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BIOTIC COMMUNITIES OF THE NORTHERN DESERT SHRUB BIOME IN WESTERN UTAH

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Graduate School of the University of Illinois. Contribution from the Zoological Laboratory of the University of Illinois. Champaign. Illinois.

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INTRODUCTION

The Biotic Community Concept

It has been only within the present century that the true significance of plant and animal community relationships has been recognized and the basic concepts of biotic communities developed. The recognition of plant communities and their distinctiveness came about as a natural consequence of the differences in the physiognomy of such communities, but the recognition of animal communities has been delayed on account of the motility and less conspicuous nature of the components. Sea-bottom animal communities were among the first to be described, probably because the animals concerned were less motile and formed a more conspicuous unit, the plants being the less conspicuous components in such situations.

The concept of the co-existence of plant and animal communities has been even slower in its development. The history of this concept is given by Clements & Shelford (1939), who were among the first to recognize the community relationships between plants and animals. Clements (1905) suggested that plant and animal communities frequently coincided. Vestal (1913) then pointed out that the relationships between plant and animal communities are so intimate that both may be considered as one biotic unit. At about the same time, Shelford (1913) emphasized the interactions between plants and animals and the importance of both components in the succession and development of biotic communities. Since then the intimate relationships between the plant and animal components of terrestrial biotic communities have been described by numerous students and co-workers of Shelford.

Ecological Investigations Within Utah and Vicinity

Inasmuch as the science of bio-ecology has developed largely within the prairie and deciduous forest areas of the United States, the major investigations upon which it is based have been concerned with the biotic communities of those areas. Most investigators within the Great Basin Region have been concerned with the flora and fauna from a taxonomic and distributional point of view, and have used the life zones of Merriam (1898) as a basis for describing the distribution of the plant and animal components concerned. Most of the major bio-ecological studies have been concerned with the plant and animal communities of the mountains at elevations above 5,000 feet (Svihla 1932; Rasmussen 1941; Hayward 1945).

An investigation of the biotic communities of Zion Canyon in southern Utah by Woodbury (1933) was concerned primarily with the succession of the plant components, although the invertebrate and vertebrate animals were included and their biotic relationships within the communities described.

The succession of plant communities occurring on the volcanic deposits in the Snake River plains area of southern Idaho has been investigated by Eggler (1941), and the plant communities of southeastern Washington and adjacent Idaho have been very intensively studied by Weaver (1917) and Daubenmire (1942).

Hardy (1945) investigated the effects of various soil characteristics on the distribution of small mammals in the vicinity adjacent to St. George in southwestern Utah. The composition of various plant communities and their relationships to the distribution of certain mammals are described.

No attempt has been previously made to investigate the biotic communities of western Utah although detailed studies have been made of the plant communities and their relationships to soil conditions in Tooele Valley (Kearney, Briggs, Shantz, McLane, & Piemeisel 1914) and in Escalante Valley (Shantz & Piemeisel 1940). Some of the plant communities at the Desert Range Experiment Station in Pine Valley are described by Stewart & Keller (1936) in which they analyze statistically the correlation between various components in these communities. The effects of over-grazing on the plant communities of Pine Valley and Wah Wah Valley, with implications as to the trends in succession, are described by Stewart, Cottam, & Hutchings (1940).

In keeping with the general trend in the development of bio-ecology, the animal community relationships have been investigated far less than the plants. Taxonomic relations, geographic distribution and occasional life history studies have been of primary concern up to the present time. The work of Linsdale (1938), on the fauna of the Toyabe Mountains and adjacent valleys of central Nevada, includes observations on 215 species of vertebrates and their responses to certain environmental factors but no attempt is made to analyze them in terms of community relationships.

Since there had been no attempt to study and describe the biotic communities in western Utah this investigation was undertaken for that purpose. The field work involved was done during a part of two years, from June to September, 1939, and from April to September, 1940. Quantitative methods were employed in studying both the plant and animal components, supplemented by general observations and extensive cruising. An attempt was made to cover as much of the region outside the intensively studied areas as possible to obtain information concerning the general extensiveness, distribution, and character of the various biotic communities. The communities investigated can hardly be considered as virgin because the activities of man, with the introduction of his domestic animals and his predator control practices, have undoubtedly altered the composition of the communities concerned and distorted the biotic relationships between some of the components. Consequently, the findings of the writer apply to the communities as they exist today. Certain general ecological relationships obtained from this investigation will apply to other similar communities within the same biome but the composition of communities in other areas may vary considerably on account of differences in physiography, soil composition, climatic variations, and the economic pursuits of man.

ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to Professor V. E. Shelford under whose direction this investigaiton was conducted. His suggestions, encouragement, and aid in placing necessary equipment at the writer's disposal have been invaluable. His assistance included a visit to the study areas during the summer of 1938 at which time the problem was outlined. Appreciation is also extended to the Society of Sigma Xi for awarding the writer a Grant-in-aid which was used in the completion of the problem in the summer of 1940. Dr. George Stewart and Mr. Selar Hutchings of the U. S. Forest Service provided the writer with living quarters at the Desert Range Experiment Station during a part of this investigation and also permitted the writer to use certain climatic data which had been recorded at the station.

Without the assistance of the many specialists who aided in the determination of the plants and animals collected, the identification of the numerous biotic components involved in this study would have been impossible. The cooperation of these people is greatly appreciated and the writer's gratitude is extended to the following: B. F. Harrison (plants); E. Raymond Hall and S. D. Durrant (mammals); Nathan Banks and H. E. Ewing (Acarina); R. V. Chamberlin and R. A. Cooley (Arachnida); Harlow B. Mills and G. Glance (Collembola); John W. E. Rehn (Orthoptera); J. C. Crawford (Thysanoptera); Herbert Ruckes, H. N. Knight, H. M. Harris, and H. G. Barber (Hemiptera); W. T. Davis, P. W. Oman, George F. Knowlton, P. N. Mason, and Harold Morrison (Homoptera); E. A. Chapin, H. S. Barber, R. E. Blackwelder, W. S. Fisher, L. L. Buchanan, and W. H. Anderson (Coleoptera); J. F. G. Clarke, and Carl Heinrich (Lepidoptera); C. T. Greene, Alan Stone and David G. Hall (Diptera); C. R. W. Muesebeck, A. B. Gahan, R. A. Cushman; M. R. Smith and Clarence E. Mickel (Hymenoptera).

THE REGION STUDIED

History and Extent of the Great Basin

When the early American explorers began to push westward beyond the Rocky Mountains they soon became aware of the distinctiveness of the area which lay between the Wasatch range of the Rocky Mountains on the east and the Sierra Nevadas on the west. This vast area of approximately 210,000 square miles is unique in that there is no drainage system or systems which lead to the ocean. The geological history, physical features, and extent of this area have been described in detail by Russell (1883) and Gilbert (1890). It is a large basin containing numerous mountain ranges which run in a general north and south direction and which consequently divide the area into many smaller basins, each of which usually has its own drainage system terminating at the lowermost parts of the valley in a barren playa, a mud flat, or a lake.

Fremont (1845) who is given credit for giving this area its present name, the "Great Basin," describes it as follows in his journal of 1841 (p. 174):

> "This mountainous region connects itself in the southward and westward with the elevated country belonging to the Cascade or California range; and, as will be remarked in the course of the narrative, forms the eastern limit of the fertile and timbered lands along the desert and mountainous region included within the Great Basin —a term which I apply to the immediate region between the Rocky Mountains and the West range, containing many lakes, with their own system of rivers and creeks, (of which the Great Salt is the principal), and which have no connection with the ocean, or the great rivers which flow into it. This Great Basin is yet to be adequately explored."

Within the Great Basin area of Utah there are a number of distinct independent drainage basins, the principal ones of which include the Escalante Desert, the Sevier Desert, Preuss Valley (now called Wah Wah Valley), White Valley, Snake Valley, Rush Valley, Cedar Valley, the upper portion of Pocatello Valley, the Pilot Peak Basin, and the Basin of the Great Salt Lake. These valleys and basins, together with a number in western Nevada, were at one time a part of two large Quaternary lakes. Lake Lahonton, situated at the base of the Sierra Nevada Mountains and fed by their snows, covered an area of 9,100 square miles. Lake Bonneville, situated on the eastern side of the Great Basin, was fed by snows from the Wasatch and Uinta Mountains and at the time of its maximum extent covered an area of 19,750 square miles. The evaporation of these large bodies of water and continual evaporation of the water which drains into these valleys and basins has resulted in the deposition of enormous quantities of mineral salts. So impregnated with salt are the bottoms of many basins, such as Psobb Valley in Nevada and the area adjacent to Great Salt Lake and Sevier Lake in Utah, that for many square miles there is nothing but a dazzling field of white salt. In other cases where the surface water has evaporated without leaving a surface layer of salt, the subsoil is so saturated with strong brine that most plant life is unable to survive.

The sides of these characteristic Great Basin valleys slope gradually from the bases of the enclosing mountain ranges. Soil from the mountains is being continually carried down and deposited at the mouths of the canyons where broad alluvial fans are often formed. The mineral salts are leeched out from the soils at the bases of the mountain ranges and are carried to the lower-most parts of the valley floors where they are deposited. Thus the salt content becomes so high that all plant growth is prohibited and barren playas are formed. Most every valley has one or more of these playas and they occur even in valleys, such as Pine Valley, which was never covered by Lake Bonneville.

MAJOR SHRUB BIOTIC COMMUNITIES

Because of the physiographic features and geological history of the Great Basin there is a wide variation in the climatic conditions and the composition of the soil, both as to texture and mineral content, which results in a corresponding variety of biotic communities. This study is concerned with some of those communities which belong to the Northern Desert Shrub Biome[1] which occurs below the piñon-juniper woodland, and which has been referred to as the "Sagebrush Climax" (Clements 1920; Weaver & Clements 1938), the "Northern Desert Shrub Formation" (Shantz 1925; Shantz & Piemeisel 1940); the "Artemisian Province" (Dice 1939), and the "Upper Sonoran Faunal Area" (Merriam 1898).

The "Northern Desert Shrub Formation" of Shantz includes most of the plant communities of the Great Basin except the greasewood and its associated halophytes which he assigns to the "Salt Desert Shrub (Greasewood) Formation." Clements, on the other hand, lumps the above two associations into the "Atriplex-Artemisia Association" with a large number of consociations.

The climax communities of this biome are characterized by scattered dominant deciduous shrubs accompanied by several species of dominant grasses and a limited number of subdominant under-shrubs and herbs. The number of major permeant influent animals is small, practically all of which range throughout all the communities. The minor influent and subinfluent components are more distinct for each community but in many cases the differences are largely quantitative rather than qualitative ones.

The dominant shrubs are rather similar in general vegetative form and present landscape aspects which are strikingly similar to the casual observer. These communities comprise one of the most extensive types of vegetation in western Utah that occur from the piñon-juniper woodland to the lowermost parts of the valleys. Their southern boundary extends to about the thirty-seventh parallel where it dovetails into communities of the southern desert. In northern Utah, southern Idaho, and southeastern Washington they merge into the Palouse Prairie. The differentiation between the shrub communities of the Northern Desert Shrub Biome and the grassland associations of the Palouse Prairie is not an abrupt one but there is a tendency for a gradual increase in the abundance of grasses and a decrease in the number of xeric shrubs as availability of moisture increases.

[1] The term biome is used as a synonym of biotic formation which consists of a complex of fully developed and developing biotic communities. The mature communities (associations) of this larger biotic unit (biome) represent the final expression of the plant and animal constituents in response to climate and biotic interactions.

These communities have been referred to as the "Basin Sagebrush Climax" (Weaver & Clements 1938), which is misleading because sagebrush is only one of the important dominant shrubs of the region and is no more conspicuous than shadscale, a fact which is implied by the same authors when they refer to the climax community as "The Atriplex-Artemisia Association." Grasses are also among the important dominants but they have been greatly reduced since the advent of the white man and his domestic animals. The early explorers of the Great Basin (Fremont 1845; Stansbury 1852; Beckwith 1855; Simpson 1859; and Hayden 1873) all record the presence of grass among the vegetation encountered. These early explorers were also prone to refer to a number of different species of shrubs all as "sage," "sagebrush," or "artemisia." This may have been partly responsible for the misconception as to the extensiveness of this species. Greasewood was usually differentiated from sagebrush but not always, and shadscale was often referred to as "sage." These early explorers also probably came in contact with the sage more frequently than some of the other shrubs because they tended to follow the bases of the mountains and streams where they were more likely to find suitable drinking water and where more grass was apt to be present for their animals.

The sagebrush community is only one of the biotic communities of the Northern Desert Shrub Biome and is restricted to those areas where the most moisture is available. Thus sagebrush is usually found at the bases of the numerous mountain ranges or in the valleys where the soil is deep, relatively free from mineral salts, more permeable, and with a greater water-holding capacity; or where there is a greater amount of precipitation, whereas shadscale is restricted to the more xeric areas and/or areas of higher mineral content than is tolerated by sagebrush.

LOCATION OF STUDY AREAS

The shadscale association and its closely related communities were studied most intensively in White Valley, located about 65 miles west of Delta, Millard County, Utah (Fig. 1). Observations were also made in Antelope Valley, Snake Valley, Pine Valley, and the eastern slope of the House Range. White Valley is bisected by the 113° 30′ W. and extends in a north and south direction from the 39° 00′ N. to 39° 35′ N. It is a closed basin more than 60 miles in length; about 900 square miles in area; and is bordered on the west by the Confusion Range, which separates it from Snake Valley, and on the east by the House Range, which separates it from the Sevier Desert. The central playa of the valley is about 4,400 feet above sea level and the sloping sides of

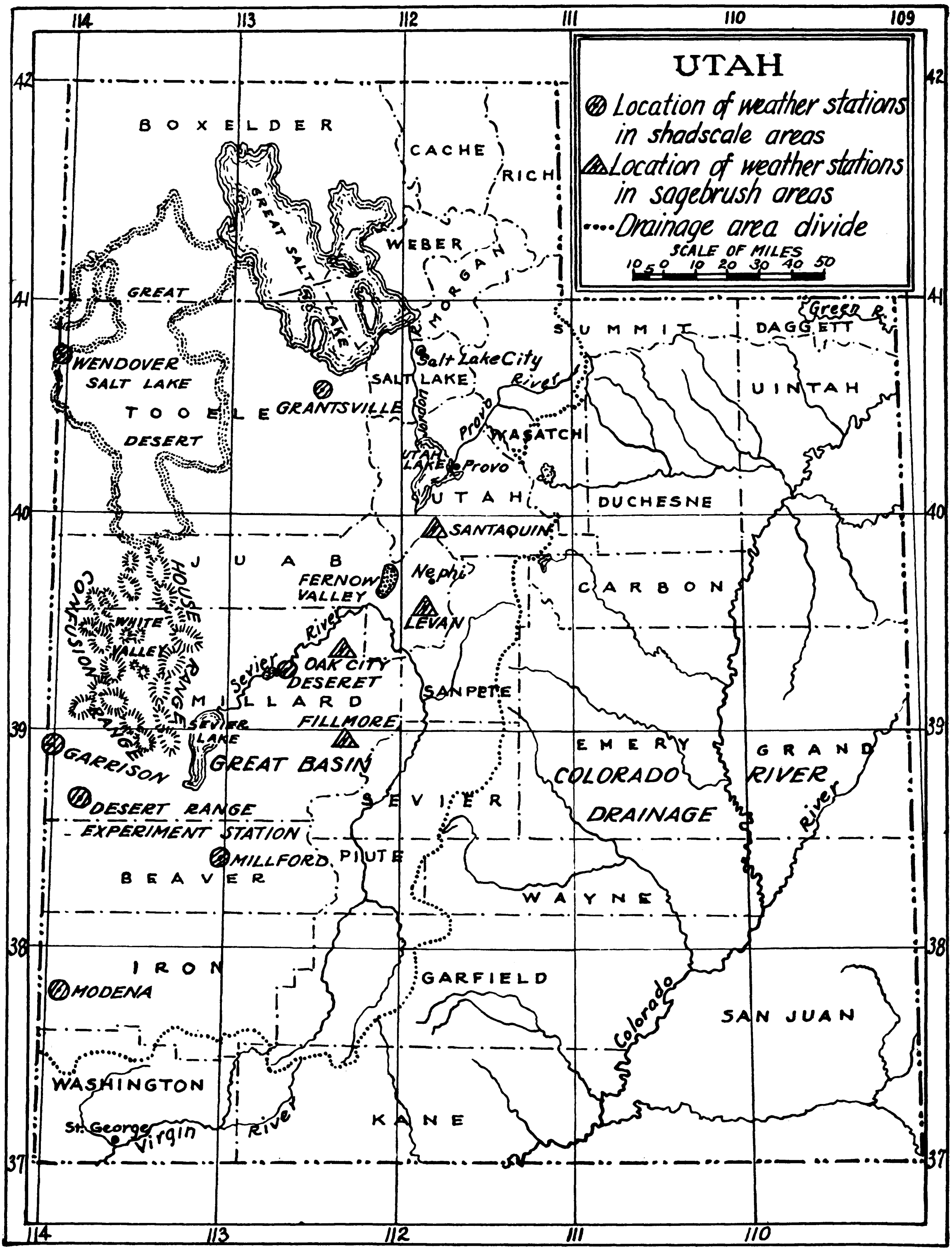

FIG. 1. Map of Utah showing the location of study areas. White Valley and Fernow Valley, and U. S. Weather Bureau Stations.

the valley gradually rise to an elevation of 5,500 to 6,000 feet at the bases of the enclosing mountain ranges.

The strata of the bordering mountains consist chiefly of Paleozoic limestone and quartzites. In the House Range they dip toward the east, away from White Valley, and their outcropping edges form a steep, rugged west-facing wall which for many miles towers precipitously above the valley. In the northern part of the Confusion Range the dip is toward the east, which is thus toward the valley, with the result that the slope from the mountains to the central valley floor is relatively long and gentle. The valley is thus asymetrical, the lowest part lying nearer the base of the House Range.

The lowermost part of the valley floor consists of a flat barren playa about 3 miles across at its widest point and 12 miles long. During heavy rains the lowest parts of the valley are flooded with water and are devoid of vegetation. The soil here was formed under water and is a dense gumbo clay so heavily impregnated with mineral salts that they form a white encrustation on its surface, hence the name "White Valley." In some parts, surrounding this lowest area, a miniature eolian topography of innumerable hummocks that range in height up to 12-15 feet is imposed on the landscape. These hummocks consist of residual clay collected and held in place by pickleweed, *Allenrolfea occidentalis* (S. Wats.) Kuntze, whereas the surrounding areas have been lowered by wind erosion (Fig. 10). Toward the south the valley becomes more constricted and troughlike, but its central axis remains low, and with the exception of some interruptions where the entire valley floor is covered with vegetation, it retains its playa character.

This White Valley drainage basin has no permanent stream and only a few springs. A group of small springs, including Coyote, Willow, Tule, and South Tule Springs occur in the low central part of the valley. Most of these springs consist of a circular depression where the water comes to the surface in one place and sinks in another. The water at Tule Springs arises at a point about 375 meters from where it again disappears into the ground. These springs are usually choked with a dense growth of rushes *Scirpus olneyi* A. Gray, and *Juncus balticus* Willd. Some are bordered by a dense growth of willows *Salix exigua* Nutt., and all of them are usually surrounded by a zone of salt grass *Distichlis stricta* (Torr.) Rydb., which often forms a solid sod.

Around the edges of the valley, sloping down from the bases of the surrounding mountain ranges, are deposits from torrential streams in the form of alluvial fans. The material varies from boulders and gravel near the base of the mountains, to sand, loam, or clay at the outer edge of the fan. Such soils vary greatly in depth, are usually productive, well drained and fairly free from alkali.

