. Two of these young were kept for observation in daylight. The next forenoon they were both active and hungry, and weighed $1\frac{1}{8}$ and $1\frac{1}{4}$ pounds (510 and 565 g.). They were covered with short quills and were quick to assume the defensive attitude upon any sudden movement or noise.

Although the distribution of the porcupines is general this animal occurs in large numbers in certain favorable localities and along their regularly used lines of travel. The old Dry Park Ranger log cabin was visited nightly by porcupines attracted by salt about the doorsteps. A coyote trap caught twenty-three individuals in twenty-five consecutive nights during June and July of 1929. At the same place, in June of 1930, eight more were killed, at which time the cabin was abandoned and no further attempt was made to keep the animals from gnawing on it.

On the National Forest porcupines have been killed by forest officers at the rate of 150 to 200 a year.

The numbers have shown no marked change, but indications in 1931 were that they are increasing.

Porcupines have not been killed on the National Park. In 1931 they were extremely abundant, doing considerable damage to the conifers within the park. There is an estimated three to five porcupines per section of forest over the entire plateau.

The most abundant mammal is the omnipresent tawny white-footed mouse. It is present in all parts of the yellow pine community. There is an increase in numbers over the piñon-juniper community, but there are not as many present in the yellow pine association as are found in the higher forest. There is some increase in numbers toward the upper limits of the community.

Mammals of minor influence because of their scarcity are the bushy-tailed woodrat, the bobcat, the rock squirrel, and the cottontail. The woodrat is found in this association and above but its natural distribution is limited by locations of suitable rocky habitats. The bobcat is found in the lower portions of this association, and its range is also limited to ledges and canyon walls. This is also true of the rock squirrel, which is present in local rocky and brushy slopes. It occurs only in the extreme lower edge. The cottontail is present in small numbers throughout the forest, their distribution being dependent upon suitable cover.

BIRDS

Resident birds of most abundance and importance in this community are:

Pigmy Nuthatch	Cassin's Purple Finch
Long-crested Jay	Red-shafted Flicker
Sharp-shinned Hawk	Red-backed Junco
Rocky Mountain Nuthatch	Western Goshawk
Mountain Chickadee	Western Red-tailed Hawk

A monotonous pine forest with a single conifer as the dominant is not conducive to a large bird population. The species that occur are quite uniform throughout the forest. The forage niches of the birds present are distinctive. In most species there is a wide range in food but a limited range in territory or strata covered, such as tree trunks, ground, limbs, twigs, and crowns.

Of the resident birds the pigmy nuthatch is one of the most uniformly distributed species, and it is limited to the yellow pine forest. It forages about small limbs and twigs.

The long-crested jay is a year-long resident of the forest above the piñon-juniper. Although occasionally seen on the ground, its usual activities are in the yellow pine trees.

The sharp-shinned hawk is an influential resident, although it is not abundant. Nuthatches and the Audubon warblers seem to suffer most from this predatory species, but no species are exempt from its attacks.

The Rocky Mountain nuthatch is abundant in the yellow pine, although its range extends above this community to some extent. It is not as abundant as is the pigmy nuthatch.

The mountain chickadee breeds throughout the montane forest and is found in the yellow pine, but is much more abundant in the higher forest. This is also true of the Cassin's purple finch.

The flicker's abundance is influenced by the presence of aspens, although not limited to it, inasmuch as the bird usually nests in aspen. This bird shows a great amount of vertical migration.

The red-backed junco is resident in this association and in the forest above. It is most abundant near the upper part of the community and in many areas is the most abundant bird. Its distribution, however, is not uniform.

The goshawk is a bird of considerable importance in the interactions of this community. Only its scarcity prevents its from being a major influent. Although Arizona is considered to be the extreme southern tip of their breeding range, birds were seen during all months over three summers of study. It was estimated in 1931 that there was one goshawk per 5 sections. In the same year a nest was located and observed from the time the eggs hatched until two young birds left it. Observations of food habits showed that adult hawks feed mostly on birds, but caught rabbits, the mantled ground squirrel, the Fremont chickaree, and the Kaibab squirrel. No great inroads were made on the Kaibab squirrel, although these hawks are known to have eaten them.

Because of interest in the food of the goshawk a number of pellets were collected from under the nest of the bird during the first week of July 1931. Dr. Clarence Cottam of the United States Biological Survey gave the following identification of the material contained in them:

"Name: *Astur atricapillus*, Number: B 2956, Type: Pellet debris.

Food contents: Fragments of rabbit, fragments of 1 Sciuridae, fragments of *Colaptes c. collaris*, fragments of 1 *Cyanocitta s. diademata*, fragments of 1 ♀ *Dendroica* sp., undetermined feather fragments, part of which appeared to be from a woodpecker, possible *Sphyrapicus* sp.

Secondary or accidental food or food of undetermined origin: Fragments of: 1 Orthoptera, 3 *Campomotus* sp., 58 *Formica* sp., 6 *Myrmica* sp., 12 *Lasius* sp., 16 *Pogonomyrmex* sp., undetermined Hymenoptera, 1 Carabidae, 1 Chrysomelidae, 1 Buprestidae, 1 Tenebrionidae, 3 Lepidopterous larvae, 20 or more *Symphoromyia* sp., Dipterous pupae cases, needles of ♀ *Abies* sp., *Picea pungens*, *Pinus* sp., undetermined plant fiber."

The western red-tailed hawk is present throughout the montane forest during the summer, but is much more abundant above the yellow pine. It forages regularly in the meadows and parks, in contrast to the goshawk, which is encountered as it flies low and swiftly under the trees. The red-tailed hawk feeds primarily on rodents, and the main article in this community is the mantled ground squirrel and the chipmunks. Cases where this hawk has killed Kaibab squirrels are known.

The common or characteristic open season birds are:

Chestnut-backed Bluebird	Western Chipping Sparrow
Audubon's Warbler	Horned Owl
Natalie's Sapsucker	Band-tailed Pigeon

Of the open season birds the chestnut-backed bluebird is the most characteristic, as well as an abundant bird of the yellow pine. Although migratory, it was present in early April, and numbers were observed within the yellow pine as late as October in 1931.

The Audubon's warbler is perhaps the most abundant bird in the pure yellow pine forest, but is also present over the entire plateau. They forage about the crowns and terminal branches of the trees, where one usually locates them by their short flights out and back from the periphery of the tree. This is in decided contrast with the usual warbler activity.

The sapsucker is a very common bird. It usually nests in the aspen, but feeds a great deal on the cambium layer of the smaller yellow pines.

The chipping sparrow is common in this association, as it is over the entire plateau, but it is in this community that it is most abundant. Its favorite location is the open spaces and groves of the young pines that are typical here.

The horned owl is present in this community, but due to its retiring habits is seldom seen. They are often heard, and they forage out over the meadows and through the forest. The common nocturnal species of mammals, as *Thomomys* and *Peromyscus* and *Microtus*, are their main source of food.

The band-tailed pigeon, although uncommon, occurs here as a summer resident. It is very spotted in distribution. Formerly it was much more abundant, and reliable sources report great flocks that visited the plateau and fed on the berries. Certain of these berries, such as serviceberry (*Amelanchier*) still exist in some numbers. All of the species of berries of which the forage is palatable to deer have been reduced, and some have been killed completely.

The winter resident birds include a small increase in population of juncos. Other than that there is very little change involving an increase of species. The forest of pure yellow pine with all the herbaceous species covered by snow offers little in winter for residents and less for immigrants.

REPTILES

The single reptile that is represented in any numbers in the yellow pine community is the horned toad. It occurred throughout the association, and was most abundant where the trees were so spaced that a great amount of sunlight reached the ground.

INVERTEBRATES

Regular quantitative invertebrate collections were made at the two stations, C and D, in the yellow pine forest. Collections were taken from the ground and herb strata, and sweepings from the yellow pine were made at shrub height (three to five feet, .9 to 1.5 m.) and at a low tree height (fifteen to twenty feet, 4.6 to 6.1 m. above ground).

In point of numbers the very small species of jumping plant lice, Chermidae, plant lice, Aphidae, and

leaf-hoppers, Cicadellidae, were most abundant on the yellow pine, in both the small trees and crowns of the larger trees. Of the chermids, *Psyllia americana* Crawford, *Paratriozza cockerelli* (Sule.), and *Trioza arizonae* Aulmann were collected, the latter species being the most abundant of the three. The aphids present belonged to the genera Eulachnus and Cinara. One species of leaf-hopper or Cicadellidae was very abundant; two others were common. The abundant spiders were the immature of *Aranea cucurbitina* Clerck, *Linyphia (phrygiana?)*, *Dictyna* sp., and *Dendryphantes* sp. A large weevil, *Triclopis ornata* Horn, appeared in a great number of the collections, and flies of family Anthomyiidae, and gall flies of family Cecidomyiidae were abundant.

Ecologically the ants are perhaps the most important invertebrate group of the arid forests. They are abundant in the numbers of species and of individuals. Eighteen percent of all invertebrates taken were ants. In their activity a number of the ground species are found high in the trees and are common on the lower trees. These include *Lasius niger* var. near *sitkensis*, *Formica fusca* var. *subaenescens* and *Formica (Proformica) neogagates lasiooides* var. *vetula*. A sawfly of genus *Xyela*, a Geometrid larva, and the western syrphid fly, *Syrphus opinator* Astan Sacken, whose young feed on aphids, were also definite components of these strata.

The herb and grass stratum does not have a distinctive population here as is often the case. The vegetation covers only two to ten percent of the ground surface. This gives a mixture of herb and ground species of invertebrates, and the occurrence of species that are usually found in such type of habitat. The most conspicuous elements are the banded-winged locusts or Oedipodinae. These normally rest on the bare ground and feed on the herbaceous species. Numerous immature and a number of adults were collected in quantitative collections. The most abundant species, in order of their numbers, were: the yellow-winged locust *Trimerotropis suffusa*, *Trimerotropis pallidipennis pallidipennis*, and *Circotettix coconino*, all species showing preference for the fairly open and more sunny areas within the yellow pine forest.

The two aphids, *Aphis* sp. and *Macrosciphum* sp. (not *packi*), were abundant on herbs, as were the leaf-hoppers, Cicadellidae spp. The spiders, *Phidromus pernix*, and *Linyphia phrygiana?* and the chermid, *Paratriozza cockerelli* (Sule.) were also common species.