The area selected for the sagebrush community study is known as "Fernow Valley" and is located about 15 miles west of Levan, Juab County, Utah, at an elevation of about 5,600 feet (Fig. 1). The valley runs in a north and south direction and drains toward the south. It is hemmed in on the east, north, and southwest by low rocky mountain ranges covered with a piñon-juniper forest into which the sagebrush community extends as a shrub layer. The soils in this valley are largely the result of stream deposition and range from a sandy clay loam along the valley floor to gravel at the bases of the enclosing hills. The soils are deep, well-drained and permeable. Ravines in the south end of the valley indicate that the soil is more than 20 feet in depth.

METHODS OF STUDY

The determination of the plant constituents of each community was accomplished by taking 0.25 square rod samples with a quadrat frame whose dimensions were 8′ 3″ per side. Three cross-wires were strung from the opposite sides of the frame thus dividing it into 16 equal parts. This frame was placed on the ground and the positions and area covered by each plant plotted with reference to the cross-wires. The samples were taken within the plots which were used for sampling rodent populations. Four quadrat samples were taken per trapping plot. From these samples the principal plant components for each community were calculated in terms of percentage of total floral composition, frequency of occurrence in the samples taken, and percentage of total ground surface covered.

One square meter samples of the invertebrate populations of the various dominant shrubs were obtained by making 50 sweeps with an insect net 30 centimeters in diameter. These quantitative collections were taken from sagebrush, greasewood, shadscale, and tetradymia communities at intervals of about 7 to 10 days.

No one method is adequate in estimating vertebrate populations and consequently different methods were used for different groups. The frequency with which the larger mammals such as antelope, coyotes, and badgers were seen and heard, together with the frequency of their "signs," in the form of scat, tracks, dens, and excavations were used an indices of relative abundance.

The relative abundance of rabbits and birds were estimated by staking out 4-hectare (10-acre) plots within which the number of birds and rabbits were counted by walking back and forth across the area until it had been thoroughly covered. The pellet-count method was also utilized in determining differences in the relative abundance of rabbits from one community to another. Each sample consisted of one square meter of ground surface on which the number of rabbit pellets were counted. These random samples were taken at intervals of 25 meters along transects running through the various communities.

The relative abundance of small rodents was esti mated by trapping 0.4-hectare (1-acre) and 0.2 hectare (0.5-acre) plots for 4 consecutive nights

Circular plots were used with the traps arranged in 9 circular rows in the 0.4-hectare plots and 6 rows in the 0.2-hectare plots. Traps were spaced 16-18 feet apart and thus made an average of 219 traps per 0.4-hectare plot and 105 traps per 0.2-hectare plot.

Food relations of the various animals were investigated by examining the contents of their stomachs and pellets; by making observations on their feeding activities in the field; and by observing food preferences of captive animals.

The time of reproduction was determined by examination of the reproductive organs of collected animals; by observing the nesting and mating activities of animals in the field; and by observing the time at which the young made their appearance.

The trapping plots described above were also utilized in estimating relative lizard populations. The lizards within a plot were counted as the area was thoroughly covered by making 6 to 7 complete circles at intervals of 5 to 6 meters apart from the outside to the center. Duplications in such counts were guarded against by noting the position and course taken by each flushed specimen. Although the counts obtained by this method probably do not represent the actual number of lizards present, because of the possibility that some were not flushed, yet by employing this method in all the different communities it served to indicate relative differences between them.

Daily temperature and relative humidity data were recorded by means of a hygro-thermograph placed beneath a weather shelter on a platform six feet above the surface of the ground. The temperature recordings were checked against a thermometer at least once a day and the relative humidity recordings against a sling psychrometer reading every two to three days. The rates of evaporation were measured by means of standardized white porous porcelain cylindrical atmometers placed at three different levels. One was placed at 52 inches above the ground (greasewood level); another at 18 inches (maximum shadscale level); and the third one at ground level.

The scientific names used in the designation of the biotic components encountered in this study follow the nomenclature of the specialists who identified the specimens collected, and the following authorities: "Flora of Utah and Nevada," I. Tidestrom, 1925; "Manual of the Grasses of the United States," A. S. Hitchcock, 1935; "List of North American Recent Mammals, 1923," G. S. Miller, Jr., 1924; "Check-list of the Birds of Utah," William H. Behle, 1944: "A Check List of North American Amphibians and Reptiles," Stejneger & Barbour, 4 ed. 1939; "Insects of Western North America," E. O. Essig, 1934.

The terms and concepts used with reference to the biotic components and their relationships within the various communities are adopted from "Bio-ecology" by Clements & Shelford (1939).

CLIMATE

Comparison with Climate of Southern Desert

Although this biome is referred to as a "desert" biome, its climate is very different from the climate of the southern desert biome in southwestern United States. The term "Northern" is used to denote a semi-desert condition and to differentiate it from the true southern desert.

The differences in the climate of the Southern Desert Scrub Biome and the Northern Desert Shrub Biome are readily discernible from the climographs in Figure 2. Climograph A, that represents the climatic conditions in the southern desert, is based on climatic data taken from United States Weather Bureau reports for eight different weather stations ranging in latitude from Tuscon, Arizona to Logandale, Nevada and in elevation from sea level at Calexico, California to 2,033 feet above sea level at Las Vegas, Nevada. Climographs B and C are based on United States Weather Bureau reports from government weather stations the locations of which are described below.

Temperatures are much higher in the southern desert, and reach a maximum of 130-134° F. in the Imperial Valley region with maxima of 110-120° F. of rather common occurrence in other parts of the biome, whereas the maximum for the northern desert biome is about 115° F. and in most places it seldom exceeds 105° F. The annual mean temperature of the southern desert ranges between 60 and 72° F. as compared with 45-50° F. for the northern desert. Minimum temperatures, which are often the critical temperature factors as far as plant and animal distribution are concerned, are strikingly different in the two biomes. Many parts of the southern desert seldom experience frost and in all parts below 5,000 feet the temperatures usually remain above 10° F. as contrasted with minimum temperatures of −20 to −30° F. in the northern desert areas. Such characteristic southern desert plants as *Covillea tridentata* (DC.) Vail, *Strombocarpa odorata* (Torr. & Frém.) Torr., and *Prosopis glandulosa* Torr. have been known to sustain severe frost damage in southern Utah (the northern limit of the southern desert) when, for a period of only 7 days, the temperature abnormally fell to below 32° F. with a minimum of −11° F. for one night (Cottam 1937; Turnage & Hinckley 1938; Woodbury 1938).

The yearly distribution of precipitation in the two biomes is similar in some respects but different in others. Both biomes are characterized by having two wet periods during the year but these periods occur at different times and the proportions of the annual rainfall received during these periods are different (Fig. 2). In the southern desert the wet spring season ends about the last of March and a long dry period follows from April to July, whereas in the northern desert the wet winter and spring period extends into May and the dry summer period lasts only until mid-July or early August.

The annual precipitation of the southern desert varies from 3-10 inches per year, seldom being more (Smith 1930), whereas in the northern desert it seldom falls below 5 inches, except in the southern part and in periods of drought, and exceeds 16 inches in some sagebrush areas of the northern part of the biome.

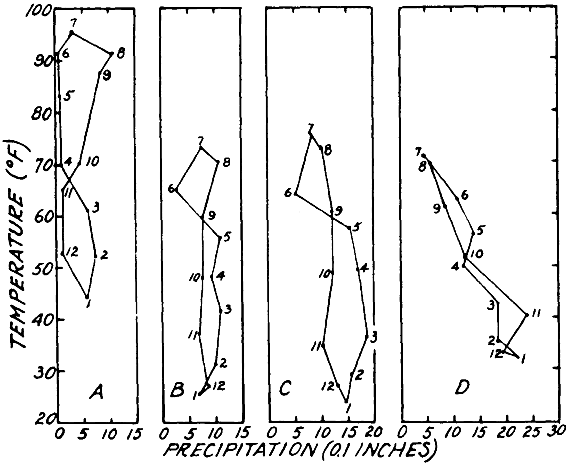

FIG. 2. Climatic diagrams representing the monthly mean temperature-precipitation relationships of: A. Southern Desert Scrub Biome; B. Shadscale Association; C. Sagebrush Association; D. Palouse Prairie (Pomeroy, Washington). Data from U. S. Weather Bureau Reports.

SOURCES OF CLIMATIC DATA

Climatic data for the shadscale areas were obtained from United States Government Weather Bureau reports for 6 weather stations located in areas where shadscale and its associated communities are prevalent. These stations are so distributed that the extremes as well as the average climatic conditions are represented. The stations chosen are all within the altitudinal range of 4,000 to 5,000 feet above sea level and are distributed latitudinally from Modena, at the southern extreme and within 60 to 70 miles of the southern boundary of the biome, to Wendover on the north (Fig. 1.). The Wendover station, because of its location at the eastern base of a low mountain range to the northwest, is representative of extremes as to maximum temperatures, low precipitation and minimum snowfall. The other stations are located in a triangular fashion in three different directions from White Valley. The Garrison station is the nearest one to White Valley and is located about 35 miles to the southwest. Precipitation data was also obtained from the Desert Range Experiment Station about 35 to 40 miles south of White Valley and in an intermediate position between the Garrison and Milford stations.

Temperature, relative humidity and evaporation data were recorded at White Valley during the course of the investigation.

Climatic data for sagebrush areas were obtained from the records of four United States Government Weather Bureau stations located at Fillmore, Oak City, Levan, and Santaquin which range in elevation from 4,900 to 5,250 feet above sea level (Fig. 1). These stations are all located within sagebrush areas situated along the western bases of mountain ranges.

TEMPERATURE

Temperature values within the shadscale and sagebrush areas are very similar. The annual range in temperature is very great and may be as much as 145° F., ranging from a maximum of 110° F. to a minimum of —30° F. in the shadscale areas and from a maximum of 115° F. to a minimum of —28° F. in the sagebrush areas. The annual mean temperature is slightly higher in the sagebrush areas varying from 47.5° F. at Levan to 51.7° F. at Fillmore with an average of 49.9° F. In the shadscale areas it varies from 47.6° F. at Modena to 52.8° F. at Wendover with an average of 49.5° F. (Fig. 3). July is the hottest month of the year, with a mean temperature of 73.7° F. for the six stations in the shadscale areas and 74.6° F. for the 4 stations in the sagebrush areas. The monthly mean temperatures during 1939 and 1940 were 1 to 4 degrees above normal, being abnormally high during July and August.

The daily fluctuations in temperature are also very wide, ranging from an average of 21.5° F. in January to an average of 43.2° F. in June, with a maximum range of 56° F. during June, July, and August. Maximum daily temperatures occur from 2 to 6 p.m. and the minimum temperatures from 2 to 4 a.m.

PRECIPITATION

The amount of precipitation is much lower in the shadscale areas than in the sagebrush. It varies from an annual minimum of 3.50 inches at the Desert Range Experiment Station to a maximum of 19.06 inches at Modena, whereas the minimum for the sagebrush areas is 7.20 inches and the maximum 26.22 inches. The annual mean precipitation in the shadscale areas varies from 11.01 inches at Modena to 4.53 inches at Wendover with an average of 7.95 inches for the six stations. This is slightly more than half the amount received in the sagebrush areas, which average 14.84 inches per year (Fig. 3).

Sagebrush areas are often located along the windward border of the mountain ranges where the precipitation is higher than it is in the open valleys because the moisture-bearing winds drop their moisture as they rise when the mountains are encountered. Deseret, situated in a large open valley at an elevation of 4,541 feet, 25 miles to the windward side of the Pavant Mountain, has a normal annual precipitation of 8.16 inches, while Fillmore, at an elevation of 5,250 feet and located at the windward base of the mountain, receives an average of 14.30 inches of moisture per year. This difference in precipitation is very markedly reflected in the type of vegetation present; sagebrush is the dominant plant along the base of the Pavant range and shadscale and greasewood in the open valley in the vicinity of Deseret.

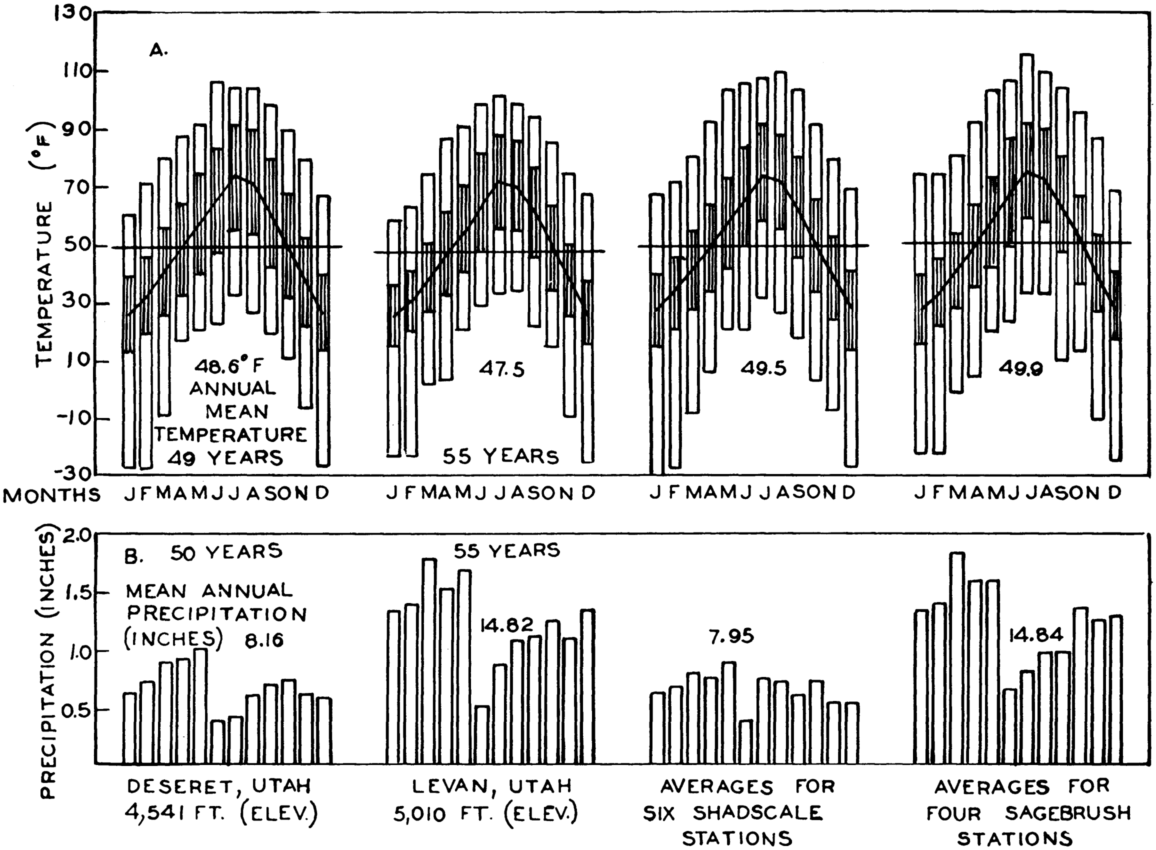

FIG. 3. Temperature and precipitation data for shadscale and sagebrush areas: A. Monthly maxima, minima, means, mean maxima, mean minima, and annual mean temperatures; B. Average monthly precipitation. From U. S. Weather Bureau Reports. Records ended with 1944.

The precipitation is unevenly distributed throughout the year, most of it comes during 2 periods. The wettest period of the year occurs from March to May with March usually receiving the greatest amount in the sagebrush areas and May in the shadscale areas (Fig. 3). June is normally the driest month of the year but during 1939 and 1940 July received the least amount of precipitation. In the shadscale areas the average amount of rainfall during June is only 0.36 inch, varying from 0.20 inch at Garrison to 0.65 inch at Grantsville. In the sagebrush areas the average for June is 0.62 inch. This dry period is normally followed by an increase in precipitation during July and August when the average for the shadscale areas is 0.75 inch with a range from 0.28 inch at Wendover to 1.08 inches at Modena.

The distribution of rain is very uneven as far as the entire region is concerned. The amount of precipitation varies greatly from one station to another. Storms are very localized and on several occasions enough rain may fall in one part of White Valley to cause a considerable run-off, while in another part, 10 to 15 miles away, not a drop falls. Many of the summer storms are "cloudbursts" that result in a very heavy downpour which may last for only a few minutes. The utilization of this summer precipitation is often very low because it is temporary and available to the plants for only a short time. The suddenness and intensity of such thunder showers, together with the sloping topography of much of the terrain and the sparseness of the vegetation, results in a heavy run-off, especially in the shadscale areas. What moisture does soak into the soil does not penetrate to very great depths and is soon lost by evaporation because of the high temperatures, low relative humidity, and high wind velocities. Thus the soil surface moisture, that results from a storm, may be dissipated within a few hours after the storm is over.

The plants of both the shadscale and sagebrush areas are subjected to great variations in the amount of precipitation they receive from one year to the next. During the 25-year period from 1920 to 1944 such yearly variations amounted to as much as 6.78 inches at Deseret, Utah and 13.11 inches at Levan, Utah (Fig. 4). The annual precipitation of the sagebrush areas very seldom falls below the annual mean of the shadscale areas.

The sagebrush areas receive more than twice the

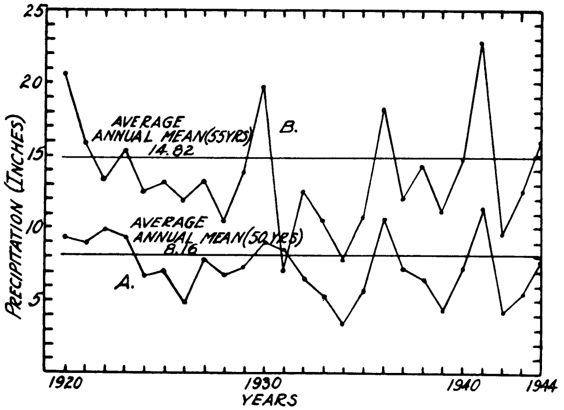

FIG. 4. Fluctuations in annual precipitation during a 25-year period from 1920 to 1944, inclusive, at: A. Deseret, Millard County, Utah; B. Levan, Juab County, Utah. Data from U. S. Weather Bureau Reports.

amount of snow that is received in the shadscale areas. The average annual snowfall varies from 45.5 inches at Oak City to 78.6 inches at Fillmore with an average of 66.2 inches for the 4 stations, as compared with an average of 27.2 inches for the stations in the shadscale areas where the range varies from 8.8 inches at Wendover to 33.9 inches at Milford (Table 1).

TABLE 1. Average monthly and annual snowfall in inches (Kincer 1936).

Stations	Length of Record	January	February	March	April	May	September	October	November	December	Annual
		SHADSCALE AREAS									
Deseret	33 yr.	5.2	7.0	4.9	2.7	0.1	0.1	0.5	2.4	5.3	28.2
Grantsville	18 "	9.0	6.1	4.4	2.3	T[2]	0	1.2	2.9	7.8	33.7
Milford	20 "	6.3	6.8	5.2	3.8	0.9	T	0.3	4.0	6.6	33.9
Modena	30 "	6.8	6.5	6.4	2.7	1.0	T	1.4	2.7	4.0	31.5
Wendover	18 "	2.3	1.6	0.7	T	T	0	T	1.0	3.2	8.8
Average	....	5.9	5.6	4.3	2.3	0.4	T	0.7	2.6	5.4	27.2
		SAGEBRUSH AREAS									
Fillmore	16 "	14.7	13.3	14.2	8.6	0.6	0	4.3	8.5	14.4	78.6
Levan	38 "	12.6	12.4	13.1	5.9	1.2	0.2	2.3	6.7	13.2	67.6
Oak City	18 "	9.5	7.2	8.4	4.4	0.2	T	1.8	5.1	8.9	45.5
Santaquin	15 "	17.2	15.2	11.5	6.0	T	T	1.5	6.6	15.2	73.3
Average	....	13.3	12.0	11.1	6.2	0.5	T	2.5	6.9	12.2	66.2

[2]Trace.