On the ground the abundant species were the same ants that are named in tree strata species and also *Myrmica scabrinodis* var. and *Liometopum apiculatum luctuosum*. A carabid beetle, *Dyschirius globulosus* Say, a tenebrionid of genus *Eleodes* and the centipede, *Scolopendra polymorpha* Wood were present. Following the summer rains the soil contained myriads of Collembola, which were not in evidence earlier in the season.

A very common and definite type of microhabitat existed throughout this community in the form of

dead yellow pine trees. Dead trees occur naturally throughout the forest, and some in all stages of decomposition are found. The presence of any healthy trees that are being killed at the present time by insect infestation is extremely rare or lacking, but there is normally a loss of some trees by old age, lightning, mistletoe, and other causes.

The plateau shows evidence of numerous former insect infestations. There are large areas, bug kills, covered with dead trees; some of these are extremely old, others of very recent date. The insect responsible, no doubt, for most of them is the Black Hills beetle, *Dendroctonus ponderosae* Hopkins. Collecting and cruising failed to show the presence of a single live specimen of this beetle during the three summers of 1929, 1930, 1931, yet the beetle was epidemic on the plateau from 1920 to 1925 and killed an estimated 15 million feet of standing yellow pine.

In trees that are freshly killed or weakened by the former attack of *D. ponderosae* Hopk. there were great numbers of engraver beetles, *Ips integer* Eichh. In trees that had been dead several years there were the beetles *Hylurgops subcostulatus* Mannh. and *Rhyncolus* sp., and penetrating the woods were the shot-borers, *Orthotomicus ornatus* Sw. Under the bark of all dead trees of all ages was the large black ant, *Camponotus herculeanus* var. *modoc*. (Whlr.), and the smaller one *Camponotus maculatus vicinus* var. *nitidivertris* was also frequently found. Late in the summer the large winged form of *Camponotus* was extremely abundant throughout the forest.

The absence of Mollusca is striking; none were found on the vegetation or ground surface. One species, *Oreohelix strigosa depressa* (Cockerell), occurs several feet below the ground surface, among rocks and ledges, and is rarely seen near the surface, and then only following rains.

In point of number of invertebrate animals present, the two stations showed a surprising agreement of numbers and seasonal abundance for the ground surface, herbs, and tree strata. The station collections averaged near .22 million per acre (.55 ha.), with a single serotinal maximum of about .36 million per acre (.90 million per ha.). (See Fig. 12.)

There was not the distinct bimodal curve of the piñon-juniper community; the vernal increase was later; the autumnal decrease began earlier. The population curve showed an early increase in the number of insects of the yellow pine (sweepings made of the terminal branches), followed by a fairly gradual decline in the numbers obtained in the collections. In the herbs the maximum number collected at both stations was in the twenty-sixth and twenty-seventh weeks (early July), and in both cases there was a considerable number at this stratum until the thirty-sixth week (September 1). The number on ground stratum varied, but no significant changes were apparent during the season.

In each station the smaller yellow pine trees (those less than six feet tall) were swept. This was done to determine the difference in invertebrate population of pines, those very severely browsed as compared

with those browsed only slightly. At station D the small trees had the appearance of artificially trimmed conifers, with the periphery of the tree a compact growth of needles, due to the deer's constant check on them.

At station C trees were of nearly normal reproduction. The numbers of invertebrate animals present under these two conditions differed greatly. There were nearly twice as many in the sweeping from the browsed pine. The species were, in the main, Aphidae, Cicadellidae, Chermidae, and ants. There was an increase of certain smaller invertebrates with the compact arrangement of the needles; also, the yearly browsing left the trees somewhat damaged and the wounds caused by such attacks attracted certain

species. The damage resulting from the increased infestation is perhaps of minor importance in comparison with the effect on the trees of losing their terminal shoots each spring, year after year.

Within the yellow pine association of the montane forest biome, the invertebrate population showed some definite characteristics, namely:

- (1) Greatest summer population in the herb stratum.
- (2) Early seasonal maximum in invertebrate population of yellow pine.
- (3) No significant variation shown in ground species.
- (4) A marked increase of invertebrates on heavily browsed trees.

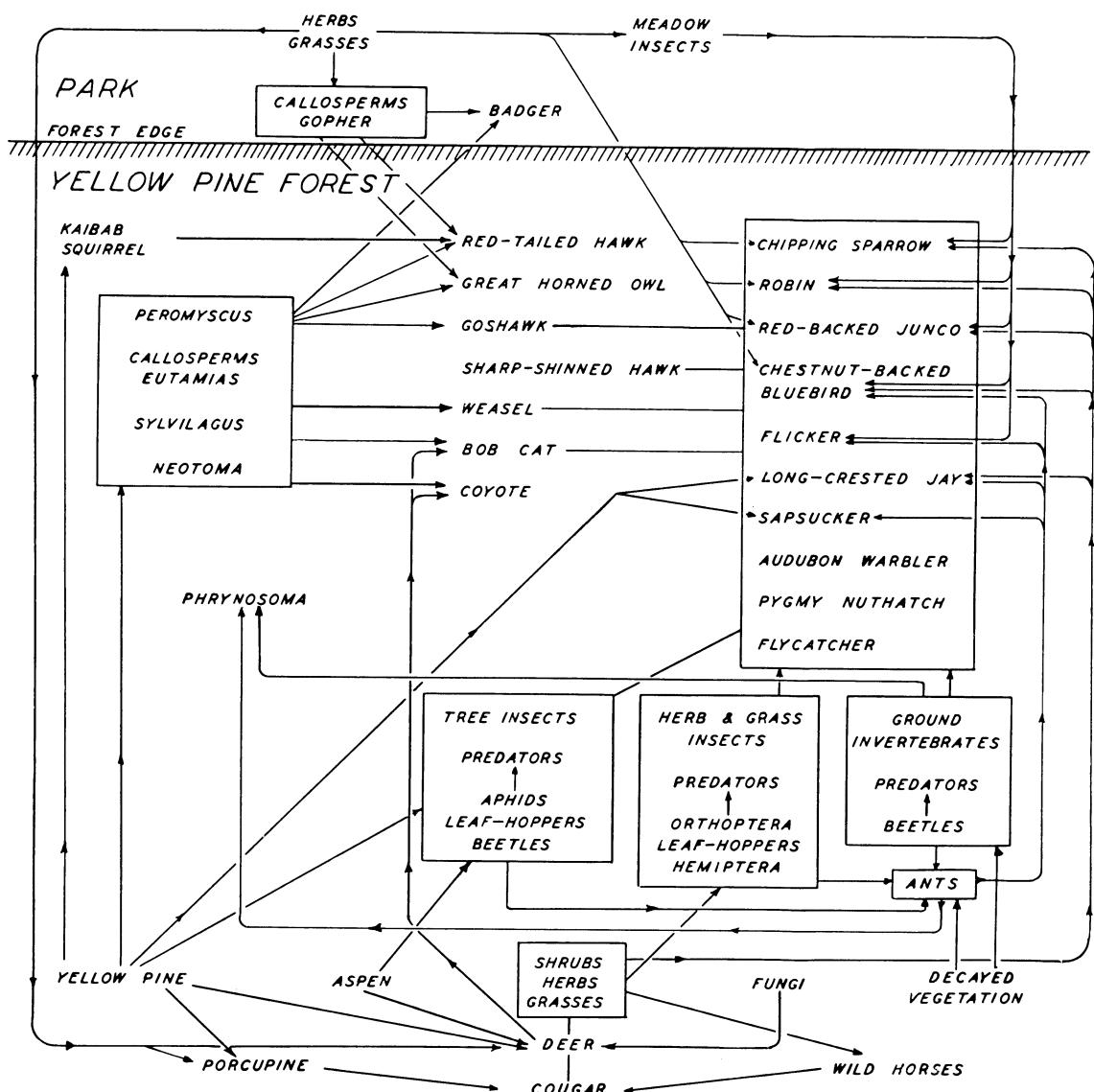


FIG. 16. Diagram of food chain or food coaction within climax yellow pine forest and bordering grassland. Arrows point from animals or plants eaten to the animals that eat them.

(5) The presence of great numbers of insects not obtained by sweeping, as shown by foraging habits of certain birds.

(6) A very definite microhabitat in the form of the dead yellow pine trees, the invertebrates of which are of considerable importance in the community, but are independent of usual stratification.

Figure 16 pictures diagrammatically the food chain or food coaction with the yellow pine community and bordering park of grassland.

VIII. THE MONTANE FOREST CLIMAX THE *Picea-Abies-Sciurus fremonti* ASSOCIATION

GENERAL

A mixed coniferous forest occurs above the yellow pine. The uniformity of its physiognomy and similarities as concerns many influent animal species lead to its consideration as a single large biotic community, although the dominant trees that are present there have been given as typical of the two plant formations, i.e., montane and subalpine (Clements, '16).

This mixed forest occurs above an average of 8,200 feet (2,500 m.) elevation and includes the highest portions of the plateau. It has an area of 112,200 acres (45,400 ha.). A number of the dominant trees occur at lower elevation on cool slopes and in the canyons some below 6,800 feet (2,075 m.) within the Grand Canyon.



FIG. 17. Montane forest climax (*Picea-Abies-Sciurus fremonti* Association).

The forest differs greatly in appearance from that of the yellow pine (Fig. 17). The trees are closely spaced, and in certain localities there is a great amount of fallen timber, making travel through the forest extremely difficult.

VEGETATION

The dominant trees are the two spruces, *Picea engelmanni*, and *Picea pungens*; the Douglas fir, *Pseudotsuga taxifolia*; the white fir, *Abies concolor*. Aspen, *Populus aurea*, and yellow pine, *Pinus brachyptera*, occur throughout the forest, but appear to be of secondary importance.

The occurrence of the trees is uniform only in a general way. *Abies concolor* and *Pseudotsuga taxifolia* extend downward slightly more than do the spruces, but they also dominate the highest ridges. *Picea pungens* shows a preference for the edge of meadows; the *Pinus brachyptera*, when it occurs in any numbers, is on the more exposed hillsides. *Populus aurea*, although a subclimax tree, is present throughout the forest; very few, if any, forest areas of an acre or larger show an absence of this species. Other areas show definitely the reproduction of spruce under the aspen. In some local areas the aspen forms practically pure stands.