LENGTH OF GROWING SEASON

The frost-free period averages 120 days in the shadscale areas and about 136 in the sagebrush areas, and extends from about May 20 to September 20 in the shadscale areas and from May 18 to October 1 in the sagebrush areas. The number of clear days per year averages 181 with a maximum of 19 in June, the driest month of the year. The annual sunshine percentage amounts to 74 at Modena with a maximum of 86 during the month of June (Kincer 1936).

WIND

Scarcely a day passes without the wind blowing. This air movement reduces the intensity of the high summer temperatures but it also increases the rate of evaporation to which the plants are subjected. The average hourly wind movement is 11.5 miles at Modena, being highest during May and June. Monthly maximum velocities vary from 44 to 53 miles per hour (Kincer 1936).

RELATIVE HUMIDITY AND RATES OF EVAPORATION

The annual average relative humidity, based on the average of 3 readings taken at 8:00 a.m., noon, and 8:00 p.m., are 46% for Modena and 49.6% for Salt Lake City.[3] The relative humidity is lowest during June and July when the minimum monthly average drops to 26.6% at Modena and 33.3% at Salt Lake City. The highest percentage occurs during the winter months when it reaches 79% at Modena and 75% at Salt Lake City (Kincer 1936).

At White Valley the maxima occurred in early morning between 2:00 and 6:00 a.m. and the minima during late afternoon from 2:00 to 6:00 p.m. The daily maxima fluctuated considerably and seldom got above 60% during the spring and summer except during rain storms. The mean minimum during July, 1940 was 20.3% with a range from 3% to 31%. Monthly means for June and July were 28.3% and 30.2% respectively.

Evaporation is moderately heavy because of the dry atmosphere and the high wind velocities during the afternoon when temperatures are highest and relative humidity lowest. The average loss of water from the Weather Bureau pan is about 60 inches (Table 2). Pan losses frequently exceed 10 inches a month during June, July, and August and have exceeded 12 inches several times. The greatest loss was 16.75 inches in July, 1928. The evaporation-precipitation ratio varies during the summer months from 8.50 in April to 37.02 in June (Table 2).

TABLE 2. Average monthly and annual evaporation and precipitation data (inches) for Sevier Bridge Dam, Juab County, Utah; located about 13 miles southwest of Levan and 15 miles east of Oak City. (Compiled from Kincer 1936.)

	Length of Record	April	May	June	July	Aug.	Sept.	Annual
Evaporation	9 years	4.847	9.827	12.588	13.652	10.858	7.967	59.739
Precipitation	9 "	0.57	0.82	0.34	0.85	1.28	0.71	8.49
Evap. / Prec.	....	8.50	11.98	37.02	16.06	8.48	11.22	7.03

Evaporation rates from standardized atmometers set up in the shadscale association in White Valley varied considerably at different levels and at different times of the day, being highest during the afternoon hours. The average rate during 15 weeks of observation from April 16 to July 16, 1940, was 3 milliliters per hour at the 52-inch level; 2.25 milli-

[3] Data for Salt Lake City is used because no data on relative humidity is available for the other stations in the vicinity of the sagebrush area studied

liters at the 18-inch level; and 2.18 milliliters at the ground level, with an average weekly range from 1.33 milliliters per hour at the ground level in April to 4.41 milliliters at the 52-inch level in June. The absolute range varied from a minimum of 0.6 milliliters to a maximum of 7.22 milliliters per hour.

The rate of evaporation is greatly affected by air movement since there was a definite increase in the rate from the ground level to a height of 52 inches. Although the temperature at the ground level gets higher than at the higher levels, the effect of this factor in increasing the rate of evaporation is evidently more than compensated for by the increased air movement at the higher levels (Fig. 5).

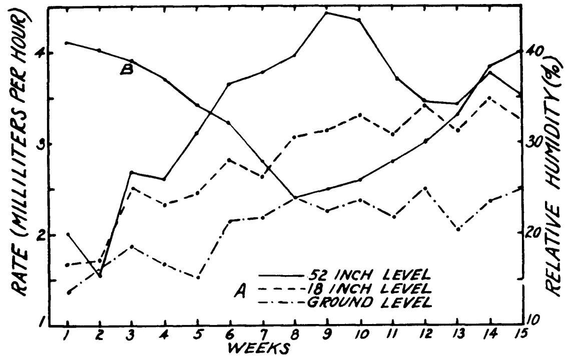

FIG. 5. Evaporation and relative humidity during a 15-week period from April 16 to July 16, 1940 at White Valley, Millard County, Utah: A. Evaporation rates in milliliters per hour from standardized atmometers placed at three levels; B. Average weekly relative humidity.

The taller plants, such as greasewood, may be subjected to much greater water losses through increased transpiration than those that grow at lower levels because of this higher evaporating power of the air. This may be a very important factor in the distribution of the greasewood which is found almost exclusively in the lower parts of the valleys where the water table is higher and consequently where more moisture is available. When this plant occurs on the higher ground it seems to suffer more from drought than the other plants of such areas and is frequently killed.

BIOTIC MATRIX OF THE SHADSCALE AND ASSOCIATED COMMUNITIES

The dominants of these desert communities receive the full impact of a very rigorous climate and modify the various aerial factors, especially moisture and insolation, to which all the biotic components are exposed. The combination of dominants and subdominants also impart character to the community and play an important role in the food relationships, shelter and reproduction of the influent animals. The invertebrate animals (subinfluents) constitute the basic reactors and coactors within the communities and form the basis of the food chains of many of the larger animals. Thus, the plants because of their importance as dominants and subdominants, together with the invertebrate animals constitute the "biotic matrix" of the community which serves as a foundation and framework, on and into which, the larger influent animals fit.

Although the major and minor influents are an integral part of the community and through their coactions and reactions directly or indirectly affect the composition and structure of the biotic matrix, they are discussed by the writer in a separate section of this paper, in order to avoid repetition since many of them occur in more than one community.

THE SHADSCALE COMMUNITY

(*Atriplex-Oryzopsis-Dipodomys Association*)[4]

Dominants and subdominants—Shadscale is very widely distributed throughout the Great Basin being most prevalent in the more xeric parts. It is well adapted to xeric conditions and occurs where the precipitation is considerably less than where sagebrush is found or where the mineral content of the soil is beyond the tolerance of the sagebrush. The soil on which it occurs is rather impervious and the ground sloping so that the run-off is high. Thus the available moisture supply is low and is largely limited to the surface soil. This plant has an extensive root system near the surface as well as a taproot and can thus utilize the temporary surface moisture supply, thriving very well even though its roots may be able to penetrate the soil to a depth of only 1 or 2 feet. This characteristic also enables it to occupy areas where the subsoil is rather heavily impregnated with mineral salts. Although it is relatively salt-tolerant, and occurs in areas where the salt concentration may be as much as 1.15 percent at the 3-foot level, it thrives best where the salt content of the soil does

TABLE 3. Floral components of 40 quadrat samples taken in Shadscale Community. 1, Percent of samples in which the species occurred; 2, Number of plants per square rod; 3, Percent of total plants in samples; 4, Percent of ground surface covered.

Species	1 Frequency	2 Abundance			3 Composition			4 Coverage		
		Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
Atriplex confertifolia (Torr. & Frém.) S. Wats.	100.0	180	20	50.8	81.1	17.4	43.0	15.4	1.6	7.4
Eurotia lanata (Pursh) Moq.	80.0	108	0	38.8	77.2	0	32.6	5.5	0	1.7
Artemisia spinescens D. C. Eaton	72.5	76	0	10.0	59.4	0	9.4	2.0	0	0.4
Oryzopsis hymenoides (Roem. & Shult.) Ricker	32.5	56	0	1.1	43.3	0	2.8	4.2	0	0.5
Hilaria jamesii (Torr.) Benth.	30.0	24	0	1.1	27.8	0	4.9	5.5	0	0.8
Sphaeralcea grossulariaefolia (Hook. & Arn.) Rydb.	25.0	24	0	0.8	22.2	0	3.3	1.2	0	0.1
Tetradymia glabrata A. Gray	12.5	4	0	0.5	5.0	0	0.5	1.6	0	0.1
Sporobolus cryptandrus (Torr.) A. Gray	7.5	12	0	1.0	18.5	0	1.0	0.5	0	0.03
Chrysothamnus stenophyllus (A. Gray) Greene	7.5	4	0	0.3	4.5	0	0.2	2.5	0	0.07
Kochia vestita (S. Wats.) Rydb.	7.5	40	0	6.0	10.0	0	2.1	2.4	0	0.07
Ephedra nevadensis S. Wats.	5.0	8	0	0.1	9.0	0	0.3	8.1	0	0.03

[4] Each community is technically designated by the names of two dominant plants and one prevalent influent animal.

not exceed 0.09 percent (Kearney, Briggs, Shantz, *et al.* 1914, and Shantz 1925).

This community occupies about 20 to 30 percent of the vegetated part of White Valley. In most places it extends from near the bases of the mountain ranges to near the valley floors where it becomes associated with greasewood forming an ecotone community in some areas. Within this ecotone community shadescale and greasewood occur in about equal abundance; greasewood predominates in the lower areas and shadscale in the higher areas. Here gray molly, *Kochia vestita* (S. Wats.) Rydb., reaches its maximum abundance. This is a small subdominant perennial which occurred in large numbers in certain areas, 308 plants per square rod, but its coverage was always small on account of its small size (Table 3). It is favored by over-grazing and becomes most abundant where the shadscale has been depleted or not present because of unfavorable soil conditions.

TABLE 4. Floral components of 16 quadrat samples in Atriplex-Sarcobatus Ecotone.

Species	Frequency	Abundance			Composition			Coverage		
		Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
Atriplex confertifolia (Torr. & Frém.) S. Wats.	100.0	48	12	22.8	48.0	4.5	13.8	7.3	1.6	4.0
Kochia vestita (S. Wats.) Rydb.	100.0	308	40	161.6	85.0	40.0	69.9	7.2	1.0	3.6
Artemisia spinescens D. C. Eaton	75.0	40	0	22.0	25.6	0	8.0	2.1	0	0.7
Eurotia lanata (Pursh) Moq.	75.0	36	0	12.8	23.1	0	6.8	2.2	0	0.7
Sarcobatus vermiculatus (Hook.) Torr.	37.5	8	0	1.0	3.5	0	0.9	4.4	0	1.1
Hilaria jamesii (Torr.) Benth.	12.5	12	0	1.6	4.7	0	0.6	0.6	0	0.07

Shadscale is usually accompanied by one or more dominant grasses including Indian rice grass, *Oryzopsis hymenoides* (Roem. & Shult.) Ricker and galleta grass, *Hilaria jamesii* (Torr.) Benth. Sand dropseed, *Sporobolus cryptandrus* (Torr.) A. Gray, is present in certain areas. Blue gramma grass, *Bouteloua gracilis* (H. B. K.) Lag., occurs with shadscale in Pine Valley in rocky situations (Stewart, Cottam, & Hutchings 1940). The dominant grasses seldom occur in pure stands and where they do the areas are small. The testimonies of old residents of the region indicate that the abundance of grass has been reduced by grazing but that the characteristic desert shrubs, such as shadscale, have always been abundant. Indian rice grass is one of the most conspicuous grasses where the soil is sandy and under protected conditions it becomes abundant enough to alter the general landscape aspect of the community (Fig. 7).

Two of the subdominant shrubs associated with shadscale are winterfat, *Eurotia lanata* (Pursh) Moq., and bud sage, *Artemisia spinescens* D. C. Eaton, which is most conspicuous during the early spring. Bud sage is the only artemisia of the area which reproduces in the spring of the year. During

FIG. 6. Shadscale community on east side of White Valley, Millard County, Utah. (May 31, 1940.)

early summer it loses its leaves and dries up to the extent that it appears to be practically dead. In early spring months it is highly palatable and has consequently been reduced by grazing.

Jointfir, *Ephedra nevadensis* S. Wats., is found scattered about in the shadscale community near its upper limits but it seldom becomes abundant. It occurred in only 12.5 percent of the quadrat samples and constituted only 0.5 percent of the vegetative composition of this community.

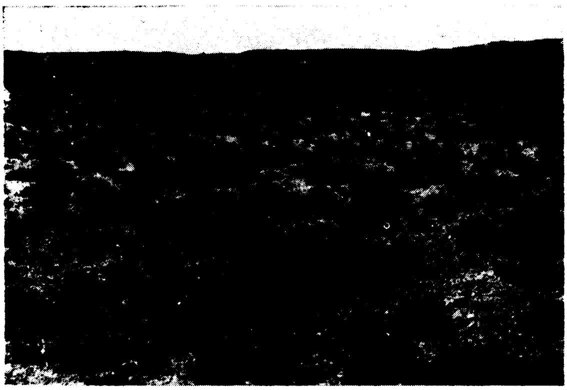

FIG. 7. Shadscale community within an exclosure protected from grazing at the Desert Range Experiment Station, Pine Valley, Millard County, Utah. Note the abundance of Indian rice grass among the shadscale. (Aug. 9, 1940.)

In early spring a number of annual and perennial herbaceous plants make their appearance. These were never abundant and many of them were restricted to the more open areas. Such seasonals included the globemallow, *Sphaeralcea grossulariaefolia* (Hook. & Arn.) Rydb.; the larkspur, *Delphinium bicolor* Nutt.; the evening star, *Montzelia albicaulis* Dougl., which occurred on very gravelly soils; the evening primrose, *Sphaerostigma utahense* Small, usually on sandy soil; *Chylismia scapoidea* (Nutt.) Small, on very gravelly and sandy soils; princes plume, *Stanleya arcuata* Rydb., which was never very abundant but was conspicuous because of its height and long yellow inflorescence; the umbrella plant, *Eriogonum hookeri* S. Wats., which readily came in where other vegetation had been removed and which was often conspicuous along the sides of newly constructed roads; the silver plant, *Eriogonum ovalifolium* Nutt.; the ragwort, *Senecio uintahensis* (A. Nels.) Greene; and the Russian-thistle, *Salsola pestifer* A. Nels., which readily invaded disturbed areas.

Invertebrates of the Shrub Layer Society[5]—Only two layer societies are found in most of the biotic communities of the desert because of the paucity of herbs. The few herbs which are present usually occur as scattered individual plants and seldom form a cover of sufficient extent to form an intermediate layer between the shrubs and the ground. In White Valley the invertebrate population of the shrub layer was much smaller than in either the greasewood or tetradymia communities and reached its peak during the middle part of May (Fig. 9). Since the shadscale plants are smaller and widely scattered their ground coverage averaged only about half as much as tetradymia or greasewood. Consequently the actual amount of vegetation covered by a sweep net in taking quantitative samples would tend to be less even though the total area covered by the net would be theoretically the same. This may have been one factor partly responsible for the apparent low invertebrate population.

After about the middle part of June the invertebrate populations rapidly began to decrease and by August very few invertebrates were taken in quantitative sweepings. This decrease coincided with a rise in temperature and a lack of precipitation which reached abnormal proportions during July and August 1940.

Spiders were taken more consistently throughout the summer than any other invertebrate but constituted less than 10 percent of the total invertebrate population. Most of those taken during the late summer were immature. The most abundant species were *Philodromus* sp., *Metepeira foxi* Gertsch and Ivie, and *Misumenops celer* (Hentz).

Mites often occurred in aggregations on certain plants but were not taken consistently in quantitative samples. Eighty-six specimens of *Atomus arvensis* Bks. were taken in one sample while no more than two mites were taken in any other samples throughout the summer and they occurred in less than 25 percent of the total samples taken.

Homoptera occurred in greater abundance and with greater frequency than any other group of insects (Table 8). Cicadellids were the most numerous and most frequently encountered members of this group with *Eutettix insanus* Ball and *Aceratagallia cinerea* (O. & B.) being the most prevalent species. Fulgorids, aphids, and coccids were also important homopterans. The most abundant fulgorids were *Oecleus fulvidorsum* Ball and *Orgerius minor* Ball. The homoptera are not only important in the biotic matrix of this society because of their coactions concerned with sucking the plant juices but they are also utilized to a great extent as food by lizards and birds.

Although hemiptera constituted more than 15 percent of the total invertebrate population they were not consistently taken in collections. They were most abundant during the middle of May and were occasionally taken until September. Only six species were collected of which the mirids, *Psallus* spp. and *Phyllopidea* sp., were the most abundant. *Phyllopidea* sp. was collected in no other community.

Diptera and hymenoptera occurred in about equal abundance and were much less numerous than in the greasewood community. The 2 most common families of flies were the Bombyliidae and Chloropidae. Robber flies were frequently seen but on account of their agility were seldom taken in the quantitative sweepings. The most common species were *Erax* sp. and *Diogmitis symmachus* (Lw.). The hymenoptera consisted primarily of parasitic wasps and ants. The last of which were seldom taken in quantitative samples although they were very common on the ground. Mutillids were attracted to lights at night but were never taken in the quantitative samples. The most common species was *Brachycistis washingtonia* Mallock.

Lepidoptera and orthoptera were less abundant than most other orders of insects and the frequence of their occurrence was far less than in any other community. Moths were frequently seen at night but were seldom taken in the sweepings. Although grasshoppers were present throughout the summer they were never abundant and were more often seen on the ground than on the vegetation. *Xanthippus lateritius* Saussure, was most frequently seen during April and May, both adults and nymphs being present at that time. *Trimerotropis p. pallidipennis* (Burm.) and the small clear-winged grasshopper, *Aeoloplus t. tenuipennis* Scudder, were most common during May. Two species of mantis, *Litaneutria minor* (Scudder) and *Stagmomantis* sp., were occasionally seen but practically never taken in the quantitative samples.

Coleoptera were very important members of this society. Eleven species belonging to 7 different families were taken in the quantitative samples. The family Cleridae was the most numerous. Two coccinellids, *Exochomus septentrionis* Ws. and *Hyperaspis fimbriolata* (Melsh.); one clerid, *Hydnocera discoidea* Lec.; the tenebrionid, *Sphaeriontis muricata* (Lec.), and the scarabaeid, *Diplotaxis* sp., were encountered at night but were never taken in the quantitative samples. Two buprestid beetles, *Acmaeodera pulchella immaculata* Horn and *A. pulchella* (Hbst.), were collected from red cloth trap markers placed in the shadscale but they could never be found on the vegetation. From June 4 to June 12 as many as 7 of these beetles were found on some flags. The scarabaeids, *Cyclocephala reflexa* Csy. and *Polyphylla arguta* Csy., were also members

[5] The term "society" designates a stratal or layer subdivision of a climax community.

TABLE 5. Summary of the invertebrates collected in quantitative samples.

	Families					Genera					Species					Specimens				
	Shadscale	Tetradymia	Greasewood	Sagebrush	Total	Shadscale	Tetradymia	Greasewood	Sagebrush	Total	Shadscale	Tetradymia	Greasewood	Sagebrush	Total	Shadscale	Tetradymia	Greasewood	Sagebrush	Total
Araneida	4	5	6	5	6	8	8	14	9	16	10	10	19	11	23	32	29	138	91	290
Acarina	2	3	3	1	4	3	4	3	1	5	4	4	3	1	6	94	42	20	3	159
Collembola	1	1	0	0	1	1	2	0	0	2	1	2	0	0	2	3	5	0	0	8
Orthoptera	1	1	1	1	1	3	3	2	2	4	3	3	2	5	7	6	8	16	43	73
Thysanoptera	0	1	1	0	1	0	2	1	0	3	0	2	1	0	3	0	180	2	0	182
Hemiptera	4	4	7	7	8	6	7	14	13	23	6	12	17	15	31	64	635	98	193	990
Homoptera	4	3	6	5	9	11	7	14	14	30	13	8	15	16	35	96	123	832	766	1817
Coleoptera	7	4	7	7	9	10	7	12	15	21	11	7	13	18	31	19	29	132	193	373
Lepidoptera	1	4	4	3	8	*	*	*	*	*	*	*	*	*	*	2	9	14	6	31
Diptera	7	8	14	5	17	9	9	16	6	22	9	9	19	7	27	39	85	229	81	434
Hymenoptera	3	5	7	5	12	6	9	13	9	24	7	9	18	10	32	33	30	146	17	226
Totals	34	39	56	39	76	57	58	89	69	150	64	66	107	83	197	388	1175	1627	1393	4583

*Larvae and pupae which were not determinable to species.

of this society although they were not taken in the quantitative samples.