Throughout the community, but especially abundant at the higher elevations, is the dwarf juniper, *Juniperus communis*. At some localities it forms a definite shrub stratum. This is the only shrub of great importance and is the single species other than tree species that appears to be of major importance. A few individuals of alpine fir, *Abies lasiocarpa*, are present near the summit of the plateau, but occurrence is too rare to be important.

Sample counts of tree species present in this association are shown in Table 6.

TABLE 6. 1/10 acre (1/25 ha) of mature spruce-fir forest. 9,000-foot elevation. VT Park, Arizona.

	Seedling	1-6	6-12	12-18	18-24	24-26
North-facing slope 10% grade						
Diameter breast high in inches						
<i>Picea engelmanni</i>	23	20	10	10	6	1
<i>Pseudotsuga taxifolia</i>	23	23	4			
<i>Abies concolor</i>	1	3	1	1		
<i>Populus tremuloides aurea</i>	1	3	2	1		
<i>Juniperus communis</i>	2*					
South-facing slope 10% grade						
<i>Picea pungens</i>						14
<i>Populus tremuloides aurea</i>	7					
<i>Juniperus communis</i>	38*					

*Mature shrubs.

There are a number of shrubs of minor importance. *Symphoricarpos* sp. is found in the more open situations. This shrub has, in the past, been a conspicuous plant, but has been greatly limited by the deer. It now occurs as small, compact bushes showing the result of heavy summer overbrowsing or as dead bushes. Numerous dead plants of this species are present. There are a number of old dead willow,

Salix sp., showing evidence of having been killed by deer browsing. It is doubtful that more than a few individuals of this species are now alive on the summit of the plateau, and a few years of current usage will completely destroy the evidence of its former occurrence. *Odostemon repens* is present in considerable numbers, and there are a few individuals of *Ceanothus fendleri*, and a species of *Chrysothamnus* in certain localities.

Ordinarily a forest of this type contains a great number of seedling aspens, but the numbers that are present on the plateau from 1929 to 1931 could almost be enumerated. From examinations of young aspen trees and shoots there have been extremely few young trees established during the period of 1916 to 1932. Only the exceptional tree has been able to grow tall enough to get out of reach of the deer during that period.

Where the conifers and aspen occur in compact stands, there is very little growth of herb and grass species. A few characteristic plants occur, but the area is extremely poor in the amount of this type of vegetation.

Beneath the heavy forest there exists a great amount of lichens, liverworts, and mosses. A species of *Carex* is the most abundant seed plant. Two shin-leaves, *Pyrola secunda* and *P. picta*, are both typical of this situation. The common plants occurring where there is not complete shade are the *Fragaria platyptala*, *Antennaria* sp., the *Geranium fremontii*, the grass, *Bromus porteri*, and the twinflower, *Linnaea borealis americana*. Where there is considerable penetration of sunlight one finds many of the meadow herbs, or *Potentilla* spp., *Silene douglasii*, and *Eriogonum* spp.

The combined rainfall for July and August averages in excess of five inches and under usual conditions there is production of enormous quantities and a great number of species of fungi throughout the whole montane forest, but especially in these higher areas. Here they grow abundantly over the forest floor and the meadows, often several per square meter, and many species growing to large size. During 1930 over twenty varieties were distinguished on the plateau. They were very palatable to the deer and they apparently fed on all of them, including certain of the poison amanitas. The red amanita, *Amanita muscaria*, was the most abundant; it grew to large size and was readily eaten by both deer and the chickaree. There was, however, no evidence of sickness or death resulting from their eating any of this species. The most conspicuous fungi were several species each of *Boletus*, *Boletinus*, *Russula* and *Amanita*. In addition there were species of *Agaricus*, *Coprinus*, *Collybia*, *Clitocybe*, *Cortinarius*, *Marasmius* and others. Also large numbers of the puff balls, *Lycoperdon* and bracket fungi, *Polyporus*.

MAMMALS

The mule deer is also the most important animal here in point of influence on this biotic community.

If an animal becomes dominant on land, it would be of the type demonstrated here, where it exercises an influence over the entire community, changes the natural order of things, prevents the growth of several species of woody plants, and by selective browsing favors other species.

The deer enter this community in early May, and remain here until storms drive them out in late September or October. The number per unit area here is not as significant as in the two other forest communities. The distribution is greatly influenced by the presence of meadows, thin stands of trees, open hillsides, and a variety of local conditions. The existence of a compact growth of timber provides extremely poor deer range.

There is a concentration of deer about VT Park, as shown by the map of deer abundance (Fig. 11). This area of forest in vicinity of VT Park is nearly devoid of deer food; the proximity of the meadows explains their presence, although they normally spend their days in the forest. They come a distance of one mile (1.6 km.) from back in the forest to the open meadows during early summer. On the basis of deer seen in the meadow and deer remaining out of the meadow, but in nearby areas, there are estimated 45 deer per section (640 acres, 260 ha.). This is the area of greatest summer concentration.

With the appearance of great numbers of fungi in the late summer of normally wet years, the majority of deer forsake the meadow and the distribution is fairly uniform through the forest.

It is impossible to say what percentage of the various plants were utilized by the deer as food under former conditions. At the present time, there is an unnatural condition as shown by the complete elimination of some species. Field observations, in addition to stomach analyses of twenty deer killed by cars and predators, have provided data for summer section of deer's food habits diagram (Fig. 18).

The following general statements can be made concerning the deer in this community:

1. The more desirable food plants have been eliminated or greatly limited in the amount of available forage.

2. Of the dominant tree species deer eat a great amount of *Abies concolor*, *Populus aurea*, and *Pinus brachyptera*. They eat a small amount of *Picea pungens* and *P. engelmanni* and *Pseudotsuga taxifolia*, and rarely *Juniperus communis* and *A. lasiocarpa*.

3. Netted veined plants make up the greater bulk of their food. There is a wide variety, but considerable selection of desirable species.

4. There is a very definite seasonal selection; for example, yellow pine is eaten mostly in early spring, as are certain pre-vernal and vernal herbs; aspen shoots are eaten in greater amounts in late summer, and certain species of the genus *Lupinus* are heavily utilized in the late summer and fall, but show little usage during summer.

5. Use is made of food that is available for short periods, as aspen leaves, which may make up seventy-

five percent or more of the stomach content of deer killed in early fall. Mushrooms often compose fifty percent or more of deer food for a period in late summer.

6. Extremely little grass is eaten, even with the paucity of preferred foods. Grass rarely consists of as much as fifteen to twenty percent of the food eaten and more often is less than ten percent.

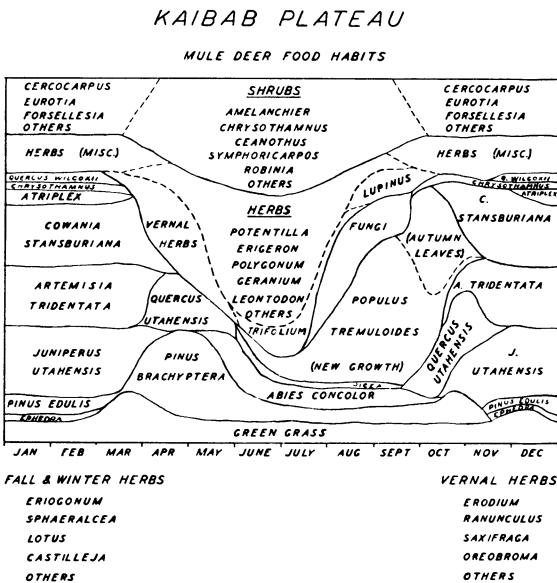


FIG. 18. Generalized year-long food habits of mule deer, Kaibab Plateau, Arizona, 1929-1931, inclusive. Height of graph equals total food taken by deer spending summer at higher portions of the plateau and migrating at peaks of migration. Based on analysis of approximately sixty stomachs and year-long field observations.

The coyote occurs here in numbers of thirty-six to forty per township during the open season; a few remain here all winter. Their main summer food is the small rodents *Peromyscus*, *Citellus*, and *Eutamias*, supplemented by a variety of minor foods, including a large number of Orthoptera. There is no marked difference in the relation of the coyote here and in the yellow pine community to rodents and deer.

Influent mammals of lesser importance are:

Fremont Chickaree	Beaver Mountain
Yellow-haired Porcupine	Chipmunk
Tawny White-footed Mouse	Wasatch Chipmunk
Mantled Ground Squirrel	Colorado Bush-tailed
Arizona Weasel	Woodrat

All of these animals, excepting the chickaree or the red squirrel and the weasel, have been discussed in their relation to the biotics within the yellow pine community of the montane forest. The difference is not great as concerns their activity and importance in the spruce-fir. There is some change in relative abundance and in the difference in population per unit area. Some differences between the yellow pine

and mixed coniferous forests are shown in their abundance (Fig. 7).

The chickaree is a climax influent and occurs throughout this community. Its distribution is confined to areas where *Abies*, *Pseudotsuga*, or *Picea* occur. This is true at the extreme lower borders of the association, where the lowest extension of any one of these trees marks the lower limits of the squirrel's range. But at these lower elevations the squirrel middens show great preponderance of yellow pine cones. This squirrel, because of some factor other than food, perhaps shelter, does not occur in the pure yellow pine forest.

During late August, while gathering the cones of *Picea pungens*, they appeared in numbers of several per acre in the narrow strip of the blue spruce along certain meadows. On the basis of early summer counts, it was estimated that there was one squirrel per fifteen acres (six ha.) of mixed coniferous forest.

The food of this squirrel is a variety of seeds of conifers and some few herbs and fungi. It is active the year-long, but depends upon its caches of food for winter subsistence. These food stores showed a preference for *Picea pungens* and *Pseudotsuga taxifolia*, with some *Pinus brachyptera* and *Abies concolor*. The latter two were eaten in large quantities during late summer. Their habit of storing mushrooms is usually shown by investigations of their caches in the fall. Mushrooms drying on the limbs of conifers are a familiar sight during the late summer.