The ground layer society—Tenebrionid beetles were very conspicuous components of this society, *Eleodes hispilabris* (Say), *E. hirsuta* Lec., and *E. obscura* (Say) being the most common species. They were most abundant in late spring and early summer at which times they were active both day and night. During the hottest part of the summer they were much less conspicuous and were most active at night. The largest species of the group, *Eleodes obscura,* was very widely distributed and occurred in all communities.

Ants are very important members of these arid regions and through their burrowing activities they perform similar reactions in soil formation that are credited to the earthworm in more moist areas. They are also an important source of food for many lizards, especially the horned-toads (Table 29). The 2 most abundant species were the harvester ant, *Pogonomyrmex occidentalis* (Cress.) and the honey ant, *Myrmecocystus mexicanus navajo* Whlr. Both of these species utilized small pebbles in the construction of their mounds which were most conspicuous where the soils were moderately gravelly. The honey ant was largely restricted to the shadscale, winterfat, and tetradymia communities but the harvester ant occurred throughout all communities. Other species included *Dorymyrmex pyramicus* (Roger), *Eciton (Acamatus)* sp. and several species of *Formica* (Appendix B).

Although grasshoppers probably belong more specifically to the shrub layer where they feed, they occurred very commonly in the open areas where there was no vegetation and where they deposited their eggs. The 4 most common species include *Trimerotropis p. pallidipennis, Xanthippus lateritius, Aeoloplus t. tenuipennis,* and *Capnobotes occidentalis* (Thomas). Other orthoptera such as crickets are primarily nocturnal and consequently were much less conspicuous. These included the field cricket, *Gryllulus assimilis* (Fabr.), the camel cricket, *Ceuthophilus fossor* Hubbel, and the sand cricket, *Stenopelmatus fuscus* Haldeman. The field cricket was very scarce being restricted to the more moist situations. The camel cricket was usually found beneath stones and only infrequently seen at night. The large sand cricket was quite common at night, especially in areas where the soil was sandy, and it was readily attracted to mammal traps baited with oatmeal.

Nocturnal arachnids including the scorpion, *Vejovis borealis* (Girard), the solpugid, *Eremobates pallipes* (Say), and the tarantula, *Aphonopelma melanius* C. and I., were only occasionally seen because of their secretive habits.

THE TETRADYMIA COMMUNITY

(Tetradymia-Atriplex-Dipodomys Faciation)[6]

Ecological status—Under varying conditions of soil texture, salt content of the subsoil, the presence or absence of a hard-pan, topography, and level of the water table, the composition of the vegetation changes to such an extent that a number of distinct communities are differentiated in which shadscale plays a minor role and some of its associates become the most abundant. Although these communities are all subject to similar climatic conditions, as far as precipitation and temperature are concerned, the availability of the precipitation is altered by the chemical and physical factors which have been described. Whether the water is limited by decreased amounts of precipitation or whether its availability

[6] The term "faciation" is used to designate a biotically distinguishable variation of an association due to the addition or disappearance of one or more dominants. Such additions or deletions are induced by the response of the dominants to alterations in climatic factors. In the area under consideration these alterations in the climatic factors are due primarily to differences in available soil moisture resulting from differences in mineral content and texture of the soil.

to the plants is limited by the soil texture or the mineral content of the soil, the effects on the plant life are essentially the same. Most of these variations of the shadscale association are edaphic communities whose distribution is discontinuous and localized.

The differences which occurred in the floral components were accompanied by differences in the composition of the animal components. Because of the individuality of these biotic communities, although they are subjected to the same climate as the shadscale community, they are herein regarded as climax variations (faciations) of the shadscale association.

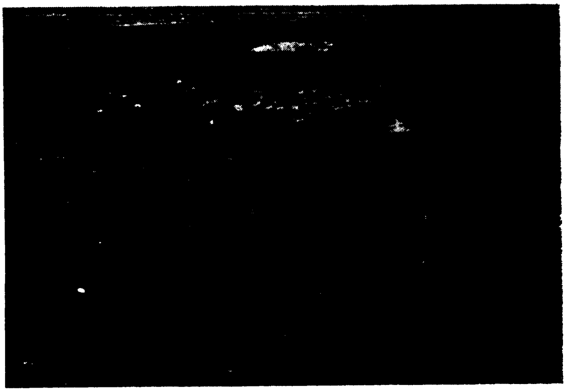

FIG. 8. Tetradymia community near base of the House Range on the east side of White Valley, Millard County, Utah. Note coarse texture of the soil and the mixture of the larger tetradymia and smaller shadscale shrubs. (May 18, 1940.)

Dominants and subdominants—As the shadscale community extends towards the base of the mountains, *Tetradymia glabrata* A. Gray, becomes the most prevalent dominant. This community was largely limited to the higher bench lands of the valleys being most extensive on the more gentle slopes. In general it occurred at higher elevations than the shadscale community. It was far more extensive on the west side of White Valley where the slope is more gradual than on the east side. A very extensive area also occurred on the east side of the House Range where the slope is long and gentle.

The soil texture of areas on which this community occurred was usually very coarse varying from large boulders to gravel, however sandy areas occurred to a limited extent. The landscape aspect is quite different from the typical shadscale community, due to the increased height of the tetradymia, and is readily recognizable (Fig. 8). The average ground coverage of the vegetation was much greater, being 21.2 percent as compared with an average of 11.0 percent for the shadscale community.

Eight species of plants occurred in the quadrat samples taken in White Valley, among which were the following dominants: tetradymia, shadscale, Indian rice grass, and galleta grass. The subdominants included the little rabbitbrush, *Chrysothamnus*

TABLE 6. Floral components of 24 quadrat samples taken in the Tetradymia Community.

Species	Frequency	Abundance			Composition			Coverage		
		Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
Tetradymia glabrata A. Gray	100.0	48	8	23.2	83.3	20	47.2	34.9	8.4	14.5
Atriplex confertifolia (Torr. & Frém.) S. Wats.	75.0	48	0	8.4	52.2	0	9.2	8.2	0	1.7
Chrysothamnus stenophyllus (A. Gray) Greene	50.0	24	0	8.0	66.7	0	19.7	8.9	0	2.1
Hilaria jamesii (Torr.) Benth.	41.7	76	0	9.2	61.3	0	14.2	4.0	0	0.7
Ephedra nevadensis S. Wats.	41.7	4	0	1.6	16.7	0	3.5	7.1	0	1.9
Eurotia lanata (Pursh) Moq.	33.3	8	0	0.4	11.2	0	2.5	0.4	0	0.08
Aristida fendleriana Steud.	25.0	8	0	1.6	15.4	0	2.4	1.8	0	0.2
Artemisia spinescens D. C. Eaton	8.3	4	0	0.8	3.8	0	0.3	0.5	0	0.04

stenophyllus (A. Gray) Greene, bud sage, prickly pear, *Opuntia* sp., globemallow, Indian paint brush, *Castilleja* sp., jointfir, three-awn grass, *Aristida fendleriana* Steud., squirrel-tail grass, *Sitanion jubatum* J. G. Smith, and triodia grass, *Triodia pilosa* (Buckl.) Merr. Along the sides and bottoms of ravines, rabbitbrush, *Chrysothamnus nauseosus* ssp., and big sagebrush extended into this community. The spiney hop-sage, *Grayia spinosa* (Hook.) Moq., occurred on sandy areas. On the east side of the House Range where grazing had been quite severe the little rabbitbrush had become very abundant.

Invertebrates of the shrub layer society—Insect populations were much greater than in either the greasewood or the shadscale communities until about June 20 after which time they declined very rapidly (Fig. 9). This large population was made up primarily of hemiptera and thysanoptera which were attracted to the flowers of the tetradymia plants during May and early June. The areas on which this community occurs were usually very rocky and well drained so that as the summer drought began and temperatures rose these plants were subjected to the most xeric conditions of the region. In response to these conditions the seeds were rapidly matured and shed and most of the leaves fell off, with the result that during midsummer these plants were often merely a mass of dry stems and appeared as if they were practically dead. The rapid decline in the insect populations was very strikingly reflected in the seasonal change of this plant, very few insects occurring on it after the first part of July (Fig. 9).

The mirids were the most numerous hemiptera. They were represented by 8 species, of which *Lygus elisus* Van D. and *Psallus* sp. occurred in greatest abundance and with the greatest frequency. Nymphs of *Lygus elisus* were most abundant during the last part of May. False chinch bugs of 2 species, *Nysius ericae* (Schilling) and *N. californicus* Stal., also occurred in considerable numbers.

Homoptera were fairly numerous. Eight species were collected, of which 6 were cicadellids. The most abundant and frequently collected species was *Cera-*

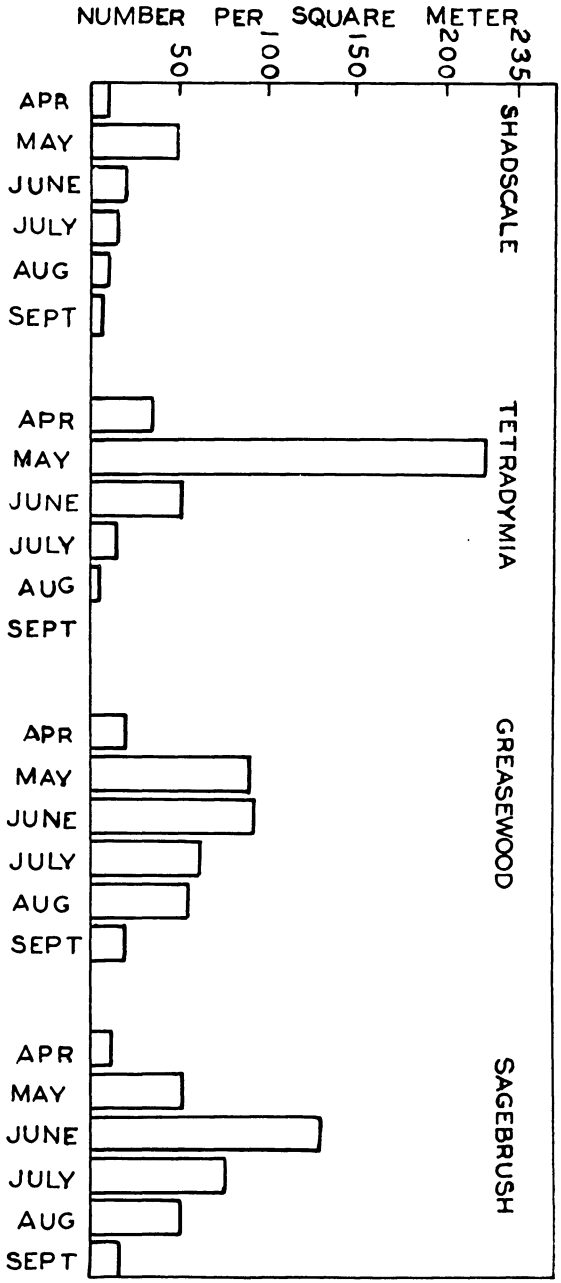

FIG. 9. Seasonal fluctuations in insect populations of the dominant shrubs of the shadscale, tetradymia, greasewood, and sagebrush communities.

tagallia artemisia Oman. Other homopterans included the chermid, *Paratrioza cockerelli* (Sulc.), and one species of fulgorid, *Oeclidius nanus* Van D., neither of which occurred in samples from other communities.

Coleoptera consisted chiefly of Chrysomelidae. The most abundant species was *Monoxia* sp. Two species of snout beetles, *Eupagoderes varius* Lec. and *Cercopeus artemisiae* Pierce, also occurred here, the second one being taken in no other community. During the early part of April the June beetle, *Paracotalpa granicollis* (Hall), was very conspicuous, being most abundant on the scattered jointfirs.

Diptera were rather scarce and constituted less than 10 percent of the total invertebrate population. The most abundant species were *Oscinella* sp. and *Madiza* sp.

Lepidoptera were very scarce. Only 9 larvae were taken in all the quantitative samples.

Hymenoptera were also few in number. Only 4 species of ants and 5 species of parasitic hymenoptera were taken in the quantitative samples during the entire period of investigation. The most prevalent ants were *Dorymyrmex pyramicus* (Roger) and *Myrmacocystus* sp. Four of the 5 species of parasitic hymenoptera were taken in no other community. The 2 most abundant species were *Leptacis* sp. and *Platygaster* sp.

The grasshoppers included *Melanoplus* sp. and *Aeoloplus t. tenuipennis,* the first species being the more numerous. Nymphs of *Melanoplus* sp. appeared almost a month earlier than they did in the greasewood community, probably because of the more arid and warmer conditions prevailing here. Other orthopterans include the walking stick, *Pseudoserymle straminea* (Scudder) and the mantis, *Litaneutria minor.*

Colembola belonging to the genus *Dueterosminthurus* made their appearance during the early part of May. During the time of flowering a small yellow thrips, *Frankliniella occidentalis* Perg., was very abundant on the flowers of the tetradymia.

Spiders occurred rather regularly in the samples until about the middle of August but they were never abundant. Of the 8 species collected *Metepeira foxi* and *Misumenops celer* were the most abundant. *Araneus carbonarius* (C. Koch) was very conspicuous because of its webs which extended from one plant to another. Four species of mites were found to be present, the most abundant of which was *Bryobia praetiosa* Koch.

The ground layer society—The ants were among the most prevalent subinfluents of this society and were practically the same species as occurred in the shadscale community, with the honey ant and the harvester ant being the most common. Other than ants, the remaining invertebrate composition consisted primarily of orthoptera and coleoptera. Three species of grasshoppers, *Xanthippus lateritius, Eremiacris pallida* (Bruner), and *Melanoplus m. mexicanus* (Saussure), were common, especially during the early part of the summer in the most open parts of the community. The sand cricket was common where the soil conditions were suitable. Tenebrionid beetles were common but not so abundant as in the greasewood community. Three species, *Eleodes longicollis* Lec., *E. hispilabris,* and *E. obscura,* were the most prevalent, the first one of which was observed in no other community.

THE GREASEWOOD COMMUNITY

(Sarcobatus-Suaeda-Reithrodontomys Faciation)

Although greasewoods may occur on sand dunes and sometimes at higher elevations in association with shadscale and rabbitbrush or sagebrush, they normally require conditions where considerable amounts of soil moisture are available. When they do occur at these higher elevations, where the water table is low, they are often killed during periods of drought. White (1932) found that in the Escalante Desert the largest areas of greasewood occur where the depth of the water table is less than 15 feet, though at the upper limits of its range the water table may be 25 feet below the surface. The occurrence of this plant at these occasional higher elevations is due to the development of a long taproot which penetrates the soil to depths where water is available. Their roots have been found to extend down 20 to 57 feet below the surface of the soil (Meinzer 1927). Although this species usually occurs on saline soils it is not an infallible indicator of high salt content. Alkali is not necessary for its growth but a high moisture content in the soil is, and inasmuch as the water table is much nearer the surface in the bottoms of the valleys than at higher elevations this plant is largely restricted to such situations even though the salt content of the soil may reach 1.08 percent in the third foot below the surface (Shantz and Piemeisel 1940). When the salt content gets much higher than one percent this shrub becomes yellow and dwarfted and gives way to salt grass, *Distichilis stricta* (Torr.) Rydb., *D. spicata* (L.) Greene, pickleweed, *Allenrolfea occidentalis* (S. Wats.) Kuntze, or samphire, *Salicornia utahensis* Tidestrom, depending on the locality.

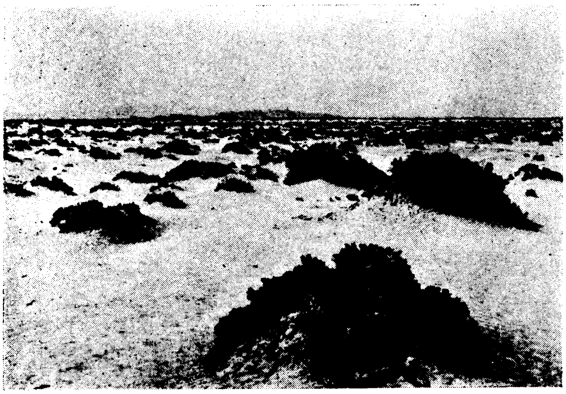

FIG. 10. Hummocks of pickleweed *(Allenrolfea occidentalis)* bordering the barren playa in White Valley, Millard County, Utah. (Aug. 10, 1939.)

In White Valley the entire valley floor, except the barren playa and its border of pickleweed, was occupied by this community (Fig. 10). The greatest expanse occurred in the vicinity of Tule Springs where the valley floor attains its greatest width. This shrub is large, in comparison with some of the other desert shrubs, and often attains a height of 3 to 4 feet. The plants were rather widely spaced, averaging 13 per square rod, but the total ground coverage was greater than that of any other community except sagebrush (Table 7).

TABLE 7. Floral composition of 24 quadrat samples taken in the Greasewood Community.

Species	Frequency	Abundance			Composition			Coverage		
		Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
Sarcobatus vermiculatus (Hook.) Torr.	100.0	24	4	13.0	100.0	5.6	45.2	29.5	4.4	15.0
Suaeda fruticosa Forsk.	79.2	40	0	10.8	60.0	0	27.2	11.5	0	3.9
Atriplex confertifolia (Torr. & Frém.) S. Wats.	37.5	48	0	2.2	80.0	0	15.8	11.3	0	2.3
Kochia vestita (S. Wats.) Rydb.	20.8	124	0	10.0	74.0	0	9.5	3.2	0	0.3
Distichilis stricta (Torr.) Rydb.	8.3	4[7]	0	0.3	25.0	0	1.9	9.0	0	0.6
Artemisia spinescens D. C. Eaton	4.2	20	0	0.8	11.1	0	0.4	1.4	0	0.06

[7]Number of patches of sod rather than individual plants of *Distichlis stricta*.

The number of species of plants in this community was very limited in most localities, only 6 occurring in the quadrat samples taken in White Valley. Although salt blites, *Suaeda fruiticosa* Forsk., was the principle associate of the greasewood in the vicinity of Tule Springs, the salt bush, *Atriplex nuttallii* S. Wats., was common in some other parts of the valley and *Atriplex falcata* (Jones) Standl. has been reported as a prominent member of this community in other localities (Shantz & Piemeisel 1940). Pickleweed extended into this community from its border around the barren playa as one of the subdominants in the vicinity of Tule Springs. Salt grass formed a solid sod around some of the springs but it did not extend very far out into the greasewoods. Alkali sacton, *Sporobolus airoides* Torr., and big rabbitbrush were only occasionally encountered although in some areas they may be important constituents of this community.

The soil on which this community occurred was usually a heavy clay or clay loam. In some parts of the valley, which are subjected to flooding, the soil surface was hard and baked. In other places

FIG. 11. Greasewood community in White Valley, Millard County, Utah. (Sept. 1, 1940.)

the soil was often so loose that one sank half way to his ankles when walking through it. Some sand dunes were also present thus making a diversity of habitats as far as soil conditions were concerned.

The leaves of the greasewood were later in coming out than those of shadscale and tetradymia so that during the early spring this community looked very barren in comparison with communities of higher elevations. However, during the summer the picture was completely reversed, the greasewoods became very green and appeared like an oasis in comparison with the tetradymia community.

The relationship between the greasewood and shadscale communities has been described on page 262, where it was pointed out that a wide ecotone occurs where the two meet in some areas.

Invertebrates of the shrub layer society—The greasewoods retained their leaves and remained green throughout the summer and thus maintained a more constant invertebrate population than did some of the other dominant shrubs (Fig. 9).

Spiders were very abundant averaging 4 to 5 specimens per sample (Table 8). In 1939 they were most abundant during the middle part of August when many immatures were present, but during 1940 they were most numerous during the last part of June. *Philodromus* sp., *Dendryphantes* sp., and *Pellenes* sp., were the most abundant and frequently encountered species. The species *Sassacus papenhoei* Peckham occurred less often in quantitative samples than some of the other species but it seemed to be restricted to this community.

Mites occurred much less frequently than in either the shadscale or teradymia communities. *Bryobia praetiosa* was most abundant although other species included *Erythraeus* sp. and *Trombidium* sp.

Orthoptera were commonly seen and occurred in the quantitative samples with about the same frequency and abundance as in the tetradymia community. The nymphs of *Melanoplus* sp. first appeared during early July, becoming most abundant about July 15. Nymphs of *Aeoloplus t. tenuipennis* were most abundant about August 10.

Hemiptera were far less numerous than they were in the shadscale community and constituted only 6.3 percent of the total invertebrate population. The pentatomids, *Thyanata rugulosa* (Say) and *Chlorochora sayi* Uhl., were more abundant than in any other part of the valley and were most numerous about the middle of August. Miridae was the most abundant family, being represented by 7 species, of which 4 were restricted to this community (Appendix B).

Homoptera constituted half of the total insect population due primarly to the great abundance of one species of membracid, *Echenopa permutata* Van D. This species occurred in 56 percent of the collections and was most abundant during the latter part of July in both 1939 and 1940. The cicada, *Neoplatypedia constricta* Dan's, was conspicuous during midsummer because of its singing and it was an important source of food for some of the lizards of this community. The Cicadellidae were represented by 8 species, of which *Ceratagallia dondia* (Oman) and *Ophiola clavata* (Ball) were the most prevalent. Three species of fulgorids were collected of which *Hysterapterum cornutum* Mel. and *Oliarus* sp., were the most numerous. The coccid, *Orthezia* sp., occurred in about 20 percent of the quantitative samples and was most abundant during the early part of May. The greasewood is also the host plant of the aphid, *Aphis bonnevillensis* Knlt. although this species was seldom taken in the quantitative samples.

Coleoptera were much more abundant than in the shadscale community. The chrysomelid, *Pachybrachis* sp., was the most abundant species, occurring in almost 50 percent of the collections. The coccinellids, *Hyperaspis fastidiosa* Csy. and *Hippodamia convergens* Guer., were taken in no other community.

Diptera constituted a greater percentage of the total invertebrate population in this community than in any other. They were represented by 19 species of which 10 were taken in no other community (Appendix B.). Agromyzidae was the most abundant and frequently collected family.

The lepidoptera were represented principally by larvae in the quantitative samples. Phalaenidae and Geometridae were the most abundant families and were most common during the middle part of May.

Hymenoptera constituted slightly less than 10 percent of the total invertebrate population. Ants were more abundant on the greasewoods than on any other shrub, the 3 most numerous species being *Tapinoma sessile* (Say), *Formica neogagates* Emery, and *Camponotus (Myrmentoma)* sp. They were most conspicuous during the middle of May.

The ground layer society—Tenebrionid beetles were the most conspicuous components of this society and were more numerous than in any other community. Of the following 6 species, *Eleodes hispilabris*, *E. obscura*, *E. hirsuta* Lec., *E. pilosa* Horn, *E. extricata* (Say), and *E. nigrina* Lec., the last 3

TABLE 8. Frequency, average number per square meter (50 sweeps), and percentages of total invertebrates collected in quantitative samples.

Orders	Frequency of occurrence (%)				Average number per collection (M²)				Percent of total invertebrates collected			
	Shadscale	Tetradymia	Greasewood	Sagebrush	Shadscale	Tetradymia	Greasewood	Sagebrush	Shadscale	Tetradymia	Greasewood	Sagebrush
Araneida	50.0	58.8	70.0	64.7	1.2	1.4	4.6	5.4	8.2	2.4	8.5	6.5
Acarina	25.0	35.3	16.1	11.8	3.4	2.5	0.7	0.2	24.2	3.8	1.2	0.2
Collembola	3.6	5.9	0	0	0.1	0.3	0	0	0.8	0.4	0	0
Orthoptera	14.3	29.4	24.0	35.4	0.2	0.4	0.5	0.8	1.6	0.7	0.9	3.1
Thysanoptera	0	11.8	3.2	0	0	10.5	0.1	0	0	15.3	0.1	0
Hemiptera	39.3	58.8	54.8	88.2	2.3	37.4	3.0	11.3	16.5	54.0	6.3	13.9
Homoptera	57.2	52.9	80.6	64.7	3.4	7.2	27.7	45.1	24.7	10.4	51.1	54.9
Coleoptera	32.0	58.8	74.6	82.4	0.7	1.7	4.4	5.5	4.9	2.5	8.1	13.9
Lepidoptera	3.6	35.3	32.2	29.4	0.1	0.4	0.5	0.4	0.5	0.8	0.8	0.5
Diptera	42.8	52.9	64.5	58.8	1.4	5.0	7.6	1.8	10.1	7.2	14.1	5.8
Hymenoptera	35.7	41.2	80.6	47.1	1.1	1.8	4.9	1.6	8.5	2.5	8.9	1.2

were restricted to this community. *Eleodes pilosa* is covered with numerous small hairs to which the white soil of the valley floor adheres thus making it very inconspicuous and easily overlooked. *Eleodes obscura* was not only the most conspicuous tenebrionid because of its size, but it was also the most numerous. It was active both day and night, and was often observed until after midnight. Carrion beetles, *Necrophorus guttulus* Mots. and *N. guttulus hecata* Bland were found wherever an animal had been dead for a day or more. The hister beetle, *Saprinus* sp., and the dermestid, *Dermestis marmoratus* Say, which also feed on carrion, were usually found in the same carcass with the carrion beetles. So voracious are these beetles that a large jack rabbit would be completely devoured within three or four days.

The hymenoptera were represented primarily by ants of which *Dorymyrmex pyramicus* (Roger), *Solenopsis molesta* (Say), and the harvester ant were the most frequently encountered, the first 2 species being found only on or near sand dunes. The litter beneath the greasewood bushes harbored hymenoptera and assilidae larvae.

Winterfat Community

(*Eurotia-Oryzopsis-Microdipodops Faciation*)

Although the shadscale, tetradymia, and greasewood communities were the most extensive and ecologically important communities of the White Valley area there are several others which must also be considered. One of these is the winterfat community, which was probably much more extensive before the advent of white man than it is at the present time. A study of the age of these shrubs in various communities of Pine and Wah Wah Valleys by Stewart, Cottam, and Hutchings (1940), reveals that under conditions of overgrazing winterfat fails to grow and reproduce. Because of its greater palatability it has been greatly reduced in abundance and areas it once occupied have been invaded by the little rabbitbrush.

Winterfat, the principal dominant, has rather high water requirements and is intolerant of high concentrations of mineral salts, being found only where the salt content of the soil does not exceed 0.04 to 0.05 percent in the upper 2 feet (Shantz & Piemeisel 1940). It was usually found in the purest stands on a sandy soil which is permeable and which readily absorbs a large share of the available precipitation. It also occurred on sandy soils where watercourses spread out over flat areas and where the normal amount of precipitation is thus augmented by the run-off from higher areas.

FIG. 12. Winterfat Community in Pine Valley, Millard County, Utah. (Aug. 3, 1940.)

TABLE 9. Floral components of 16 quadrat samples taken in the Winterfat Community.

Species	Frequency	Abundance			Composition			Coverage		
		Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
Eurotia lanata (Pursh) Moq.	100.0	148	28	106.0	100.0	53.8	83.8	15.7	5.9	8.65
Sphaeralcea grossulariaefolia (Hook. & Arn.) Rydb.	50.0	32	0	6.0	21.1	0	4.3	0.8	0	0.2
Atriplex confertifolia (Torr.& Frém.)S.Wats.	25.0	16	0	3.4	30.8	0	5.6	6.3	0	1.1
Oryzopsis hymenoides (Roem. & Shult.)Ricker	25.0	16	0	2.5	20.0	0	2.9	1.8	0	0.23
Hilaria jamesii (Torr.) Benth.	25.0	12	0	2.0	7.1	0	1.2	0.3	0	0.05
Tetradymia glabrata A. Gray	12.5	8	0	1.0	15.4	0	1.9	0.2	0	0.16
Artemisia spinescens D. C. Eaton	12.5	4	0	0.5	2.2	0	0.3	0.5	0	0.09

This community often occurs as "islands" within the more extensive shadscale community, with which it was always closely associated. These "islands" are readily discernible because of the light color of the dominant plant which may attain a height of 18 inches under most favorable conditions but which is usually only 8-12 inches in height (Fig. 12). Winterfat and Indian rice grass were the principal dominants. The subdominants included galleta grass, globemallow, and bud sage. Gray molly, matchweed, *Gutierrezia sarothrae* (Pursh) Britt., and Rusby., and the little rabbitbrush were also present in varying degrees of abundance under conditions of overgrazing. *Astragalus cibarius* Sheld., *Eriogonum cernuum* Nutt., *E. hookeri* S. Wats., and *Sphaerostigma boothii* (Dougl.) Walp. also occur in this community in Escalante Valley (Shantz & Piemeisel 1940).

Black Sage Community

(*Artemisia nova-Atriplex-Neotoma Faciation*)

Situated along the west border of the White Valley floor, near the central and north-central parts of the valley, are several black lava rock knolls which attain an elevation of slightly over 5,000 feet above sea level (Fig. 13). The soil on these knolls is very shallow. Large rocks and cliffs comprise a large part of the terrain.

Black sage, *Artemisia nova* A. Nels., was the most prevalent dominant. Other dominants included shadscale, at the lower elevations of the community, and 2 species of tetradymia, *Tetradymia spinosa* Hook. & Arn. and *T. glabrata* A. Gray, at the higher elevations. Galleta grass and wheat grasses, *Agropyron* spp., were conspicuous among the dominant shrubs.

TABLE 10. Floral components of 24 quadrat samples taken in Black Sage Community.

Species	Frequency	Abundance			Composition			Coverage		
		Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
Artemisia nova A. Nels.	83.3	20	0	9.2	62.5	0	22.5	7.8	0	3.4
Chrysothamnus stenophyllus (A. Gray) Greene	83.3	64	0	13.2	66.7	0	20.3	6.4	0	1.5
Hilaria jamesii (Torr.) Benth.	75.0	80	0	19.2	71.5	0	23.2	10.4	0	2.0
Tetradymia spinosa Hook. & Arn.	41.7	12	0	3.0	33.3	0	6.9	8.3	0	2.3
Atriplex confertifolia (Torr. & Frém.) S. Wats.	33.3	96	0	9.6	63.1	0	8.4	8.8	0	0.9
Agropyron spp.	25.0	20	0	2.7	17.8	0	2.9	1.6	0	0.4
Ephedra spp.	25.0	8	0	1.6	14.3	0	2.5	4.0	0	0.8
Suaeda fruticosa Forsk.	16.7	56	0	7.0	43.7	0	6.7	1.5	0	0.2
Oryzopsis hymenoides (Roem.& Shult.) Ricker	16.7	4	0	0.7	16.7	0	2.0	0.7	0	0.07
Tetradymia glabrata A. Gray	8.3	12	0	1.0	33.3	0	2.8	8.8	0	0.7
Artemisia spinescens D. C. Eaton	8.3	8	0	0.6	12.5	0	1.0	0.3	0	0.03
Eurotia lanata (Pursh) Moq.	8.3		0	0.3	8.3	0	0.8	0.3	0	0.03

The jointfir, *Ephedra viridis* Coville, was scattered throughout the community being most abundant at higher elevations. *Laphamia stansburyi* A. Gray occurred in the more rocky situations, being especially conspicuous along crevices on the face of cliffs. Other floral components included Indian ricegrass, three-awn grass, little rabbitbrush, gray molly, and matchweed.

The invertebrates of this community were not investigated but the minor influent animals were found to be very distinct.

FIG. 13. Shadscale community in foreground and Black Knolls on which the black sage community occurred in White Valley, Millard County, Utah. (July 2, 1940.)

PICKLEWEED COMMUNITY

This community (Fig. 10) forms a narrow fringe around the barren playa adjacent to the greasewood community in the vicinity of Tule Springs. The dominant plant, *Allenrolfea occidentalis* (S. Wats.) Kuntze, is highly salt-tolerant and is largely restricted to areas where the salt concentration is beyond the tolerance of the greasewoods. Consequently

TABLE 11. Floral components of 8 quadrat samples taken at the convergence of the Greasewood and Pickleweed Communities.

Species	Frequency	Abundance			Composition			Coverage		
		Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
Allenrolfea occidentalis (S. Wats.) Kuntze	100.0	76	4	41.6	100	50	91.6	13.5	6.2	9.0
Sarcobatus vermiculatus (Hook.) Torr.	37.5	4	0	1.5	50	0	8.4	6.7	0	2.4

it is seldom accompanied by any other plants. The greasewoods which do occur in this community were usually stunted, yellowish in color and very sickly looking.

THE LITTLE RABBITBRUSH ASSOCIES[8]

The most common species of little rabbitbrush was *Chrysothamnus stenophyllus* (A. Gray) Greene; however, in certain localities this species may be accompanied by several other species including *C. laricinus* Greene, *C. puberulus* (D. C. Eaton) Greene, and *C. greenei* (A. Gray) Greene, all of which are very similar in general appearance and cannot be reliably distinguished in the field. Their ecological requirements also seem to be apparently the same so that these offer no criteria for differentiating them. The landscape aspect of this community is very distinct, especially where it is adjacent to the winterfat community which is much lighter in color (Fig. 14).

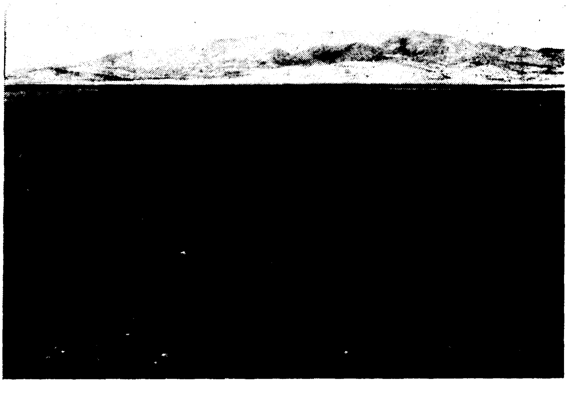

FIG. 14. Little rabbitbrush community (dark vegetation) within which are interspersed "islands" of winterfat (light vegetation) in Antelope Valley, Millard County, Utah. (Aug. 9, 1940.)

This community is not found on soils with a high mineral content or on heavy soils where the water table is near the surface. It was most abundant where a hard-pan is near the surface or on sandy or rocky soils where there was little or no competition with the climax dominants of the area. It quickly invades areas where winterfat and shadscale have been removed or reduced in vitality and abundance.

[8] An associes is the developmental stage of the climax community (association). It is characterized by its lack of permanence and is replaced by another community in the process of development or succession.

Because it is less palatable than some of the dominant shrubs it suffers less from the effects of grazing and consequently occupies a greater area at the present time than it did before man's domestic animals were introduced. There is a high negative correlation between little rabbitbrush and winterfat and Indian ricegrass and when the winterfat and ricegrass are decreased in abundance the little rabbitbrush is greatly increased (Stewart, Cottam & Hutchings 1940).

THE SAGEBRUSH COMMUNITY

Extent and Climax Status

The sagebrush community (*Artemisia-Agropyron-Lepus* Association) is one of the most important biotic communities of the Northern Desert Shrub Biome. It was formerly very widespread throughout the northern Great Basin area and the Columbia River Drainage Basin, but has been greatly reduced by the agricultural pursuits of man. Scattered fragments extend as far south as the Mexican border, but it ceases to be a dominant about 70 miles south of Modena, Utah where it merges into the Southern Desert Scrub Biome. Within the piñon-juniper association it often forms a shrub layer beneath and between the dominant trees, and it may extend to elevations of 8,500 feet as a scattered remnant in the open areas within the lodgepole pine association (Svihla 1932).

The northern limit of this association merges into the grassland communities of northern Utah, southern Idaho and southeastern Washington. As has been pointed out by Weaver (1917) no sharp geographical line can be drawn where these two biomes meet. The moisture requirements for the driest grassland community (Agropyron Association) and the sagebrush community are very similar, the principal difference being in the distribution of the precipitation during the year (Fig. 2). The similarity in the climatic requirements of these two communities is reflected in the compatibility of the dominants. *Agropyron spicatum* (Pursh) Scribn. & Smith, the principal dominant of the Agropyron community, together with other associated grasses and herbs such as *Stipa commata* Trin. & Rupr. and *Balsamorhiza sagittata* (Pursh) Nutt., occur as common associates of the big sagebrush within the Artemisia community. Thus it is often difficult to determine just what the true climatic climax community is within this ecotone area where the two biomes converge, and it is possible that various disturbances, such as over-grazing and fire, may be largely responsible for determining the relative abundance and dominance of one or the other of the principal dominants at the present time.

There is considerable evidence in certain areas of Utah (Pickford 1932 and Stoddart 1941), southern Idaho (Craddock and Forsling 1938), Idaho and Washington (Humphrey 1945), that over-grazing decreases or eliminates the competition of the more palatable dominant grasses and promotes the development of a disclimax sagebrush community. Within these same areas it is evident that sagebrush is greatly reduced when burned and may be practically eliminated by fire in the drier areas (Pickford 1932, Daubenmire 1942). To what extent fire may have destroyed large areas of climax sagebrush, even before the advent of white man is problematical. Captain Bonneville, whose early explorations date back to 1832, made note of the fact that the sky was darkened for days at a time by smoke from fires that were set by the Indians (Irving 1843). Much of the evidence used to support the theory that many of the present sagebrush areas are disclimax is based on observations of unplowed corners of cultivated fields, roadways, cemeteries, etc. The degree to which such areas have been protected from grazing is usually quite certain but the history of such areas as to the previous occurrence of fires is not always known. Many of the areas used as cemeteries have originally been burned and the remaining stubs of sagebrush removed.

The dominance of sagebrush and its ability to resist the artificial establishment of forage grasses, in the vinicity of Wells, Nevada, is attested by Robertson (1943) who reports that for the successful establishment of grass seedlings, the vigor and competition of the sagebrush for soil moisture must be reduced by pruning its roots with a scarifier or ripper to a depth of 9 to 12 inches below the soil surface.

The evident dominance of sagebrush in Idaho has been determined by Eggler (1941) who studied the succession of plant communities on the volcanic deposits of the Snake River plains area and found that the primary communities are all replaced by a climatic climax association dominated by six shrubs, of which *Artemisia tridentata* is the principal one, and five important grasses. It is his opinion that, "Sage is and evidently has been a dominant member of the vegetation since the advent of white man into the region." (Eggler 1941, p. 280).

Biotic Matrix

Dominants and subdominants—Sagebrush communities are largely confined to deep, permeable, salt-free soils of well-drained valleys and bases of mountain ranges, especially alluvial fans. The soils vary in texture from clay and sandy loam to gravel and usually have a high water-holding capacity. Big sagebrush, the principal dominant, has a long tap root with numerous lateral branches which facilitate its utilization of moisture to a considerable depth as well as near the surface of the soil. Where sufficient soil moisture is available at depths of 3 to 6 feet and where the salt content of the soil is very low this plant attains its greatest growth, becoming 4 to 6 feet in height and having a trunk diameter of 5 inches or more (Fig. 15). In areas where there is a hard-pan within 12 to 18 inches of the surface or where the salt content of the soil becomes more than 0.5 percent in the third or fourth foot it fails to thrive and becomes sickly looking (Kearney, Briggs, Shantz, *et al.* 1914).