There is a little overlapping of range of the chickaree with Kaibab squirrel, but no great mingling or avoiding of each other. The distribution of both species can be explained purely on the basis of the presence of certain conifers.

The weasel occurs throughout the montane forest. It is more in evidence in the higher forest, due, no doubt, to relative greater abundance of rodents. Individuals were observed killing *Citellus* and *Eutamias*.

The porcupine is more numerous per unit area than in the yellow pine association.

The chipmunks are more abundant in the spruce-fir than the yellow pine, but the great amount of suitable habitat of forest edge type seemed to be the factor accounting for this. The ratio of species was changed. Instead of a one-to-one ratio that exists within the yellow pine, here there are four or five *Eutamias adsitus* to each *E. minimus consobrinus*.

The tawny white-footed mouse is common, but not as abundant as in the yellow pine association.

BIRDS

Although the mammal species were fairly well distributed over both the yellow pine and mixed coniferous portions of the montane forest, many bird species show marked selection for one or the other of these associations. Certain species are wide-ranging; others, especially the open season birds, are typical of the spruce-fir community.

A number of species are closely associated with the aspen, and its occurrence throughout this community

accounts for distribution of part of the species, while the mountain meadow-montane forest border accounts for a number of others.

Resident birds of the community are:

Long-crested Jay	Sharp-shinned Hawk
Mountain Chickadee	Red-backed Junco
Alpine Three-toed Woodpecker	White-breasted Woodpecker
Woodpecker	Rocky Mountain Nuthatch
Dusky Grouse	Red-shafted Flicker

Open season birds are:

Mountain Bluebird	Cassin's Purple Finch
Pine Siskin	Western Robin
Natalie's Sapsucker	Western Evening Grosbeak
Olive-sided Flycatcher	Wright's Flycatcher
Violet-green Swallow	Western Ruby-crowned Kinglet
Audubon's Warbler	Kinglet
Western Warbling Vireo	Western Chipping Sparrow
Audubon's Hermit Thrush	Townsend's Solitaire

The greatest bird population of the plateau occurs along the borders of the meadow. The robin, mountain bluebird, flycatchers, chipping sparrow, junco, and flicker are typical here. The warbling vireo shows a preference for a forest of aspen. The deep forest has the Audubon's hermit thrush and the Townsend's solitaire. In the tree-tops the purple finch and evening grosbeak are found. The terminal limbs are forage ground for the kinglet and the chickadee; the limbs and tree trunks for the woodpeckers, nuthatch, and sapsucker, and oddly enough, the long-crested jay. The dusky grouse occurs in certain local areas near the canyon rim, usually in localities that have abundant growth of *Juniperus communis*. A number of the species present only in the open season in this community were present in winter around the base of the plateau and are in reality year-long residents of the plateau.

Area counts differ greatly for bird populations. A forest edge of blue spruce and aspen gave in a selected two-acre (.81 ha.) plot the actual nesting records in 1931 of nine pairs of birds: two kinglets, two chipping sparrows, one chickadee, one olive-sided flycatcher, one warbling vireo, one mountain bluebird, and one flicker. This area included the VT Ranger Station, at an 8,900-foot (2,715 m.) elevation.

IX. MOUNTAIN GRASSLAND

Stipa-Carex-Thomomys ASSOCIES

MEADOWS AND PARKS

There are some 10,000 to 15,000 acres (4,000 to 6,000 ha.) of open parks and meadows present on the entire plateau. These vary greatly in size, but are very similar in their general appearance and features. They are located, as a rule, in fairly level basins and in the bottom of shallow valleys.

Certain localities show an interesting phenomenon in the presence of a near timber-line or Krumholz condition along the meadow border at the foot of a forested slope at an elevation of 9,000 feet (2,740 m.). A factor study in VT (De Motte) Park, the Plateau's most famous park, showed a marked dif-

ference in daily minimum temperatures in adjacent forest and meadow (Fig. 4). (Mead, '30.)

Care, however, must be used in not assigning the environment created by the forest as the explanation of its presence. Climatic factors, influenced by air currents and soil differences, may account for the occurrence of these parks and meadows. Explanation of these areas as resulting from forest fires does not seem reasonable on the Kaibab Plateau. There is a usual growth of small conifers along their edges, giving the appearance of invasion of forest species. These trees, however, show by the annual growth rings that they are much older than they appear. Sample blue spruces of less than five feet (1.5 m.) in height present on the edge of the meadow showed as many as thirty annual rings. But in the forest proper, fifteen to twenty feet (4.6 to 6.1 m.) from the edge of the meadow, spruces of six inches (15 cm.) diameter and thirty-five feet (11 m.) height were shown to be the same age.

VT Park, the second largest park of the plateau, and named from the cattle brand of the first large cattle outfit that controlled the area, has an elevation of 8,800 to 9,100 feet (2,680 to 2,775 m.) and an area of approximately 3,000 acres (1,200 ha.). The main road to the north rim extends the length of the park, and this is the location in which deer are most abundant during the summer and most often seen by visitors to the Kaibab.

The explanation of deer presence and variation in numbers in the meadows has been one of the interesting features to observe during this study. Figure 19 shows the evening counts in the northern end of VT Park during the summers of 1930 and 1931. This is an area of 750 acres (305 ha.) bordered by spruce-fir-aspen forest. The maximum number of deer visiting the area is believed to represent near the total population for a radius of one mile (1.6 km.) of the meadows or 2,500 acres (1,000 ha.) of forest.

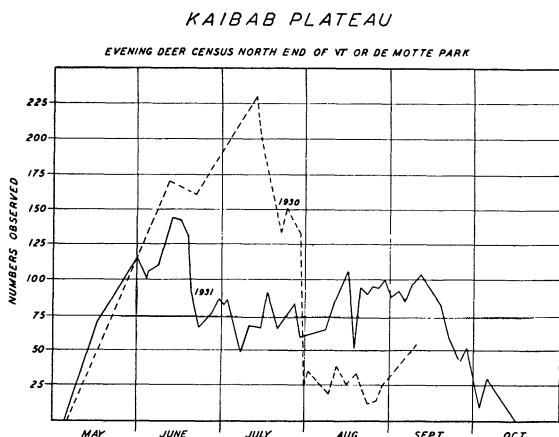


FIG. 19. Evening deer census at the north end of VT (De Motte) Park, Kaibab Plateau, Arizona. Counts made at sundown during years 1930 and 1931 in an area of approximately 750 acres (305 ha.).

The 1930 and 1931 data differ markedly in two respects, namely, (1) maximum number of deer in 1930 is greater than 1931. This appears to be indicative of differences in total summer population between the two years, although perhaps this is somewhat exaggerated; (2) the marked difference in late summer population between the two years is directly correlated with precipitation. In 1930 the first heavy summer rain storm occurred on July 12,



FIG. 20. Fenced plot at border of mountain park summit of plateau, showing growth of quaking aspen, *Populus aurea* and spruce, *Picea pungens*, when given eight years protection from deer browsing. Spruces are hedged and no aspen are conspicuous enough to show on picture outside of plot.

and storms continued regularly during the remainder of July and August, resulting in the production of enormous numbers of mushrooms. The deer left the meadow and were observed throughout the montane forest feeding on the fungi. A similar change in numbers occurred in 1929, also a year with abundant late summer rains. In 1931 the first heavy summer storm occurred on July 28-29, but rains did not continue after that time. No mushroom crop was produced that year. Deer continued to visit the meadows until the aspen leaves began to fall, although under these dry conditions the mountain clover in the parks provide very little of the late summer food.

The sex ratio of the deer herd differed in different localities during the summer, but was consistent on individual areas. The group in the north end of VT Park, exclusive of fawns present in late summer, averaged 60% does, 23% yearlings, and 17% bucks during 1931. During the same year a herd in the southern part of VT Park consisted of 61% adult bucks, 11% yearlings, and 28% does. A small number of fawns appeared in the meadow during late August and September. Maximum counts of the southern herd were 288, June 22, 1930, and 188, August 10, 1931.

From all evidence, it appears that the habit of the deer of visiting the meadows as they now do is a

fairly recent change in their activity. The livestock men who have spent years on the plateau say that deer first began visiting the park in large numbers about 1916 and that before that time there was little or no use of the meadow by the deer. T. G. Pearson (1925) reported counting 1,028 deer on the evening of August 21, 1924. This was at the time of maximum numbers visiting the meadow. The present poor condition of adjoining summer range and small amount of available food indicated that the deer, by all evidence, were forced into the meadow in order to obtain forage.

The future existence of the herd will depend on a variety of factors affecting biotic balance. Present indications are that the numbers that visit the meadows will continue to decrease with an increase in desirable forage near-by, and that restoration of near natural conditions to the plateau will limit the number of deer that visit the open parks each evening. This was the situation at the time the area was first set apart as a game preserve. Restoration of the former large show herds would no doubt indicate once again the absence of suitable and sufficient forage in the surrounding forests.

VEGETATION

There are two definite divisions of the meadows that are recognizable. One is the low, more mesic portion, where the deer ordinarily concentrate, and where near 90% of the vegetation consists of netted-veined plants. The bulk of this consists of several species of *Trifolium*, with dandelions, both *Agoseris* and *Leontodon*, a small *Erigeron*, *Achillea lanulosa*, *Potentilla*, *Ranunculus subsagittatus*, and *R. alismellus*. Species of *Polygonum* occur on newer denuded areas. The grass and grass-like species composing about 10% of the vegetation of this part of the mountain meadows are mainly *Phleum alpinum* and species of *Poa*, *Deschampsia* and *Carex*.

In the higher and more xeric portions of the park, the grass makes up near 50% of the total ground cover. The grasses consist of species of *Deschampsia* and *Festuca* with *Blepharoneuron tricholepis*, *Stipa comata* and some others. The most conspicuous herb species include species of *Antennaria*, *Eriogonum*, *Potentilla*, *Saxifraga*, a tall *Erigeron*, *Phlox caespitosa*, *Pseudocymopterus montanus*, *Actinea richardsonii*, *Orthocarpus purpureo-albus*, and *O. luteus*.