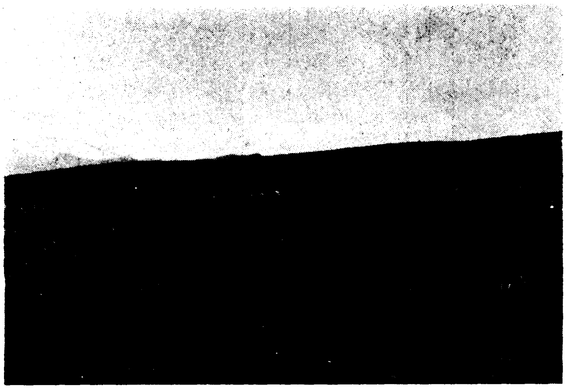

FIG. 15. Sagebrush community in Fernow Valley, Juab County, Utah. (Aug. 3, 1939.)

Sagebrush may occasionally be found associated with the more salt-tolerant shrubs such as shadscale and greasewood but when it does extend into these other communities it is found only along ravines where the soil is deeper, more permeable and well drained. On rocky knolls and hillsides, where the soil is more shallow and coarser in texture, the big sagebrush is replaced by black sage, *Artemisia nova* A. Nels.

When sagebrush is removed by burning or cultivation, various annual and biennial subdominants such as brome grass, *Bromus tectorum* L., Russian-thistle, pigweeds, *Amaranthus* spp., sunflower, *Helianthus annus* L., and verbena, *Verbena bracteosa* Michx., invade and occupy the area. Such plants are usually replaced by matchweed which eventually gives way to the dominant sagebrush and its associates under natural conditions.

Sagebrush forms one of the most dense covers of any of the shrubs encountered. The individual bushes grow much closer together and in some places in Fernow Valley attain almost treelike proportions. Unfortunately Fernow Valley is a winter range for sheep and consequently much of the virgin herbaceous undergrowth has been removed. However, remnants of the following dominant grasses still persist: wheat grass, *Agropyron spicatum* (Pursh) Scribn. & Smith, needle-and-thread grass, *Stipa commata* Trin. & Rupr., Indian rice grass, and galleta grass. Other herbaceous components include the three-awn grass, *Aristida longiseta* Steud., squirrel-tail grass, brome grass, balsam root, *Balsamorhiza sagittata* (Pursh) Nutt., sego lily, *Calochortus nuttallii* Torr. and Gray, plantago, *Plantago purshii* Roem., and Shult., phlox, *Phlox* sp., milk-vetches, *Astragalus uintahensis* Jones and *A. cibarius* Sheld., *Applopappus nanus* (Nutt.) D. C. Eaton, *Eriogonum cernuum tenue* Torr. & Gray, *Erigeron pumilus* Nutt., *Castilleja* sp., and *Crepis occidentalis* Nutt. These plants were not sufficiently numerous nor large enough to alter the aspect of the community but they formed an integral part of the biotic matrix during the spring and summer. Big rabbitbrush was prevalent along ravines at the lower end of the valley. *Atriplex nuttallii* and Russian-thistle were abundant within small areas in the central part of the valley which had been previously cultivated.

Invertebrates of the shrub layer society—The invertebrate population was about the same as in the greasewood community, reaching a maximum during June (Fig. 9). The late summer decline was less rapid than in the shadscale and tetradymia communities where the dominant plants were more widely spaced and where there was a considerable amount of defoliation due to the more xeric conditions to which those communities are subjected.

Spiders were very prevalent and averaged 5.4 per collection. Most species became most abundant during the latter part of July and early August when a great many immatures were present. The most abundant species were *Philodromus* sp. and *Dendryphantes* sp. Species collected in no other community included *Xysticus conctator* Thorell and *Icius* sp.

Atomus arvensis Bks. was the only species of mite collected and it occured with a frequency of only 11.8 percent (Table 8).

Grasshoppers were taken in about one-third of the quantitative sweepings but constituted only 3.1 percent of the total invertebrate population although they were very frequently seen.

The hemiptera were very distinct. Seven of the 15 species collected were found in no other community. They occurred in almost 90 percent of the collections and constituted about 14 percent of the total invertebrate population (Table 8). Miridae was the most prevalent family and *Chlamydatus uniformis* Uhl. and *Tuponia* sp. were the most numerous species. The wide-ranging damsel bug, *Nabis alternatus* Parshley, occurred with greater frequency in this community than in any other. The greatest total abundance of hemiptera occurred during June but a few species were most numerous during the latter part of the summer.

Homoptera were more prevalent in this community than in any other. They averaged 45.1 individuals per collection and constituted 54.9 percent of the total invertebrates collected. The spittle bug, *Clastoptera brunnea* Ball, occurred in 35.3 percent of the collections and was taken in no other community. Cicadas, *Neoplatypedia constricta* Dan's, were very conspicuous although they were seldom taken in quantitative collections. They tend to remain close to the main branches of the sagebrush and thus escape being taken when sweepings are made. Cicadellids were far more numerous than in any other community, the most prevalent species being *Empoasca nigra typhlocyboides* G. & B., *E.* sp. (*nigra* group), and *E.* sp. (*aspersa* group). The fulgorid, *Hysteropterum cornutum* Mel., was more abundant in this community than in any other and occurred in 52 percent of the quantitative collections.

Coleoptera averaged 5.5 per collection and constituted almost 14 percent of the total invertebrate population (Table 8). Coccinellids were abundant and very distinct. Six species were collected, none of which occurred in any other community. The most abundant of these were *Hippodamia apicalis* Csy., *Scymnus* sp., and *Hyperaspis lateralis montanica* Csy. The most abundant chrysomelid was *Pachybrachis* sp., but it was less abundant than in the greasewood community. Two species of snout beetles, *Promecotarus densus* Csy. and *Apion sordidum* Smith, were fairly common and were not encountered elsewhere.

Lepidoptera constituted less than 1 percent of the total invertebrate population. Only 6 larvae representing 3 families were collected in all the quantitative samples.

Although diptera occurred in more than 50 percent of the collections they were never abundant and made up only 5.8 percent of the total invertebrates collected. Bombyliids belonging to the genus *Geron* were the most common.

Hymenoptera were also scarce, only 6 species of ants and 4 species of parasitic hymenoptera were collected (Appendix B). The ants most frequently taken were *Camponotus (Myrmentoma)* sp., *Monomorium minimum* (Buckley), and *Iridomyrmex* sp.

Ground layer society—The most conspicuous component of this society was the western harvester ant which was far more abundant than in any other community. The number of its mounds varied from 4 to 8 per acre with an average of 6.2 for five 1-acre plots. The effect of these ants on the vegetation adjacent to their mounds was very striking. Around each mound all the vegetation was removed for a distance varying from 2.5 to 12 feet. Thus the denuded area per mound varied from 95 to 454.4 square feet with an average of 300.7. Their coactions within the community not only involved the plants which they feed on and store in their burrows but they were also observed carrying insects into their mounds. Another ant which was not so frequently encountered because it is nocturnal was *Camponotus maculatus vicinus* Mayr. This is a large brown ant whose burrows were found to extend two to three feet below the surface of the ground, usually at the base of a large sagebrush. This species is carnivorous and often stripped almost all the skin and flesh from the heads of trapped rodents.

Although grasshoppers were seldom taken in the quantitative sweepings from the sagebrush, they were very common both on the vegetation and on the ground. The 2 most numerous species were *Trimerotropis p. pallidipennis* (Burm.) and *Trimerotropis g. gracilis* (Thomas).

Two beetles encountered only in this community included the carabid, *Pterostichus californicus* (Dej.), and the cerambycid, *Prionus palparis* Say. Tenebrionid beetles were far less abundant than in other communities, *Eleodes obscura* (Say) being the only species collected.

INFLUENT ANIMALS

MAJOR PERMEANT INFLUENT[9]

Mammals

The badger, *Taxidea taxus* ssp., has been greatly reduced by the predator control practices intended for the coyote (Davis 1939, Hall 1930, Dixon 1930, and Howell 1930), but it is still present throughout all the communities studied. Its presence is conspicuously revealed by the excavations it produces in search of ground squirrels, kangaroo rats, and pocket gophers. Fresh diggings were found in every community except winterfat, however, old excavations being utilized by burrowing owls, were also found in that community. For some reason the number of excavations found in 1940 were much fewer than the number in 1939. Inasmuch as the ground squirrels were much less numerous in 1940 than in 1939, it may be possible that the badgers had gone to other areas in search of these prey. The Tule Springs area, where ground squirrels were abundant, was visited both years by badgers, and near cultivated areas of Deseret and Garrison, where ground squirrels were prevalent both years, badger excavations were very much in evidence.

The excavations produced by the badger are utilized to a great extent as dens and places of refuge by many other animals. The burrowing owl is almost entirely dependent on the badger for providing it a place of abode. Coyotes often enlarge badger holes and use them as dens in rearing their young. They were used to a very great extent by cottontail rabbits both as a place of refuge when being pursued and also as a place in which to rear their young. Rodents often use them as retreats and as permanent places of residence. Lizards and snakes retreat into them in times of danger and to hibernate. Rock wrens were using abandoned badger holes as a nesting place in the tetradymia community.

The kit fox, *Vulpes macrotis* ssp., ranges throughout the biome but it has been considerably reduced in numbers by trapping and poisoning campaigns. Yarrow (1875, p. 55), in referring to this species says, "It is thought to be tolerably common in Utah and Nevada, as Indians were seen with skins in their possession." Four dens of this species were found, one of which was located in the winterfat area and the others in the shadscale. The dens were located in open areas unprotected by vegetation, but since the kit fox is largely nocturnal and remains in its den during most of the day, protective vegetative cover is not so important as in the case of the coyote. When it does come out during the day it ventures only a short distance from its den and depends very largely on the den as a means of escape.

The kit fox is small and feeds on smaller prey than does the coyote. Around the mouth of two of the dens were strewn the remains of many rodents

[9] "Major influents" is an arbitrary category which includes the larger mammals and birds whose coactive effects within the community are significant, primarily because of their size. The term "major" is not used in the sense that members of this category are biotically of major (greatest) importance within the community.

on which these foxes had been feeding. Among these were 19 kangaroo rats, 2 kangaroo mice, 1 pocket mouse, 1 white-footed mouse and rabbit bones. So important is the kangaroo rat in the diet of this fox that in some areas its distribution is found to be very closely correlated with that of the kangaroo rat (Bailey 1931).

The coyote, *Canis latrans lestes* Merriam, is one of the most important major influents of the biome. Although it was more abundant in some communities than others it ranged throughout all of them. No quantitative data were obtained as to the absolute abundance of this species, but signs such as tracks, scat, dens, and calls indicated that it is much more abundant in the greasewood and sagebrush communities than in the more open type of communities.

Three dens were located in the greasewood community but only one was in use at the time they were found. The active one was located almost in the center of White Valley near the south end and looked as if it had originally been a badger excavation that had been cleaned out and enlarged by the coyote. The burrow was in the east side of a greasewood-covered hummock and sloped slightly downward at its entrance but was practically horizontal the remainder of the way back. The evening it was found the young whelps could be plainly heard not far back from the entrance. When the den was visited the following day all the whelps had been removed. This demonstrates how cunning these animals are, a factor which has undoubtedly been responsible for their perpetuation in spite of the heavy pressure constantly being exerted to exterminate them.

Coyotes breed from late January to early March in Utah and Nevada, and the whelps are usually born in April and early May (Hamlett 1938). The size of the litter may vary from 4 to 17 with 7 being about the average number produced. Two litters which were dug out in White Valley in 1940 by Civilian Conservation Corps workers each consisted of 6 whelps. When the young whelps are 8 to 10 weeks old the family leaves the den and travels together for a considerable time (Young & Dobyns 1937). Young coyotes about half to two-thirds grown were not seen alone until August.

The coyote is a very important coacter within all the communities because it is active throughout the year and because of the large number of biotic components which it utilizes as food. Its food habits have been studied very extensively because of its economic importance (Lantz 1905; O. J. Murie 1935; A. Murie 1940; Sperry 1933, 1934, 1939, 1941; Bond 1939). These studies indicate that rabbits are the coyote's main source of food. Practically all types of rodents are also included in its diet as well as birds, reptiles, insects, and some vegetable matter. Rabbits occurred in 43 percent of the 8,339 coyote stomachs examined by Sperry (1941), and ranged from 37 percent in September to 52 percent in May; they constituted 33.25 percent of the total food volume. Rabbits and rodents together constituted more than 50 percent of the food eaten. One stomach from a female coyote collected in California contained 30 pocket mice and one kangaroo rat. Reptiles occurred in 3 percent of the stomachs examined by Sperry and snakes occurred about two and a half times as often as lizards. The number of insects eaten by coyotes is usually small but in some cases the total stomach contents have been found to be composed of insects (Sperry 1941). Murie (1940) observed coyotes feeding on grasshoppers on several occasions.

Although a continuous warfare is waged against the coyote by stockmen and the Predator and Rodent Control Division of the Fish and Wildlife Service it continues to be very abundant. From July 1, 1915 to June 30, 1939 the Fish and Wildlife Service agents killed a total of 86,889 coyotes in Utah, or an average of 3,620 per year. During the fiscal year of 1939 from July 1 to June 30, 1940, 19,513 coyotes were killed. The average yearly kill from 1915 to 1940 amounted to 4,056. A large portion of these were taken in western Utah because that part of the state is the principal winter range of sheep and is consequently the focal point of predator control activities. In Millard County alone, 6,465 coyotes were killed by the Fish and Wildlife Service from 1930 to March 1941, although no regular campaigns were conducted during 1935 and 1936. The numbers killed per year varied from 53 in 1930 to 1,188 in 1940 (Zimmerman, personal correspondence). These numbers do not include the ones that were not found after being poisoned or the ones that were killed by stockmen and individual trappers not in the employ of the government. This increase in the yearly number killed may be due to an increase in the number of government predator control agents in the field and the development of more efficient trapping and poisoning methods and does not necessarily mean that coyotes are increasing in numbers. However, many long-time resident stockmen in western Utah are of the opinion that coyotes are just as abundant now as they have ever been within their experience. The elimination of part of the coyote population decreases the competition for food of those that remain and thus increases the survival value of themselves and their offspring. Since much of the predator control work is done during late summer, autumn, and winter most of the survivors of these seasonal campaigns are able to reproduce the following spring and bring forth a new generation to replace the ones that were killed the previous year. The cunningness of the coyote has enabled enough of them to survive each winter so that there is an ample breeding stock each spring to restock the area again by autumn.

Evidence of the bobcat, *Lynx rufus* ssp., was found only twice. The tracks of one were found along a dusty road in the shadscale about 3 miles below the base of the mountains and one was seen in King Canyon on the west side of White Valley May 21, 1940. This species is probably only an occasional visitor in these valley communities and is of very little ecological importance.

Remnants of the once-numerous pronghorned antelope, *Antilocapra a. americana* (Ord), still remain within the Great Basin. Their numbers are greatly reduced at the present time but the small scattered bands that still exist indicate that they originally ranged throughout Utah and Nevada. In 1922-24 the total number of antelope in Utah was estimated to be 670, of which 520 occurred in the western part of the state (Nelson 1925).

At the present time the antelope is given full protection and in some places is showing signs of increasing. Fourteen head were seen in the area between White Valley and Pine Valley during the two summers that were spent in that area, 5 being the maximum number seen at any one time. Groups of 16 to 20 were observed by local residents in the north end of White Valley and in the vicinity of the Desert Range Experiment Station during the winter of 1939-40. A Fish and Wildlife Service trapper reported a band of about 20 head in the vicinity of Fish Springs just north of White Valley during the summer of 1940. During the summer the antelope tend to scatter out and remain in the low hills and are consequently seldom seen in the valleys. Reports of sheepherders and Civilian Conservation Corp workers indicate that during the winter they congregate in much larger bands and are more commonly seen in the valleys.

Although the antelope reached its greatest abundance in the short grassland communities of the western plains region it was never restricted to such areas. Evidence from the early explorers of Utah and Nevada and testimonies of early residents make it very certain that the Great Basin supported thousands of these animals before white man began taking his toll. Although grasses may be very important in the diet of this animal it also consumes a large amount of browse from shrubs, especially in winter (Rouse 1941).

The antelope is not restricted to any one community but ranges throughout all of them. Although the reduced numbers now present probably exert very little influence in the communities as a whole their browsing and grazing effects on the vegetation may be noticeable where larger bands of these animals occur. Under natural conditions they constituted a basic part of the food supply of such predators as the coyote and bobcat, especially during the winter when the snow would tend to impede their movements. Nelson (1922, 1923) reported that a herd of 60 antelopes, at the National Bison Range, Montana, were destroyed by wildlife predators (chiefly coyotes) and Indian dogs during the winters of 1921-22 and 1922-23.

Birds

The major influent birds observed include the Cooper hawk, *Accipiter cooperii* (Bonaparte), western red-tailed hawk, *Buteo jamaicensis calurus* Cassin, Swainson hawk, *Buteo swainsoni* Bonaparte, golden eagle, *Aquila chysaëtos canadensis* (Linnaeus), Southern bald eagle, *Haliaeetus l. leucocephalus* (Linnaeus), marsh hawk, *Circus cyaneus hudsonius* (Linnaeus), prairie falcon, *Falco mexicanus* Schlegel, western burrowing owl, *Speotyto cunicularia hypugaea* (Bonaparte), and the long-eared owl, *Asio otus wilsonianus* (Lesson).

The Cooper hawk and red-tailed hawk were seen only occasionally during late summer and were of little ecological importance within these communities because of their limited numbers and limited seasonal activities.

The Swainson hawk ranged throughout all the communities and was seen throughout the summer, being most common in the sagebrush areas. Two nests were located April 11, 1940 in juniper trees adjacent to Fernow Valley. These hawks were most frequently seen foraging for food about 8 to 10 o'clock in the morning and about 5 o'clock in the afternoon. Animal remains at their nests indicate that they feed on insects, chiefly grasshoppers, as well as chipmunks and ground squirrels.

The biotic influence of eagles is very small, being practically negligible in the case of the bald eagle. Only two individuals of this species were seen during the entire period of investigation. The golden eagle was seen more frequently but it was not common. Rabbits seem to be the principal source of food of this species. On 3 occasions golden eagles were flushed from the greasewood community where they were feeding on freshly killed jack rabbits.

Marsh hawks were consistently seen only in the greasewood community and near cultivated areas in the vicinity of Deseret, Hinckley and Garrison, but they were occasionally seen foraging over practically all communities. Either one or the other of a pair was regularly seen in the vicinity of Tule Springs but no nest could be located. On several occasions these hawks were observed catching lizards. Since diurnal species of rodents are scarce in these communities it is possible that lizards may be a very important source of food for the marsh hawk in such areas. Linsdale (1938), reports that during 6 weeks of observation in Nevada, lizards were brought to the nests of this hawk more often than any other kind of food. He (Linsdale 1936a) also makes reference to the fact that stomachs of the marsh hawk, taken at Pyramid Lake in Nevada by Ridgway, contained nothing but small lizards.

The prairie falcon is a fairly common summer resident in White Valley. It was seen with a frequency of 35 percent in 1939 and 28 percent in 1940. This species is widely distributed and ranges throughout all the biotic communities. Although it nests in the low cliffs of the adjacent mountains it does much of its foraging within the valley communities. One nest was found on a shelf beneath an over-hanging ledge about 30 feet above the base of a perpendicular cliff. Small birds are probably preyed upon to a greater extent by this hawk than by any other, and lizards are also an important item in its diet from the evidence at the nest previously mentioned. These hawks were observed in pursuit of passerine birds on several occasions and their presence would always cause considerable alarm among the smaller birds. Rodents are also preyed upon by this species (Fisher 1907, Dawson 1923, Tyler 1923), as well as rabbits (Henninger & Jones 1909, Decker & Bowles 1930), and lizards and insects (Fisher 1893, Traverner 1934).

The burrowing owl occurred in all communities except sagebrush and was most abundant in the more open shadscale areas where the vegetation was sparce. In all instances except one it was occupying badger burrows. No colonies or aggregations were found such as have been described by Dawson (1923), but the pairs or family groups occurred by themselves. The shortest distance between any two pairs was 362 meters and in most cases they were from one-fourth to more than a mile apart.

The time of their egg-laying and hatching was not determined but the young were seen around the entrance of the burrows and able to fly during the middle part of July. Seven was the maximum number found in any one family, the size of the family usually ranging from 3 to 5.

This species is diurnal as well as nocturnal and was found outside its burrow at all times of the day. They were never observed hunting during the day but were seen flying about at night. The abundance of nocturnal animals utilized by them as food also indicates that they do a large part of their feeding at night. An examination of regurgitated pellets and animal remains about the entrance of their burrows indicate that their basic source of food is kangaroo rats and insects. Kangaroo rat remains were found in 100 percent of the pellets examined and insects in 96 percent. The insects eaten included grasshoppers, sand crickets, tenebrionids, and scarabaeids, together with scorpions. Other prey included pocket mice and white-footed mice as well as an occasional lizard.

The effect of this owl on rodent populations was very pronounced. A maximum of 3 rodents were caught in 4 nights on two 0.2-hectare and one 0.4-hectare plots where families of these owls were located. Other plots of equal size produced from 5 to 48 rodents during 4 nights' trapping where no owls were present. To what distance around their burrow the owls keep the rodent population at such a low ebb was not determined but it must be much greater than the boundary of a 0.4-hectare plot because other trapping data indicate that kangaroo rats travel several hundred yards away from their burrows. Had they not been depleted within that distance from the burrow more of them should have wandered into the area and been taken in the traps.

The long-eared owl was encountered in the black sage community in White Valley and the sagebrush community in Fernow Valley. One individual was consistently flushed from a ravine near the top of the Black Knolls. This species is usually found in the vicinity of tall shrubs or trees and the writer was very much surprised to find it within this area. As many as 3 individuals were seen along a deep ravine in Fernow Valley.

MINOR INFLUENTS[10]

Mammals

Bats were only periodically seen except at the Desert Range Experiment Station where a group of 5 desert pallid bats, *Antrozous p. pallidus* (LeConte), occupied the gable end of a building which they used as a place from which to hang while they consumed their food. The remains of 43 scorpions and 17 sand crickets were strewn along a window ledge below the bats over a period of three nights. The heads of some of the sand crickets would still be alive the next morning after the bats had consumed most of the other parts of their bodies. These are both terrestrial invertebrates and their capture would necessarily require that the bats go to the ground to get them. Although feeding on terrestrial non-flying invertebrates is rather unusual for most bats, it is apparently a common practice in this species, (Grinnell 1918, Nelson 1918, Hatt 1923, Huey 1936). These reports also list mole crickets, grasshoppers, and beetles as being taken by the pallid bat.

Other species of bats include the black-nosed bat, *Myotis subulatus melanorhinus* (Merriam), the pallid big brown bat, *Eptesicus fuscus pallidus* Young, and the Mexican free-tailed bat, *Tadarida mexicana* (Saussure).

Weasels were rarely seen but their apparent scarcity may be due to their secretive and nocturnal activity. One Nevada long-tailed weasel, *Mustela frenata nevadensis* Hall, was found on the highway about seven miles west of Hinckley and one other specimen was seen in a ground squirrel burrow within the greasewood community. They were reported as being seen only rarely at the Desert Range Experiment Station.

No evidence of the striped skunk, *Mephitis major* ssp., was found during the study of these communities. The writer suspected that it might occur in White Valley in the vicinity of Tule Springs but no evidence of its presence could be found. It is reported to be common near springs on Antelope Island in the Great Salt Lake (Marshall 1940).

The little spotted skunk, *Spilogale gracilis saxatilis* Merriam, occurred in rocky areas near the mouths of canyons just above the border of White Valley. A family was also found beneath an old building at the Desert Range Experiment Station. Because of their limited distribution these mammals are of little ecological importance in the communities studied but they may be important in other parts of the Great Basin where they are more abundant because of their food habits. Insects, chiefly grasshoppers and beetles as well as mice, rats, small birds, and lizards, are preyed upon by this skunk (Howell 1906).

The piute ground squirrel, *Citellus townsendi mollis* (Kennicott), is widespread throughout Utah

[10] The term "minor influents" is not used in the sense that members of this group are biotically less important than the major influents, but it is used as an arbitrary category which includes those smaller mammals, birds and reptiles which occur within the community. In many cases, members of this category may be biotically more important than some of the major influents.

and Nevada and becomes very numerous in some areas. These rodents tend to occur in colonies so that their distribution is usually spotty and localized. These concentrations were found where there was the greatest abundance of green herbaceous vegetation and consequently this species was most numerous near cultivated fields and in grassy areas around springs. They were only occasionally seen in the sagebrush community at Fernow Valley but were common in sagebrush areas farther south in the vicinity of Fillmore and Beaver, Utah. Very few were encountered in the shadscale, tetradymia and winterfat communities of White Valley, but they were numerous in the greasewood community in the vicinity of Tule Springs where there was an ample supply of salt grass.

They come out of hibernation during late February and early March, and according to Alcorn (1940), the males appear about two weeks before the females. Their breeding season must occur very soon after they come out of hibernation because by May 5, the young had emerged from their burrows and were actively feeding. Their seasonal activity is of short duration because they begin to aestivate during late summer. The time of aestivation seems to be correlated with the availability of food materials and the accumulation of body fat (Alcorn 1940). Consequently the males go into aestivation first and the young last. By the middle of June the adults had begun to aestivate and by the first of August none could be found in White Valley although young were seen as late as August 4 at higher elevations of the Confusion Range.

During their short seasonal period of activity they spend much of their time outside their burrows, voraciously feeding (Table 12). Grasses and other herbaceous plants seemed to be the principal source of their food but greasewoods are also utilized. The young ground squirrels often climbed to the tops of the greasewood where they fed on the terminal buds. They are not strictly herbivorous because they were observed feeding on individuals of their own species which had been killed by passing automobiles.

Their diurnal activities expose them to considerable predation by hawks and snakes. The stomach contents of two rattlesnakes and one gopher snake all contained ground squirrels. One of the rattlers had swallowed two young about two-thirds grown. They are also a favorite source of food for badgers. A badger began working on the colony at Tule Springs May 29th and within a week it had dug out 23 burrows.

The antelope ground squirrel, *Citellus l. leucurus* (Merriam), was very common during the summer of 1939 and was observed in all the biotic communities. At the writer's base camp these animals were so abundant that special precautions were necessary to keep them from robbing the tent. They were most abundant in the shadscale and tetradymia communities. They were seldom seen in the greasewood and seem to prefer the higher elevations where the vegetation is more sparse. Only 2 were caught in the

TABLE 12. Counts of the Piute ground squirrel in an area 15 meters wide and 72 meters long (0.37 acre), at Tule Springs, White Valley.

May 5, 1940				May 17, 1940			
Time of day	Temp. °F	No. of Squirrels		Time of day	Temp. °F	No. of Squirrels	
		Adults	Young			Adults	Young
5:00 a.m.	45	0	0	6:00 a.m.	55	3	0
5:30	46	2	0	6:15	57	3	5
6:00	48	4	2	6:30	58	2	4
6:15	48	3	2	6:45	58	4	7
6:30	49	3	6	7:00	59	4	9
6:45	51	5	4	7:15	60	1	8
7:00	52	4	7	7:30	62	1	9
7:15	52	4	3	7:45	62	3	9
7:30	53	5	8	2:00 p.m.	75	0	3
12:00	65	2	3	2:15	75	2	5
12:15 p.m.	65	2	2	2:30	76	2	4
12:30	66	0	3	2:45	77	1	2
12:45	66	1	5	3:00	77	1	4
1:00	65	3	4	3:15	78	3	5
1:15	65	2	3	6:30	73	3	3
1:30	66	0	4	6:45	73	2	2
1:45	67	3	2	7:00	72	1	4
2:00	68	1	3	7:15	70	2	1
2:15	69	2	2	7:30	70	0	1
2:30	70	2	4				

sagebrush community and very few were seen. During 1940 they were practically absent, only 2 being seen and one caught in White Valley from April to September. This decrease in their numbers from one year to the next was not a local occurrence restricted to White Valley, but was apparent throughout the surrounding areas. The cause for such a drop in abundance was not determined but it would appear as if a disease of some sort may have been responsible. Long (1940) states that in the southern part of the state large numbers of them were infected with a disease which caused open sores on their appendages and body.

Their burrows were most numerous along the banks of ravines although they also occurred in flat areas at the bases of the desert shrubs. Most of the young were almost full grown by the last of June although one half-grown young was caught July 26, 1939.

Unlike most desert rodents, this species is diurnal and remains active throughout the day. Its activity is not restricted to the ground and it was often seen in the top of the shrubs feeding on the leaf buds and ends of the stems. The highest shrubs of the area were also utilized as look-out posts. Their food consists mainly of green herbaceous material and shrubs, although insect fragments were found in 2 stomachs. They also fed on the carcasses of rodents of various kinds which the writer had skinned and discarded.

They remained active throughout the summer and gave no evidence of going into hibernation by the first part of September. Information from Civilian Conservation Corps workers indicates that they hibernate in late autumn and reappear very early in the spring. In the southern part of Utah and in New

Mexico, where the winters are mild, they seldom if ever hibernate (Long 1940, Bailey 1931).

Because of their diurnal habits this species forms an important part of the food supply of certain hawks such as the Swainson hawk and the prairie falcon. Their shallow burrows make them very easy prey of the badger and the kit fox and they also form part of the diet of the gopher snake and the rattlesnake.

Chipmunks, *Eutamias minimum consobrinus* (Allen), were encountered only in the sagebrush community in Fernow Valley. They were never numerous and occurred with a frequency of only 25 percent in the sample plots (Table 13).

The pocket gopher, *Thomomys bottae centralis* Hall, occurred throughout the various communities of White Valley. In most communities it was very scarce but in certain localities such as in the vicinity of Tule Springs and near the base of the Black Knolls they were rather common. None were found in the greasewood community except around the springs. Near these springs they were active throughout the summer but in the shadscale and other communities at higher elevations, they threw up mounds only during the early spring when the soil was moist.

This species is largely nocturnal, as far as foraging above ground is concerned, but it remains active throughout the day within its burrows. No animals were caught above ground except at night but they could be caught at any time of the day by placing traps in their burrows. The rate at which mounds were thrown up would indicate that they are most active underground during the early morning hours.

Because of their digging activities they play an important part in soil alteration. Grinnell (1923) estimated that 7.2 tons of earth per square mile are brought to the surface by them in Yosemite National Park, California each year and Ellison (1946) found that approximately 5 tons of soil per acre is brought to the surface in the Wasatch Plateau of central Utah, by pocket gophers. They also alter the subsurface composition of the soil and may be responsible for the penetration of hard-pans, thus bringing about changes in the composition of the vegetation such as are described on page 282. Their direct effects on the vegetation, through their foraging activities, was often very marked in the immediate vicinity of their burrow openings where the grass was clipped off even with the surface of the ground. Their subterranean feeding activities often kill many plants. At the Desert Range Experiment Station numerous bunches of rice grass were killed by their roots being eaten off just below the surface of the ground.

Young gophers about one-third grown were caught May 11 at Tule Springs and May 24 and 25 in the tetradymia community.

The relative abundance of ground squirrels and pocket gophers in the different communities was not determined because the traps used in making population studies of the other rodents were not suitable for catching these species. Whenever the writer refers to "total" rodent populations he is referring to populations exclusive of ground squirrels and pocket gophers.

Three species of pocket mice occurred in the communities studied. The most widely distributed species was the little pocket mouse, *Perognathus longimembris nevadensis* Merriam, which was taken in all communities except the black sage and sagebrush (Table 13). This species was only occasionally caught and was most abundant in the teradymia community in areas where the soil texture varied from sand to medium gravel. A total of only 21 specimens were trapped of which 13 were males. Two pregnant females were taken May 22, one of which was carrying 6 embryos and the other 4.

TABLE 13. Distribution and relative abundance of rodents, exclusive of ground squirrels and pocket gophers, in the various biotic communities.

Species	Shadscale		Winterfat		*Ecotone		Greasewood		Tetradymia		Black Sage		Sagebrush	
	No. per Hectare	Percent of Total	No. per Hectare	Percent of Total	No. per Hectare	Percent of Total	No. per Hectare	Percent of Total	No. per Hectare	Percent of Total	No. per Hectare	Percent of Total	No. per Hectare	Percent of Total
Eutamius minimus	....	....	....	....	....	....	....	....	....	....	....	....	3.0	5.5
Perognathus parvus	....	....	....	....	....	....	....	....	....	....	....	....	0.3	0.6
Perognathus formosus	....	....	....	....	....	....	....	....	0.5	1.2	8.8	21.3	....	....
Perognathus longimembris	1.3	3.1	0.5	1.6	....	....	....	....	1.3	3.1	....	....	....	....
Dipodomys microps	34.0	80.6	14.3	45.5	13.8	42.3	10.2	22.3	25.5	60.9	10.5	25.4	8.5	22.2
Dipodomys ordii	2.8	6.6	8.5	27.1	10.0	30.7	13.5	29.5	9.0	21.5	....	....	11.3	25.5
Microdipodops megacephalus	1.0	2.4	3.8	12.1	....	....	0.2	0.4	0.8	1.9	....	....	....	....
Onychomys leucogaster	0.3	0.7	0.5	1.6	....	....	0.7	1.5	0.3	0.7	....	....	....	....
Reithrodontomys megalotis	....	....	....	....	1.3	4.0	9.5	20.7	....	....	....	....	4.3	8.1
Peromyscus maniculatus	2.8	6.6	3.8	12.1	7.5	23.0	11.7	25.6	4.0	9.5	3.2	7.7	20.3	38.1
Peromyscus crinitus	....	....	....	....	....	....	....	....	....	....	12.6	30.4	....	....
Neotoma lepida	....	....	....	....	....	....	....	....	0.5	1.2	6.3	15.2	....	....
Totals	42.2	....	31.4	....	32.6	....	45.8	....	41.9	....	41.4	....	47.7	....

*Shadscale-Greasewood Ecotone Community.

In the black sage community the little pocket mouse was replaced by an ecological equivalent, the long-tailed pocket mouse, *Perognathus f. formosus* Merriam, which constituted 21.3 percent of the total rodent population (Table 13). This species also occurred in the tetradymia community in rocky situations at the base of the House Range. No pregnant females were caught but 4 immature specimens about two-thirds grown were taken in July, 1940.

The Great Basin pocket mouse, *Perognathus parvus olivaceus* Merriam, was taken only in the sagebrush community. This species occurred with a frequency of only 25 percent and constituted less than 1 percent of the total rodent population (Table 13).

One of the most prevalent minor influents of this biome is the kangaroo rat. Eleven geographic races of *Dipodomys microps* and at least 5 geographic races of *Dipodomys ordii* occur throughout Utah and Nevada (Hall & Dale 1939). Two species, *Dipodomys microps bonnevillei* Goldman and *Dipodomys ordii celeripes* Durrant and Hall, were widespread throughout most communities studied, but the relative abundance and the frequence of occurrence of each varied from one community to another. *Dipodomys microps* occurred in all communities varying in frequency from 100 percent to 69.2 percent, whereas *Dipodomys ordii* occurred in all communities except black sage, but the frequency of occurrence of this species was considerably less than *microps* except in the winterfat, greasewood and sagebrush communities (Table 14).

TABLE 14. Frequence of occurrence (percent) and relative maximum, minimum, and average abundance of kangaroo rats per hectare in various biotic communities. (Results from 64 trapping plots.)

Biotic Communities	*Dipodomys microps*				*Dipodomys ordii*			
	Freq. Per cent	Abundance			Freq. per-cent	Abundance		
		Max.	Min.	Ave.		Max.	Min.	Ave.
Shadscale	100	45	10	34.0	29.2	35	0	2.8
Winterfat	100	36	5	14.3	100	15	5	8.5
Tetradymia	100	40	5	25.5	33.3	20	0	9.0
Shadscale-Greasewood Ecotone	100	25	10	13.8	80	15	0	10.0
Greasewood	69.2	35	0	10.2	84.6	50	0	13.5
Black Sage	100	23	5	10.5	0	0	0	0
Sagebrush	75	28	0	8.5	87.5	33	0	11.3

Dipodomys microps was most abundant in the shadscale, tetradymia, winterfat, shadscale-greasewood ecotone, and black sage communities, whereas *Dipodomys ordii* was most abundant in the greasewood and sagebrush communities (Table 14). The distribution of these species seems to be very closely related to the texture of the soil. *Dipodomys microps* was most abundant where the soil consisted chiefly of medium to fine gravel, whereas *Dipodomys ordii* was most abundant in areas of fine gravel and sand or fine, loose clay loam soils (Table 15). The digging ability of kangaroo rats as a whole is limited by their small fore feet and consequently loose soil which is fine in texture seems to be preferred by most species (Bailey 1931, Grinnell 1932, Hawbecker 1940, Hardy 1945). However, *Dipodomys microps* occurred all the way to the top of the Black Knolls where the soil was very rocky and shallow. Fine sand and loose clay soils not only seem to be preferred for burrows by many species but they are utilized to a great extent by kangaroo rats for taking "dust baths." When these rodents are kept in cages without such soil their fur becomes matted and oily in appearance within a very few days.

TABLE 15. Distribution of kangaroo rats in relation to soil texture. (Results from 64 trapping plots.)

Soil Texture	*Dipodomys microps*		*Dipodomys ordii*	
	Number per hectare	Frequency percent	Number per hectare	Frequency percent
Coarse gravel and large rocks	23.8	100.0	0	0
Medium to fine gravel	28.5	100.0	6.7	22.2
Fine gravel to sand	18.2	100.0	26.3	92.9
Sand (Occasional dunes)	12.0	100.0	20.8	100.0
Clay (Surface baked)	18.2	90.0	7.3	70.0
Clay (Loose and spongy)	12.5	40.0	21.3	100.0

The abundance and kinds of vegetation are also important factors affecting the distribution of these rodents. In areas where the soil was very loose, the kangaroo rat mounds were almost invariably located at the bases of the larger shrubs. The roots of these plants presumably support the loose soils and help to prevent the kangaroo rat burrows from collapsing. Where the soils were more firm the burrows were not restricted to the bases of the plants. The greatest populations of kangaroo rats occurred in the shadscale community where the vegetation density was only about half of what it was in the greasewood and sagebrush communities. A maximum population of 103 kangaroo rats per hectare occurred in a sampling area within the shadscale community where the vegetation coverage was only 12.8 percent and where the soil texture varied from fine to medium gravel, whereas the maximum number taken per hectare in the greasewood community was 50, from a sampling area where the vegetation coverage was 21.4 percent and the soil was fine loose clay. The kinds of plants on which the kangaroo rats feed may also be an important factor in their distribution. Seventy-one percent of the rats that were harvesting food materials were found to be carrying shadscale leaves in their cheek pouches. As many as 210 leaves were found in the cheek pouches of one rat. Other food materials found in their cheek pouches included globemallow leaves (1%); winterfat leaves (3%); ephedra seeds (3%); Russian thistle seedling leaves (7%); and grass seeds (15%). Six scarabaeid beetles, *Diplotaxis* sp., were found in the cheek pouches of one rat together with shadscale leaves.