The favorite food of the deer visiting the meadow is several species of the Mountain clover or *Trifolium* spp. This is preferred to all other meadow species. They eat many other herbs readily, but only a very small amount of grass. The two main areas of clover are in close proximity of the only two springs in the park, one north of the VT hotel and one near Mason Well, four miles (6.4 km.) south of the hotel. In the days of big cattle outfits, VT Park was the summer headquarters, and the area was grazed continually by horses and subject to overgrazing by herds of cattle that were collected there.

Influent animals of the meadows and parks are:	
Mexican Badger	Colorado Pocket Gopher
Rocky Mountain Meadow Mouse	Mantled Ground Squirrel
Wasatch Chipmunk	Beaver Mountain Chipmunk
Sparrow Hawk	American Raven
Mexican Locust	Pellucid Locust
Yellow-winged Locust	Mormon Cricket

The badger is found at all elevations on the Kaibab where there is grassland or open type of country and a sufficient abundance of burrowing rodents. Its numbers are not great, but one is occasionally seen in the mountain parks and in the sage valleys of the lower portions of the piñon-juniper. Evidence of their digging for pocket gophers and other rodents is often seen. The total estimate for the plateau is 100 to 150.

The pocket gopher is fairly abundant throughout the meadows where the soil is sufficient for burrows and not subject to flooding. It is the only mammal that is regular in its distribution over the meadow. It is active year-long, as evidenced by the earth plugs present over the surface of the ground following the melting of snows. They obtain most of their food by digging, but occasionally one is observed snatching food from near the mouth of its burrow.

The Rocky Mountain meadow mouse is found in the more mesic situations, where there is sufficient cover in the way of rank growing grass. The distribution, however, is limited.

The mantled ground squirrel and the chipmunks have been discussed in relation to forest edges. The ground squirrel, especially, is abundant at the edge of meadows, enough so as to exercise considerable pressure on plant growth.

There are no birds limited to these areas, but the bluebird, the robin, and in late summer, the sparrow hawk, forage regularly over the meadows. All three species were observed feeding on the abundant grasshoppers. During the summer flocks of ravens fed regularly on grasshoppers and the large crickets in these high meadows.

Orthoptera make up the most important invertebrate group in this community. The abundant species are the Mexican locust, the pellucid locust, the yellow-winged locust, and the large western or Mormon cricket.

X. ADJACENT COMMUNITIES

SHORT-GRASS GRASSLAND

Although present vegetation maps fail to show it, there exists at the eastern edge of the Kaibab Plateau an area of some two hundred square miles of grassland. This is Houserock Valley. The severe overgrazing by domestic stock has left only a part of the former ground-cover of sod. The truly good grassland that remains is too far from water for cattle to pasture it closely during the dry season. In years of abundant rainfall the whole area regains, in part, the aspect ascribed to it before the great herds of cattle both wintered and summered there.

The vegetation is dominated by grama grasses, *Bouteloua gracilis* and *B. curtipendula* which in much

of the area constitutes a pure sod. Other prominent grasses are galleta grass, *Hilaria jamesii*, and on sand areas, *Sporobolus cryptandrus*. Small areas of false buffalo grass, *Munroa squarrosa*, burro grass, *Scleropogon brevifolius*, crowfoot and black grama, *Bouteloua rothrockii* and *B. eriopoda* are present. There are several species of caeti, *Atriplex canescens*, and a variety of shrub species.

Formerly this valley had abundant pronghorn antelope. One very old Kaibabit Indian, "Indian Charley," tells of trips he made there as a young man to hunt these animals. He reports that the Indians dug pits in which they concealed themselves until the antelope approached near enough to be shot with bows and arrows.

At present this area supports a semi-tame herd of bison that were introduced there several years ago and are now owned by the State of Arizona. Although there are no records of their former existence in this region, the herd of some 200 individuals is very much at home there. It ranges over the area, as the species formerly, no doubt, did in the short-grass plains of western Texas and New Mexico.

The area contains smaller vertebrates typical of the short-grass plains. Two species of kangaroo rats, one known as the Houserock Valley kangaroo rat, pocket mice, the Houserock Valley pocket gopher, grasshopper mice, the horned lark, and lizards of the genera *Uta* and *Sceloporus* are common.

There is also an area of short-grass grassland between Kanab Creek and the piñon-juniper and yellow pine areas of Mt. Trumbull. Dutton ('82, p. 104) tells of luxuriant grass present in the neighborhood of Pipe Springs in 1872. He returned ten years later and said, "Today hardly a blade of grass is to be found within ten miles of the spring unless on the crags and mesas of the Vermillion cliffs behind it." Overgrazing by the concentration of livestock about this famous watering hole had changed the vegetation of the whole area in a single decade.

BASIN SAGEBRUSH

Toward the northern and northwestern portions of the plateau there exist areas of *Artemesia tridentata*, an extension of the very generally distributed climax of the Great Basin. The growth is not as rank as in fertile Utah valleys, but the appearance is typical. Like most lowland sagebrush areas in the Great Basin, the associated grass species have almost all been destroyed by indiscriminate and unregulated grazing.

Such characteristic vertebrates as the sage thrasher, the vesper sparrow, Brewer's sparrow, the lark sparrow, the night hawk, the mourning dove, the sagebrush swift lizard, and the black-tailed jack rabbit are present in this association.

CANYON DESERT SCRUB

Toward the western border of the Grand Canyon proper and under the plateau along Kanab Creek is the broad Esplanade that has an area of 64,000 acres (25,900 ha.) covered with a very characteristic vegetation. Counts of the dominant plant, *Coleogyne ramo-*

sissima, showed it to make up 90% of the vegetation on the level areas. Other shrubs were *Yucca baccata*, *Ephedra torreyana*, *Quercus wilcoxii*, *Chrysothamnus* sp. and elephant ears, *Opuntia*. In the ravines *Fallugia paradoxa*, the most abundant shrub, made up about 60% and *Quercus wilcoxii* comprised near 20% of the shrubs present. *Rhus trilobata* was nearly as abundant as live oak.

The animals here include typical desert rodents, birds, and lizards. The antelope ground squirrel is the most common and uniformly distributed mammal, although the area abounds in both variety and numbers of the smaller rodents.

XI. SUMMARY

The area studied is in northern Arizona between the Grand Canyon of the Colorado and the Arizona-Utah boundary. It is a high block plateau with an area of approximately 1,650 square miles (4,275 square km.) and is included in those portions of the Kaibab National Forest and Grand Canyon National Park occurring north of the Colorado River.

The plateau proper has four major biotic communities: (1) *Picea-Abies-Sciurus fremonti* association of the montane forest climax between 8,200 feet and the plateau summit of 9,200 feet (2,500 to 2,800 m.), (2) the *Pinus brachyptera-Sciurus kaibabensis* association of the montane forest climax between 6,800 and 8,200 feet (2,075 to 2,500 m.), (3) the *Pinus-Juniperus-Neotoma* association of the woodland climax between 5,500 and 6,800 feet (1,675 to 2,075 m.) and (4) the *Stipa-Carex-Thomomys* associates or mountain grassland consisting of small areas above 7,800 feet (2,380 m.). Two major plant associations occur on the border and adjoining the plateau: (1) the short-grass grassland to the east and west and (2) Basin sagebrush to the north and northwest both below 5,500 feet (1,675 m.) and above 4,000 feet (1,220 m.). There are also two minor communities present on the edge of the plateau: canyon desert scrub below 5,000 feet (1,525 m.) located within the Grand Canyon; and a narrow discontinuous belt of oak-brush or Petran chaparral at an average elevation of 6,800 feet (2,075 m.).

The general range, seasonal or year long, of many animals found on the plateau is in agreement with the extensive plant communities. The motility of the animals, however, causes them not to show as definite marks of limitation to communities as do the sessile plant species. The range of the animals within the community is very often dependent upon local and subelimax situations and frequently the majority of mammal and bird species are associated with local conditions. However, the correlation of the plant and animal communities in their spatial relationships and their interdependence justifies their consideration as biotic communities.

The relative equal rank of "formations" (Clements, 1920) for the three mountain forests apparently does not hold in their classification as major biotic communities when a study is made of the influent animal species. There are definite recognizable major dif-

ferences between the xerophytic piñon-juniper woodland and the montane forests, but there are only minor differences between the yellow pine and spruce-fir on the basis of a study of influent animal species. Each montane forest community has some typical birds and at least one typical abundant mammal. A number of species of importance are present in both communities. On a basis of the consideration of influent animals the two montane forest communities on the Kaibab Plateau should be considered as associational rank and not formational.

The native animals of major influence in the community biotics on this area are large wide ranging mammals as deer, mountain lion and coyote; their presence during the short open season in the higher portion of the plateau and a longer period in the lower borders influences relations within the community more than do the resident animals. Influential animal groups on this area in order of their importance appear to be mammals, birds, insects, and reptiles. This order is believed to apply to the relative importance of the animals under primitive conditions on the same area.

There is a definite physiological rhythm in the animals and their activity associated with change in environmental factors due to elevation. This is shown in the time of abundance and the activity of the different animal species. The adjustment may be carried out by migration, hibernation or inactivity. Invertebrate collections show agreement with seasonal progress at different altitudes as did the early spring maxima of birds. This activity was approximately one day later in each 125 feet of latitude between the piñon-juniper and yellow pine study stations. The annual rhythm of many of the animals appears to be independent of actual climatic conditions, while others show a direct response to such conditions.

In the case of the mule deer, their time of migration both upward and downward on this area is correlated with climatic conditions. The Kaibab deer herd, however, very definitely show in their migration activity responses that cannot be explained on the basis of climatic changes, available food, lack of water, snow depth, or unfavorable terrain. The migration routes and direction appear to be a herd habit or tradition response and there are two major herds, one that migrates east and one west and these consist of several minor herds that return to definite wintering areas in these two general ranges. These definite regular migrations into depleted areas and the unwillingness to visit near-by apparently favorable areas have contributed greatly to the seriousness of the overpopulation problem on the area.

A review of the history of the Kaibab plateau from 1906 to 1940 shows variations in numbers of native animals. There has been a steady increase and sudden decrease in deer numbers; no evident increase in certain animals that have been encouraged by protection as the blue grouse; both increases and decreases in the record of the attractive Kaibab squirrel; a decrease in numbers of animals due to hunting as the case of the mountain lion and the extermination

of the timber wolf from the area; a very marked decrease in the band-tailed pigeon, a protected species; an increase in coyotes and porcupines even with moderate "control" measures and unknown fluctuations in rodents, rabbits, birds, and invertebrates. During the same time there has been a marked decrease in the numbers of domestic livestock and feral horses utilizing the area under a program designed to benefit the deer.

The vegetation of the plateau has been modified greatly by both livestock and deer during historic times. The entire plateau was severely overgrazed in the late 1880's by domestic livestock, severe enough that the general vegetational aspect was apparently changed. The result was that the livestock numbers were reduced because of the lack of forage. During the period of 1915 to 1935 a second but no less severe overgrazing took place on the plateau as a result of an overabundance of deer. Certain forage species as *Salix* and *Rubus* have been almost exterminated by this overgrazing. The growth of young aspen was halted over a period of these 20 years and an ideal winter browse range was overutilized to such an extent that carrying capacity was reduced on large areas to an estimated 5 to 10 percent of original conditions. Killing of a large percentage of browse species on much of the winter range, coupled with curtailment of use by cattle and horses has resulted in a very marked change in the composition of the vegetation on these areas. The grass is favored by the extremely small amount of utilization it receives from deer; the browse species are held in check by the moderate to heavy use they receive, with the result that grass is constituting more and more of the total vegetation.

The recent changes in animal numbers and the marked changes in the vegetation of the Kaibab plateau are evidently due in the main to biotic processes, including man, and have been influenced only in a minor way by climatic conditions. The deer herd was protected from hunting by Indians and white men; there began a program of range improvement by reducing the livestock use of the area, and a very intensive predator control program under government supervision was inaugurated. From 1906 to 1924, 674 mountain lions, 21 timber wolves, and 3,025 coyotes were removed from the area (Figure 5). This resulted in almost extermination of the wolves (a final nine were taken in 1926), it exercised a marked control on lion numbers, and a reported decrease in coyote numbers. (However, following this period, coinciding with the enormous losses of deer on the winter range, a decrease in the intensity of the control operation and the elimination of the wolves, there was an increase in the number of coyotes.)

The discontinuing of hunting and limiting of natural enemies on this almost perfect deer range is believed to have operated jointly in favoring the initial increase in deer numbers. Brooks (1926) has explained the abundance and scarcity of deer in British Columbia as influenced by the occurrence of the mountain lion, and the increase on the Kaibab is believed to have been definitely influenced by limitation

of lion numbers as well as the control of other predators.

The number of deer, estimated as 4,000 in 1906, increased to an enormous herd estimated at nearly 100,000 at their peak in 1924. This was an annual accumulative increase of approximately 20 percent over the 18-year period. With these enormous numbers both summer and winter ranges were depleted and available food for the deer was only a fraction of what the range could produce under moderate use. This resulted in a catastrophe. The deer died by the thousands. Extremely few fawns survived during the winters of 1924 to 1928, and this resulted in the composition of the herd becoming top heavy with old deer; the normal mortality of old deer continued, perhaps even increased due to the poor forage condition, but more serious was the fact that no young deer survived to replace the older animals. This would have resulted in an accelerated downward trend in total numbers even in the absence of any removal by hunters.

After an enormous amount of controversy and delay following recognition of the problem, sportsman hunting was first inaugurated in 1924 and 683 deer were killed that year. Hunting has continued each year since that time, with the greatest annual removal in 1930 when 5,033 were killed. These removals from a herd composed of old deer accelerated the downward trend of total numbers but was not the primary cause of controlling numbers of deer on the plateau inasmuch as hunting was not undertaken until after the breaking point had been reached and the "die off" was under way.

XII. APPENDICES

LIST OF VERTEBRATES

The species listed here by their complete name have been recorded from the Kaibab Plateau. All the amphibians and reptiles and practically all the mammals listed were collected during the period of the study. The list does not include all the vertebrates found in the Grand Canyon bordering the plateau on the south and the surrounding desert areas. The bird list is based on both sight records and collections.

AMPHIBIANS AND REPTILES

Amphibians

Ambystoma tigrinum (Green)

Tiger Salamander

Scaphiopus hammondii (Baird)

Western Spade-foot Toad

Reptiles

Crotaphytus collaris baileyi Stejneger

Western Collared Lizard

Uta stansburiana stansburiana Baird and Girard

Brown-shouldered Uta

Sceloporus elongatus Stejneger

Stejneger's Blue-bellied Lizard

Sceloporus magister Hallowell

Desert Scaly Lizard

Sceloporus graciosus graciosus Baird and Girard

Sagebrush Swift

- Phrynosoma douglasii ornatissimum* (Girard)
 Girard's Short-horned Horned Toad
- Pituophis catenifer deserticola* Stejneger
 Great Basin Gopher Snake
- Lampropeltis pyromelana* (Cope)
 Arizona King Snake
- Thamnophis ordinoides vagrans* (Baird and Girard)
 Wandering Garter Snake
- Crotalus confluentus lutosus* Klauber
 Great Basin Rattlesnake
- Crotalus c. abyssus* Klauber
 Grand Canyon Rattlesnake
- BIRDS
- Permanent Residents
- Astur atricapillus striatus* Ridgway
 Western Goshawk
- Accipiter velox velox* (Wilson)
 Sharp-shinned Hawk
- Accipiter cooperi* (Bonaparte)
 Cooper's Hawk
- Buteo borealis calurus* Cassin
 Western Red-tailed Hawk
- Buteo regalis* (Gray)
 Ferruginous Rough-leg
- Aquila chrysaetos canadensis* (Linnaeus)
 Golden Eagle
- Falco mexicanus* Schlegel
 Prairie Falcon
- Dendragapus obscurus obscurus* (Say)
 Dusky Grouse
- Lophortyx gambeli gambeli* Gamble
 Gambel's Quail
- Bubo virginianus* ssp.
 Horned Owl
- **Asio wilsonianus* (Lesson)
 Long-eared Owl
- Colaptes cafer collaris* Vigors
 Red-shafted Flicker
- Asyndesmus lewisi* Gray
 Lewis's Woodpecker
- Dryobates villosus leucothorectis* Oberholser
 White-breasted Woodpecker
- Dryobates pubescens leucurus* (Hartlaub)
 Batchelder's Woodpecker
- Picoides tridactylus dorsalis* Baird
 Alpine Three-toed Woodpecker
- Cyanocitta stelleri diademata* (Bonaparte)
 Long-crested Jay
- Aphelocoma californica woodhousei* (Baird)
 Woodhouse's Jay
- **Corvus corax sinuatus* Wagler
 American Raven
- Cyanocephalus cyanocephalus* (Wied)
 Piñon Jay
- Nucifraga columbiana* (Wilson)
 Clark's Nutcracker
- Penthestes gambeli gambeli* (Ridgway)
 Mountain Chickadee
- Baeolophus inornatus griseus* (Ridgway)
 Gray Titmouse
- **Psaltriparus minimus plumbeus* (Baird)
 Lead-colored Bush-tit
- Sitta carolinensis nelsoni* Mearns
 Rocky Mountain Nuthatch
- Sitta canadensis* Linnaeus
 Red-breasted Nuthatch
- Sitta pygmaea melanotis* van Rossem
 Pygmy Nuthatch
- Certhia familiaris montana* Ridgway
 Rocky Mountain Creeper
- Catherpes mexicanus conspersus* Ridgway
 Canyon Wren
- **Salpinctes obsoletus obsoletus* (Say)
 Rock Wren
- **Turdus migratorius propinquus* Ridgway
 Western Robin
- **Sialia currucoides* (Bechstein)
 Mountain Bluebird
- **Carpodacus cassini* Baird
 Cassin's Purple Finch
- Pinicola enucleator montana* Ridgway
 Pine Grosbeak
- Spinus pinus pinus* (Wilson)
 Pine Siskin
- Loxia curvirostra grinnelli* Griscom
 Crossbill
- **Pipilo maculatus montanus* Swarth
 Spurred Towhee
- **Junco phaeonotus dorsalis* Henry
 Red-backed Junco
- **Melospiza melodia fallax* (Baird)
 Mountain Song Sparrow
- Summer Residents
- Cathartes aura septentrionalis* Wied
 Turkey Vulture
- Buteo swainsoni* Bonaparte
 Swainson's Hawk
- Falco sparverius phalaena* (Lesson)
 Desert Sparrow Hawk
- Tringa solitaria cinnamomea* (Brewster)
 Western Solitary Sandpiper
- Columba fasciata fasciata* Say
 Band-tailed Pigeon
- Zenaidura macroura marginella* (Woodhouse)
 Western Mourning Dove
- Phalaenoptilus nuttalli nuttalli* (Audubon)
 Nuttall's Poor-will
- Chordeiles minor* ssp.
 Night Hawk
- Aeronauta saxatalis saxatalis* (Woodhouse)
 White-throated Swift
- Archilochus alexandri* (Bouchier and Mulsant)
 Black-chinned Hummingbird
- Selasphorus platycercus platycercus* (Swainson)
 Broad-tailed Hummingbird
- Selasphorus rufus* (Gmelin)
 Rufous Hummingbird
- Sphyrapicus varius nuchalis* Baird
 Red-naped Sapsucker
- Sphyrapicus thyroideus nataliae* (Malherbe)
 Natalie's Sapsucker
- Myiarchus cinerascens cinerascens* (Lawrence)
 Ash-throated Flycatcher
- Empidonax wrightii* Baird
 Wright's Flycatcher
- Myiochanes richardsoni richardsoni* (Swainson)
 Western Wood Pewee
- Nuttallornis mesoleucus* (Lichtenstein)
 Olive-sided Flycatcher
- Tachycineta thalassina lepida* Mearns
 Violet-green Swallow
- Petrochelidon albifrons albifrons* (Rafinesque)
 Northern Cliff Swallow
- Troglodytes aedon parkmani* Audubon
 Western House Wren

* Show marked altitudinal migration but are present within portions of the study area year-long.

<i>Oreoscoptes montanus</i> (Townsend)	<i>Chaulelasmus streperus</i> (Linnaeus)
Sage Thrasher	Gadwall
<i>Hylocichla guttata auduboni</i> (Baird)	<i>Dafila acuta tzitzioha</i>
Audubon's Hermit Thrush	Pintail
<i>Sialia mexicana bairdi</i> Ridgway	<i>Nyroca</i> sp.
Chestnut-backed Bluebird	Scap
<i>Myadestes townsendi</i> (Audubon)	<i>Querquedula cyanoptera</i> (Vieillot)
Townsend's Solitaire	Cinnamon Teal
<i>Polioptila caerulea amoenissima</i> Grinnell	<i>Querquedula discors</i> (Linnaeus)
Western Gnatcatcher	Blue Winged Teal
<i>Corthylio calendula cinereaceus</i> (Grinnell)	<i>Nettion carolinense</i> (Gmelin)
Western Ruby-crowned Kinglet	Green Winged Teal
<i>Lanius ludovicianus</i> spp.	<i>Circus hudsonius</i> (Linnaeus)
Shrike	Marsh Hawk
<i>Vireo solitarius plumbeus</i> Coues	<i>Falco peregrinus anatum</i> Bonaparte
Plumbeous Vireo	Duck Hawk
<i>Vireo gilvus swainsoni</i> Baird	<i>Oxyechus vociferus vociferus</i> (Linnaeus)
Western Warbling Vireo	Killdeer
<i>Vermivora virginiae</i> (Baird)	<i>Actitis macularia</i> (Linnaeus)
Virginia's Warbler	Spotted Sandpiper
<i>Dendroica auduboni auduboni</i> (Townsend)	<i>Catoptrophorus semipalmatus inornatus</i> (Brewster)
Audubon's Warbler	Western Willet
<i>Dendroica nigrescens</i> (Townsend)	<i>Himantopus mexicanus</i> (Miller)
Black-throated Gray Warbler	Black-necked Stilt
<i>Dendroica graciae graciae</i> Baird	<i>Steganopus tricolor</i> Vieillot
Grace's Warbler	Wilson's Phalarope
<i>Oporornis tolmiei</i> (Townsend)	<i>Otus asio</i> ssp.
Macgillivray's Warbler	Screech Owl
<i>Molothrus ater</i> ssp.	<i>Megaceryle alcyon caurina</i> (Grinnell)
Cowbird	Western Belted Kingfisher
<i>Piranga ludoviciana</i> (Wilson)	<i>Ceophloeus pileatus</i> ssp.
Western Tanager	Pileated Woodpecker
<i>Hedymeles melanocephalus papago</i> Oberholser	<i>Tyrannus verticalis</i> Say
Rocky Mountain Grosbeak	Arkansas Kingbird
<i>Passerina amoena</i> (Say)	<i>Tyrannus vociferans</i> Swainson
Lazuli Bunting	Cassin's Kingbird
<i>Hesperiphona vespertina brooksi</i> Grinnell	<i>Sayornis nigricans nigricans</i> (Swainson)
Western Evening Grosbeak	Black Phoebe
<i>Spinus tristis pallidus</i> Mearns	<i>Stelgidopteryx ruficollis serripennis</i> (Audubon)
Pale Goldfinch	Rough-winged swallow
<i>Spinus psaltria hesperophilus</i> (Oberholser)	<i>Regulus satrapa olivaceus</i> Baird
Green-backed Goldfinch	Western Golden-crowned Kinglet
<i>Oberholseria chlorura</i> (Audubon)	<i>Vermivora celata celata</i> (Say)
Green-tailed Towhee	Orange-crowned Warbler
<i>Pooecetes gramineus confinis</i> Baird	<i>Sturnella neglecta</i> Audubon
Western Vesper Sparrow	Western Meadowlark
<i>Chondestes grammacus strigatus</i> Swainson	<i>Xanthocephalus xanthocephalus</i> (Bonaparte)
Western Lark Sparrow	Yellow-headed Blackbird
<i>Amphispiza bilineata deserticola</i> Ridgway	<i>Agelaius phoeniceus</i> ssp.
Desert Sparrow	Red-winged Blackbird
<i>Amphispiza nevadensis nevadensis</i> (Ridgway)	<i>Icterus parisorum</i> Bonaparte
Northern Sage Sparrow	Scott's Oriole
<i>Spizella passerina arizonae</i> Coues	<i>Euphagus cyanocephalus</i> (Wagler)
Western Chipping Sparrow	Brewer's Blackbird
<i>Spizella breweri breweri</i> Cassin	<i>Carpodacus mexicanus frontalis</i> (Say)
Brewer's Sparrow	House Finch
<i>Zonotrichia leucophrys leucophrys</i> (Forster)	Winter Visitors
White-crowned Sparrow	<i>Haliaeetus leucocephalus</i> ssp.
<i>Otocoris alpestris</i> ssp.	Bald Eagle
Horned Lark	<i>Pica pica hudsonia</i> (Sabine)
Summer Visitors and Migrants	American Magpie
<i>Ardea herodias treganzai</i> Court	<i>Penthestes atricapillus septentrionalis</i> (Harris)
Treganza's Heron	Long-tailed Chickadee
<i>Egretta thula brewsteri</i> Thayer and Bangs	<i>Bombycilla cedrorum</i> Viellot
Brewster's Egret	Cedar Waxwing
<i>Anas platyrhynchos platyrhynchos</i> Linnaeus	<i>Leucosticte</i> sp.
Mallard	Rosy Finch

Junco hyemalis hyemalis (Linnaeus)
 -Slate-colored Junco
Junco oreganus shufeldti Coale
 -Shufeldt's Junco
Junco mearnsi Ridgway
 -Pink-sided Junco
Junco caniceps (Woodhouse)
 -Gray-headed Junco
Zonotrichia leucophrys gambeli (Nuttall)
 -Gambel's Sparrow

MAMMALS

Eptesicus fuscus fuscus (Beauvois)
 -Big Brown Bat
Bassariscus astutus nevadensis Miller
 -Nevada Ringtail
Mustela arizonensis (Mearns)
 -Arizona Weasel
Spilogale gracilis gracilis Merriam
 -Little Spotted Skunk
Mephitis estor Merriam
 -Arizona Skunk
Taxidea taxus berlandieri (Baird) ?
 -Mexican Badger
Urocyon cinereoargenteus scottii (Mearns)
 -Arizona Gray Fox
Canis lesto Merriam
 -Mountain Coyote
Canis estor Merriam
 -Painted Desert Coyote
Felis concolor kaibabensis Nelson and Goldman
 -Kaibab Mountain Lion
Lynx rufus baileyi Merriam
 -Plateau Bobcat
Citellus variegatus utah Merriam
 -Utah Rock Squirrel
Citellus leucurus ssp.
 -Antelope Ground Squirrel
Citellus lateralis lateralis (Say)
 -Say's Mantled Ground Squirrel
Eutamias mininimus consobrinus (Allen)
 -Wasatch Chipmunk

Eutamias adsitus Allen
 -Beaver Mountain Chipmunk
Eutamias dorsalis utahensis Merriam
 -Utah Cliff Chipmunk
Sciurus kaibabensis Merriam
 -Kaibab Squirrel
Tamiasciurus fremonti fremonti (Audubon & Bachman)
 -Fremont Chickaree
Thomomys perpallidus absonus Goldman
 -Houserock Valley Gopher
Thomomys fossor Allen
 -Colorado Pocket Gopher
Perognathus longimembris arizonensis Goldman
 -Little Yellow Pocket Mouse
Perognathus formosus Merriam
 -Plume-tailed Pocket Mouse
Perognathus intermedius intermedius Merriam
 -Intermediate Pocket Mouse
Dipodomys ordii cupidensis Goldman
 -Kaibab Kangaroo Rat
Dipodomys microps leucotis Goldman
 -Houserock Valley Kangaroo Rat
Onychomys leucogaster melanophrys Merriam
 -Dark-browed Grasshopper Mouse
Reithrodontomys megalotis megalotis (Baird)
 -Desert Harvest Mouse

Peromyscus maniculatus rufinus (Merriam)
 -Tawny White-footed Mouse
Peromyscus maniculatus sonoriensis (LeConte)
 -Sonora White-footed Mouse
Peromyscus truei truei (Shufeldt)
 -True's White-footed Mouse
Neotoma lepida monstrabilis Goldman
 -Kaibab Woodrat
Neotoma cinerea cinerea (Ord)
 -Colorado Bushy-tailed Woodrat
Microtus mordax mordax Merriam
 -Rocky Mountain Meadow Mouse
Erethizon epixanthum epixanthum Brandt
 -Yellow-haired Porcupine
Lepus californicus deserticola (Mearns)
 -Jack Rabbit
Sylvilagus nuttallii grangeri (Allen)
 -Black Hills Cottontail
Odocoileus hemionus macrotis Say
 -Rocky Mountain Mule Deer
Ovis canadensis nelsoni Merriam ?
 -Desert Mountain Sheep

Introduced Mammals

Bison bison bison (Linnaeus)
 -American Bison

Extirpated Mammals

Euarcetus americanus ssp.
 -Black Bear
Ursus utahensis Merriam ?
 -Grizzly Bear
Canis nubilus nubilus Say
 -Gray Wolf
Antilocapra americana americana (Ord)
 -American Antelope

PARTIAL LIST OF INSECTS

Orthoptera

Species collected in quantitative collections and identified by Morgan Hebard.

Oedipodinae

Arphia conspersa Scudder
Cannula pellucida (Scudder)
Trimerotropis cyaneipennis Bruner
Trimerotropis suffusa Scudder
Trimerotropis pallidipennis pallidipennis (Burm.)
Trimerotropis cincta (Thomas)
Trimerotropis inconspicua Bruner
Circotettix coconino Rehn
Melanoplus mexicanus mexicanus (Sauss.)

Rhaphidophorinae

Eremopedes balli Caudell
Oecanthus nigricornis quadripunctatus Beut.

Formicidae

Species collected in quantitative collections and identified by M. R. Smith.

Monomorium minimum Buckley
Crematogaster lineolata (Say)
Pogonomyrmex occidentalis (Cresson)
Myrmica scabrinodis var.
Leptothorax texanus Wheeler
Tapinoma sessile (Say)
Liometopum apiculatum subsp. *luctuosum* Wheeler
Lasius niger var. *near sitkaensis* ? Pergande
Formica fusca var. *subaenescens* Emery

<i>Formica</i> (Proformica) <i>neogagates lasiooides</i> var. <i>vetula</i>	<i>Cercocarpus ledifolius</i> Nutt.	
Emery	Curlleaf Mountain Mahogany	
<i>Camponotus</i> sp.	<i>Cercocarpus intricatus</i> S. Wats.	
<i>Camponotus herculeanus</i> var. <i>modoc</i> Wheeler	Small leaf Mountain Mahogany	
<i>Camponotus maculatus vicinus</i> var. <i>nitidiventris</i> Emery	<i>Rubus</i> sp.	
<i>Camponotus maculatus vicinus</i> var. <i>luteangulus</i> Wheeler	Raspberry	
LIST OF PLANTS		
This list includes only the names of those plants referred to in the text.	<i>Sericotheca</i> sp.	
Trees		
<i>Pinus edulis</i> Engelm.	Ocean Spray	
Piñon Pine	<i>Coleogyne ramosissima</i> Torr.	
<i>Pinus brachyptera</i> Engelm.	Blackbush	
Rocky Mountain Yellow Pine	<i>Amelanchier alnifolia</i> Nutt.	
<i>Picea pungens</i> Engelm.	Serviceberry	
Colorado Blue Spruce	<i>Robinia neomexicana</i> A. Gray	
<i>Picea engelmanni</i> Parry	New Mexico Locust	
Engelmann Spruce	<i>Rhus trilobata</i> Nutt.	
<i>Pseudotsuga taxifolia</i> (LaMarche) Britton	Squawberry	
Douglas Fir	<i>Forselia spinescens</i> (A. Gray) Green	
<i>Abies concolor</i> Lindley & Gordon	Greasebush	
White Fir	<i>Ceanothus fendleri</i> A. Gray	
<i>Abies lasiocarpa</i> (Hooker) Nuttall	Fendler Ceanothus	
Subalpine Fir	<i>Ceanothus greggii</i> A. Gray	
<i>Juniperus communis</i> (L.)	Desert Ceanothus	
Dwarf Juniper	<i>Echinocereus coccineus</i> Engelm.	
<i>Juniperus scopulorum</i> Sargent	Hedgehog Cactus	
Rocky Mountain Red Cedar	<i>Opuntia tenuispina</i> Engelm.	
<i>Juniperus utahensis</i> (Engelm.) Lemmon	Elephant-ear Cactus	
Utah Juniper	<i>Opuntia acanthocarpa</i> Engelm. & Bigel.	
<i>Populus aurea</i> Tidestrom	Stag-horn Cactus	
Rocky Mountain Quaking Aspen	<i>Opuntia basilaris</i> Engelm. & Bigel.	
Shrubs		
<i>Ephedra viridis</i> Coville	Spineless Cactus	
Mormon Tea	<i>Opuntia polycantha</i> Haworth	
<i>Ephedra torreyana</i> S. Wats.	Prickly Pear	
Torrey Joint Fir	<i>Opuntia</i> sp.	
<i>Yucca baccata</i> Torr.	Cactus	
Soapweed	<i>Coryphantha arizonica</i> Engelm.	
<i>Salix</i> sp.	Pin-cushion Cactus	
Willow	<i>Arctostaphylos patula</i> Greene	
<i>Quercus utahensis</i> (A.D.C.) Rydb.	Greenleaf Manzanita	
Utah Scrub Oak	<i>Sambucus coerulea</i> Raf.	
<i>Quercus wilcoxii</i> Rydb.	Blueberry Elder	
Wilcox Live Oak	<i>Symporicarpos</i> spp.	
<i>Quercus turbinella</i> Greene	Snowberry	
Live Oak	<i>Symporicarpos rotundifolius</i> A. Gray	
<i>Atriplex confertifolia</i> (Torr. & Frem.) S. Wats.	Round-leaf Snowberry	
Shadseale	<i>Gutierrezia sarothrae</i> (Pursh) Britt. & Rusby	
<i>Atriplex canescens</i> (Pursh) Nutt.	Snakeweed	
Chamise	<i>Chrysothamnus</i> spp.	
<i>Eurotia lanata</i> (Pursh) Moq.	Yellow Brush	
Winterfat	<i>Chrysothamnus parryi</i> (Gray) Greene	
<i>Odostemon repens</i> (Lindl.) Cockerell	Rabbit Brush	
Oregon Grape	<i>Artemisia nova</i> A. Nels.	
<i>Odostemon fremontii</i> (Torr.) Rydb.	Small Sagebrush	
Algerita or Hollygrape	<i>Artemisia tridentata</i> Nutt.	
<i>Ribes inebrians</i> Lindl.	Big Sagebrush	
Currant	Herbs	
<i>Fallugia paradox</i> (Don) Endl.	<i>Calochortus nuttallii</i> Torr. & Gray	
Apache Plume	Sego-lily	
<i>Cowanía stansburiana</i> Torr.	<i>Razoumofskya cryptopoda</i> (Engelm.) Coville	
Cliffrose	Yellow Pine Mistletoe	
<i>Purshia tridentata</i> (Pursh) DC	<i>Razoumofskya divaricata</i> (Engelm.) Coville	
Bitterbrush	Piñon Mistletoe	
	<i>Eriogonum</i> spp.	
	Wild Buckwheat	
	<i>Polygonum</i> spp.	
	Knotweed	
	<i>Silene douglasii</i> Hooker	
	Catchfly	

<i>Ranunculus alismellus</i> (A. Gray) Green	<i>Artemisia gnaphalodes</i> Nutt.
Buttercup	Cudweed Sage
<i>Ranunculus subsagittatus</i> (A. Gray) Green	<i>Artemisia forwoodii</i> S. Wats.
Buttercup	Herbaceous Sage
<i>Saxifraga rhomboidea</i> Greene	<i>Artemisia mexicana</i> Willd.
Saxafrage	Sweet Sage
<i>Potentilla</i> spp.	<i>Leontodon taraxacum</i> L.
Cinquefoil	Common Dandelion
<i>Fragaria platypetala</i> Rydb.	<i>Agoseris</i> sp.
Strawberry	Mountain Dandelion
<i>Lupinus</i> spp.	<i>Achillea lanulosa</i> Nutt.
Lupine	Yarrow
<i>Lupinus barbiger</i> S. Wats.	Grasses and Grasslike Plants
Lupine	
<i>Trifolium</i> spp.	<i>Hilaria jamesii</i> (Torr.) Benth.
Mountain Clover	Galleta Grass
<i>Lotus wrightii</i> (A. Gray) Green	<i>Stipa comata</i> Trin. & Rupr.
Red and Yellow Pea	Needle and Thread Grass
<i>Astragalus</i> spp.	<i>Oryzopsis hymenoides</i> (Roem. & Shult.) Ricker
Milk Vetch	Rice Grass
<i>Geranium fremontii</i> Torr.	<i>Muhlenbergia</i> sp.
Geranium	Muhly
<i>Erodium cicutarium</i> (L.) L'Her.	<i>Muhlenbergia montana</i> (Nutt.) Hitchc.
Filaree	Mountain Muhly
<i>Sphaeralcea marginata</i> York	<i>Phleum alpinum</i> L.
Globemallow	Mountain Timothy
<i>Pseudodycyopterus montanus</i> (A. Gray) Coulter & Rose	<i>Sporobolus cryptandrus</i> (Torr.) A. Gray
Wild Carrot	Sand Dropseed
<i>Pyrola secunda</i> L.	<i>Blepharoneuron tricholepis</i> (Torr.) Nash
Shinleaf	Hairy Dropseed
<i>Pyrola picta</i> Smith	<i>Deschampsia caespitosa</i> (L.) Beauv.
Shinleaf	Hairgrass
<i>Phlox caespitosa</i> Nutt.	<i>Koeleria cristata</i> (L.) Pers.
Phlox	Junegrass
<i>Gilia</i> spp.	<i>Bouteloua gracilis</i> (H. B. K.) Lag.
Gilia	Blue Grama Grass
<i>Oreocarya</i> spp.	<i>Bouteloua rothrockii</i> Vasey
Beggar Lice	Crowfoot Grama
<i>Pentstemon</i> spp.	<i>Bouteloua eriopoda</i> Torr.
Pentstemon	Black Grama
<i>Castilleja</i> spp.	<i>Bouteloua curtipendula</i> (Michx.) Torr.
Paintbrush	Side-oats Grama
<i>Castilleja pinetorum</i> Fernald	<i>Munroa squarrosa</i> (Nutt.) Torr.
Yellow Pine Paintbrush	False Buffalo Grass
<i>Orthocarpus luteus</i> Nutt.	<i>Scleropogon</i> sp.
Yellow Owl's Clover	Burro Grass
<i>Orthocarpus purpureo-albus</i> A. Gray	<i>Poa</i> spp.
Orthocarp	Blue Grass
<i>Linnaea borealis americana</i> (Forbes) Rehder	<i>Festuca</i> spp.
Twin Flower	Fescue
<i>Campanula parryi</i> A. Gray	<i>Bromus porteri</i> Coulter
Hairbell	Bromegrass
<i>Solidago</i> sp.	<i>Sitanion hystrix</i> (Nutt.) J. G. Smith
Goldenrod	Bottlebrush Squirreltail
<i>Aster</i> spp.	<i>Carex</i> spp.
Aster	Sedge
<i>Erigeron</i> spp.	XIII. LITERATURE CITED
Daisy	
<i>Erigeron divergens</i> Torr. & Gray	Bailey, F. M. 1928. Birds of New Mexico. New Mex. Dept. of Game and Fish. Santa Fe. 1-807.
Daisy	
<i>Solidago petradoria</i> Blake	Bird, R. D. 1929. Biotic communities of the aspen parkland of central Canada. Ecology 11: 356-442.
Goldenrod	
<i>Antennaria</i> spp.	Blake, I. H. 1926. A comparison of the animal com- munities of coniferous and deciduous forests. Ill. Biol. Monogr. 10: 371-520.
Pussytoes	
<i>Hymenopappus lugens</i> Greene	Brooks, A. 1926. Past and present big game conditions in British Columbia and the predatory mammal ques- tion. Jour. Mammal. 7: 37-40.
Hymenopappus	
<i>Actinea</i> spp.	
Pingue or Rubberweed	

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