Since the examination of 72 stomach contents revealed nothing but vegetable materials, it is unlikely that these beetles are utilized as food, and it is presumed that they were accidentally placed in the pouches while the rat was harvesting shadscale leaves. Captive kangaroo rats readily stripped the leaves from shadscale stems and preferred them to any other vegetation. Whether this plant is utilized to a greater extent under natural conditions because it is actually preferred or whether it is so utilized because it is the plant most available was not satisfactorily determined, but the fact still remains that the greatest populations of kangaroo rats were attained within the shadscale community and shadscale leaves were found more often in their cheek pouches than the total of all other kinds of vegetation.

Much of the nocturnal activity of kangaroo rats is spent in harvesting and storing food materials. They constantly scurry about in search of food materials which they carry back to their mounds. Plant leaves were often placed in surface caches scattered about on their mounds outside the burrows. Small pits, 1 and 2 inches in diameter and about 1.5 inches deep, were excavated on the surface of the mounds and filled with harvested food materials. Some of these caches were lightly covered with soil while others were fully exposed. Bailey (1931) and Shaw (1934) have suggested that the purpose of these caches is to "cure" the food which is later removed to the burrows. Large piles of food materials were also occasionally encountered on the surface of the mounds. Within the greasewood community such piles consisted chiefly of *Atriplex nuttallii* leaves, the volume of one such food cache amounting to slightly less than 2 quarts. Another such cache in the tetradymia community consisted of ephedra seeds and had a volume of 1.5 quarts. Stored food materials found within their burrows consisted of various grass seeds, leaves of annual herbs, shadscale leaves, and ephedra seeds.

The breeding season of both species evidently begins in early spring. No pregnant females were trapped after the end of April. The differential occurrence of lactating and pregnant females and the occurrence of immature rats suggests that the breeding season of *Dipodomys microps* is slightly earlier than that of *Dipodomys ordii*. The last lactating females of the first species were taken April 16 whereas lactating females of the second species were taken as late as May 15. The maximum percentages of immature rats of both species occurred in May but the percentages were higher for *Dipodomys microps*. Although the percent of immature *Dipodomys ordii* were not as high during June as they were in May, they were higher than they were for *Dipodomys microps* (Table 16). The number of young per litter seems to vary from 2 to 4. Seven out of 11 pregnant females examined were carrying only 2 embryos and the other 4 were each carrying 4 embryos.

The sex ratio of trapped individuals was approximately even, being 49.8% males in *Dipodomys microps* and 56.6% males in *Dipodomys ordii*. Individual kangaroo rats exhibit a very decided intolerance for each other and when placed in the same cage or when caught in the same live trap they would often fight until one of them was killed. This intolerance was exhibited not only between individuals of the same sex but also between the opposite sexes. Such intolerance is also evident from the fact that in many other species only one individual is found in each mound (Vorhies & Taylor 1922, Bailey 1931, Grinnell 1932, Monson & Kessler 1940). The number of mounds found in this study varied from 3 to 40 per hectare with an average of 16.8. This is slightly more than one mound per rat when compared with the trapping data, the average number of rats caught per hectare being 13.2. This difference may be due to the fact that not all of the rats were caught during four nights' trapping or to the possibility that some of the counted mounds were not occupied. It does indicate however, that the number of mounds may be used as a relative approximation of kangaroo rat populations.

TABLE 16. Percentages of immature kangaroo rats trapped from May to August, 1940.

Months	*Dipodomys microps bonnevillei*			*Dipodomys ordii celeripes*			Combined
	Males	Females	Total	Males	Females	Total	Total
May	73.3	76.7	75.0	63.6	64.3	64.0	69.5
June	45.2	33.9	39.6	55.6	50.0	52.8	46.2
July	63.0	28.2	45.6	8.3	25.0	16.7	31.2
August	21.1	33.3	27.2	18.2	20.0	19.1	23.2

Although the home range of the kangaroo rat was not determined there is evidence that the area over which it travels is rather large. One rat was caught on a barren playa 1046 feet away from the nearest vegetation and 1231 feet from the nearest burrow. Live trapping also indicated that there is a considerable shifting of individual rats in the same area from one time of the year to another. One 0.2-hectare plot was trapped with live traps for

FIG. 16. Kangaroo rat-winterfat interaction. Note increased height of winterfat plants on kangaroo rat mound, in center of photograph. (Aug. 14, 1940.)

5 consecutive nights from May 13 to 17 during which time 12 rats were caught, marked and released. This same plot was then retrapped with killer traps from August 29 to September 1. Although 16 rats were caught only 2 of them had been previously marked. The mortality and replacement of the marked rats must have been very high during the interval of time between the two trapping periods or most of the ones that were marked had come into the plot from adjacent areas and had failed to return at the time the area was retrapped.

The interactions between the kangaroo rats and other biotic components of the community are many and varied. Their herbivorous feeding habits result in the consumption of considerable quantities of plant materials in the form of leaves and seeds. The storage of these seeds may in turn aid in the distribution of the plants. It is quite possible that seeds in the surface caches may sprout and grow. Although the writer was unable to find any direct evidence for this coaction, Hawbecker (1940) has found grain seeds of such surface caches sprouting and growing. The role which burrowing rodents play in soil formation has been very widely recognized (Grinnell 1923, Formosou 1928, Taylor 1935). Kangaroo rats may not only influence the distribution of plants through their seed harvesting activities but they may also influence the growth of plants by altering the chemical and physical composition of the soil as a result of their burrowing activities. The actual excavation of burrows not only facilitates the penetration of water and oxygen to greater depths but it brings the subsoil to the surface where it is mixed with the topsoil and it tends to produce finer sized soil particles which increase the moisture equivalent values and waterholding capacity of the soils, thus actually increasing the amount of water available to the plants (Greene & Murphy 1932). Not only do these rodents alter the physical nature of the soil but through the production of excreta and the storage of plant materials in their burrows they also alter the chemical composition of the soil. Soils taken from the kangaroo rat mounds have been shown to contain greater quantities of soluble salts, especially calcium, magnesium, bicarbonate, and nitrate ions than soils adjacent to the mounds (Greene & Reynard 1932). These effects are often very noticeably reflected in the growth and development of the plants. This reaction was especially conspicuous in certain winterfat areas where the height of the plants in the vicinity of the kangaroo rat mounds was almost twice as great as in the adjacent areas (Fig. 16). Another effect of rodents on the distribution of winterfat was very noticeable in Antelope Valley. Within this valley there is a hard-pan so near the surface that winterfat is unable to establish itself because of the shallowness of the soil and the consequent lack of sufficient moisture. Such areas are occupied by the subdominant little rabbitbrush within which are interspersed small circular "islands" of winterfat (Fig. 14). Wherever these islands of winterfat occurred there were numerous pocket gopher and kangaroo rat burrows. An investigation of the soil conditions in these places, by digging a transect through some of them, showed that within such islands the hard-pan had been broken and the roots of the winterfat were thus able to penetrate the soil to greater depths and thus obtain sufficient moisture to support the plant.

Kangaroo rat burrows are used by reptiles, especially lizards, as avenues of escape from their enemies, as a means of avoiding high summer temperatures, and as places in which to hibernate. The abandoned burrows are also utilized as places of abode by many invertebrates such as spiders, tarantulas, scorpions, and insects especially tenebrionid beetles.

Kangaroo rats also constitute a large part of the food supply of kit foxes, burrowing owls, badgers, and coyotes. Because of their nocturnal habits they are seldom taken by hawks but rattlesnakes and gopher snakes often prey on them by entering their burrows.

The kangaroo mouse, *Microdipodops megacephalus paululus* Hall & Durrant was consistently present only in the winterfat community where it occurred in 100 percent of the trapping plots. Its distribution seems to closely correlate with soil texture. Eighty percent of the total number caught were taken in areas of sandy soil. It was never abundant, even within the winterfat community, and comprised but a small part of the total rodent population (Table 13).

Little evidence of kangaroo mouse's food habits and time of reproduction was obtained. The cheek pouches of only two specimens contained food materials, one of which was carrying shadscale leaves and the other one Indian rice grass seeds. Two females, trapped May 4, each contained 4 embryos. The average number of embryos found in 37 females by Hall and Linsdale (1929) was 4 with a variation from 1 to 6. Thirty-five of these females were taken in May.

The ecological importance of this species is low because of its scarcity. This apparent scarcity may be due to the fact that the communities studied are on the eastern border of its range. Only 23 specimens were caught during the entire period of this investigation whereas 92 specimens were caught in 198 traps during one night in Lincoln County, Nevada, near the center of its range, by Hall and Durrant (1937). Such a population would greatly add to its ecological significance.

The grasshopper mouse, *Onychomys leucogaster brevicaudus* Merriam, occurred in most of the communities of White Valley (Table 13). Although only 10 specimens were caught this trapping data may not necessarily represent the true relative abundance of this species in comparison with the data for other rodents, because its food habits are so different. Since this species is largely insectivorous and carnivorous it is possible that the oatmeal bait, which was routinely used for baiting the traps, may not have been as attractive to it as to the herbivorous species. Sand crickets comprised 66%; grasshoppers, 17%; beetles, 6%; lizards, 2%; and bait only 9% of the stomach contents from 6 specimens. The stomach containing the lizard (Uta) also contained 22 small ants which were thought to have probably been in the stomach of the lizard at the time it was eaten. The examination of 96 stomachs from 13 states by Bailey and Sperry (1929) shows that 79.28 percent of the food of this mouse consists of insects, chiefly orthoptera and coleoptera, and that vegetable materials comprise only 11.13 percent. They also found lizards (Sceloporus and Uta) in 3 stomachs.

The interactions between the grasshopper mouse and invertebrates and small rodents is probably greater than for any other small mammal of these communities. This mouse not only preys on invertebrates and small lizards but it also kills other rodents as large or larger than itself. Kangaroo rats and mice of other species caught in the same live trap with a grasshopper mouse were killed and partly eaten on several occasions.

The harvest mouse, *Reithrodontomys m. megalotis* (Baird), was found only in the greasewood, shadscale-greasewood ecotone, and sagebrush communities (Table 13). Within the greasewood community it was taken in 61.1 percent of the trapping plots and comprised almost 20 percent of the total rodent population. It was most abundant where the vegetation was most dense and was most frequently caught at the base of large shrubs.

The breeding season of this species is very extended. Pregnant and lactating females were taken in early September as well as in April and May. Immature specimens were also taken in early May.

The white-footed mouse, *Peromyscus maniculatus sonoriensis* (LeConte), is a very widespread species and occurred in all communities (Table 13). It was most abundant in the sagebrush and greasewood communities. The dominant shrubs of these two communities are very similar in vegetative form and provide more cover and nesting places for this species than do the dominant shrubs of the other communities.

The breeding season within the areas studied apparently occurs during early spring. No pregnant females were taken after the last of April and no lactating females were caught after the middle of May. The number of embryos varied from 3 to 6 with 4 being the most frequent number. Males were caught much more frequently than females, the number taken being 79 and 42 respectively. This may indicate that the home range of the males is much larger than it is in the females and they consequently come in contact with the traps more often than do the females.

In the black sage community *Peromyscus maniculatus* was largely replaced by another species of white-footed mouse, *Peromyscus crinitus pergracilis* Goldman (Table 13). This species was most abundant in very rocky areas especially in the vicinity of ledges. No pregnant females were trapped but 6 immatures were caught during June and 1 in July.

The desert pack rat, *Neotoma l. lepida* Thomas, was largely restricted to areas where there are numerous large boulders and cliffs beneath which it builds its den. Its dens were very conspicuous because of piles of sticks and debris that are accumulated by the rats. One abandoned den was found in the greasewood community but no rats were caught except in the tetradymia and black sage communities. Within the tetradymia community these rats occurred only at the base of the House Range where there was an abundance of large rocks beneath which the dens were located.

This species was most abundant in the black sage community where it was caught in 75 percent of the trapping plots. The relative abundance of the pack rat (Table 13) is probably low because the Museum Special traps used were too small to hold all the rats that came in contact with them. Twenty-five percent of the traps set in the black sage community were frequently sprung, presumably by pack rats.

The pack rat apparently breeds throughout the spring, summer, and autumn. Pregnant or lactating females were taken during every month from April to September. A female captured in May with 3 suckling young gave birth to another litter of 4 in June while being kept in captivity. Five out of 8 pregnant females were carrying 3 embryos, one 4, and the remainder 2 each.

The black-tailed desert jack rabbit, *Lepus californicus deserticola* Mearns, is an important minor influent of all the biotic communities, but it was most abundant in the greasewood and sagebrush areas. (Tables 17 and 18.) The relative abundance of rabbits in the greasewood community by actual counts on 4-hectare plots was 6.7 times greater than in the shadscale community but the number of pellets found per square meter of ground surface was only 3.7 times greater. This difference seems to be a reflection of the daily activities of the jack rabbit. Counts made during mid-day tended to be higher in the greasewood community and lower in the more open types of communities such as shadscale and winterfat because the rabbits moved into the more dense vegetation within which they "shaded up" during the heat of the day. During the early morning hours and again in the evening the rabbits leave their resting "forms" and many of them move out

TABLE 17. Abundance of jack rabbits per 10-hectares based on counts made on 4-hectare plots.

Communities	Freq. (Percent)	Abundance		
		Max.	Min.	Average
Shadscale	17	1	0	0.75
Tetradymia	40	3	0	1.0
Greasewood	100	22	3	5.0
Sagebrush	100	19	2	4.3

into the more open communities to feed. Since most of the pellets are deposited while the rabbits are feeding their apparent relative abundance within the feeding areas tended to be greater when the pellet count method was used.

The number of pellets per sample in the shadscale community in White Valley average 2.2 while the number in the same type of community at the Desert Range Experiment Station was only 0.8 (Table 18). This difference is presumably due to a difference in the location of the two areas with respect to greasewood communities. The shadscale community in White Valley is adjacent to a greasewood area, whereas the shadscale community at the Desert Range Experiment Station is many miles from any greasewood area and consequently was not used as the forage ground by rabbits from any other community, as was the shadscale community of White Valley.

TABLE 18. Jack rabbit pellets per square meter of ground surface. 1, Samples taken at the Desert Range Experiment Station; 2, Samples taken in vicinity of Tule Springs; 3, Samples taken around border of Tule Springs.

Communities	Samples taken	Freq. (Percent)	Abundance		
			Max.	Min.	Ave.
Shadscale[1]	220	27.6	22	0	0.8
Ungrazed area	104	40.4	22	0	1.4
Open Range	116	15.5	6	0	0.3
Shadscale	240	35.0	19	0	2.2
Winterfat[1]	226	11.4	9	0	0.3
Ungrazed area	192	19.8	9	0	0.6
Open Range	134	6.0	6	0	0.1
Tetradymia	174	38.0	8	0	1.4
Greasewood	240	95.0	51	0	8.2
Greasewood[2]	200	100.0	47	1	10.5
Salt grass[3]	20	100.0	414	66	280.0
Sagebrush	128	97.0	39	0	8.0

Pellet counts were considerably higher in the shadscale and winterfat communities at the Desert Range Experiment Station which had not been grazed than they were in the same types of communities which had been subjected to grazing (Table 18). Observations on the feeding activities of jack rabbits by the writer indicate that they prefer grass when it is available. Since grasses were more abundant within the protected areas it would appear as if that was one of the factors responsible for the higher pellet counts. The salt grass areas near Tule Springs were favorite feeding grounds of many rabbits from adjacent areas. Distinct, heavily trodden trails led into these grassy areas from all directions. Rabbits would begin to come to these grassy areas near sundown and as many as 11 were observed feeding at the same time in an area less than one-half acre in size.

Young jack rabbits about one-fourth grown were seen as early as May 1 and young ones just a few days old were observed during the latter part of June. Although more than one litter may be produced during the spring and early summer there was no evidence that young were born after the first of July. Young jack rabbits were never found in a nest but always occurred alone, concealed beneath a shrub. They escape notice by remaining perfectly motionless and will not move unless one practically comes in contact with them. The number per litter varies from 1 to 6 with an average of about 2.5 (Vorhies & Taylor 1933). Only 2 pregnant females were examined, one of which contained 5 embryos and the other 6.

The jack rabbit is a very important influent because of its effects on the vegetation which it utilizes as food and because it is an important source of food for many of the predatory mammals and birds. Vorhies & Taylor (1933) estimate that 30 rabbits consume as much forage as one sheep or 148 eat as much as a cow. A large number of plants are utilized as food, grasses of all kinds seeming to be highly preferred. Many of the grasses which have been greatly reduced in abundance by over-grazing are now eaten by the rabbits before the sheep arrive in the autumn. Within some areas practically every globemallow was clipped off about 6 to 8 inches above the ground just at the time they were beginning to blossom. If this plant were not a perennial, such consumption would soon greatly decrease its abundance. Shadscale, winterfat, and greasewood were all used as food. The greasewood seemed to be eaten more often than the other two, probably because the rabbit population was higher where it was present. The lower branches were usually cut off about 4 or 5 inches back from their tips and all but about an inch of the tip eaten. *Atriplex nuttallii* seemed to be one of their favorite foods especially during late summer. The remains of this plant in the spring also gave evidence that it had been greatly utilized during the winter. In many instances the stems were cut off at the root crown below the surface of the soil. In such cases the ends of the stems were not eaten and stems 5 to 6 inches long were strewn about the surface of the ground. Pickleweed was occasionally eaten during mid-summer. This plant was usually cut off about 2 inches below the surface of the ground and only the most succulent lower 2 or 3 inches of the stems eaten.

Cottontails, *Sylvilagus nuttallii grangeri* (Allen), were found regularly only in the tetradymia, black sage, and sagebrush communities. Within these communities there were either large rocks, crevices, or ravines which afforded them protection. They were never numerous and averaged only 2.8 individuals per 10 hectares in the tetradymia community and 0.5 in the sagebrush. Although their pellets were found in shadscale areas adjacent to the tetradymia, they were never encountered in the shadscale census areas.

The young reared in an old badger excavation, were seen for the first time May 18. Several young one-third to one-half grown were observed in the early part of June. Because of their scarcity their ecological importance is not very great within the communities studied.

Birds

Most of the minor influent birds are wide-ranging and occurred in more than one community. The birds occurring in the shadscale tetradymia, and winterfat communities are very similar, presumably because the dominant plants of these communities are low, sparse, and similar in vegetative form. The writer has combined his general cruising data for these three communities and whenever a reference is made to the birds of the shadscale it is to be understood that such a reference also includes the tetradymia and winterfat communities unless otherwise stated.

A total of 61 species of birds were observed during the course of this investigation (Appendix A) of which 52 species have been arbitrarily designated as minor influents. Summer residents which occurred in all communities included the following:

Turkey Vulture, *Cathartes aura teter* Friedmann
Mourning Dove, *Zenaidura macroura marginella* (Woodhouse)
Summer vagrant in all communities except sagebrush.
Arkansas Kingbird, *Tyrannus verticalis* Say
A summer vagrant except in the vicinity of buildings.
Horned Lark, *Otocoris alpestris utahensis* Behle
Raven, *Corvus corax sinuatus* Wagler
Sage Thrasher, *Oreoscoptes montanus* (Townsend)
Summer vagrant in shadscale communities.
Shrike, *Lanius ludovicianus nevadensis* Miller
Cowbird, *Molothrus ater artemisiae* Grinnell
Never abundant in any community.
Desert Black-throated Sparrow, *Amphispiza bilineata deserticola* Ridgway
Most abundant in shadscale community.
Sage Sparrow, *Amphispiza belli nevadensis* (Ridgway)
Summer vagrant in shadscale community.
Brewer Sparrow, *Spizella breweri breweri* Cassin
Summer vagrant in shadscale community.

The turkey vulture was only occasionally seen, but it was observed throughout the summer in one community or another. The sharp-shinned hawk, *Accipter striatus velox* (Wilson), was seen only twice and is considered a minor influent because of its scarcity.

Mourning doves nested only in the sagebrush area and were seen only infrequently in other communities, being most prevalent during late August and early September. Their breeding season was very prolonged and more than one brood of young was evidently produced each year. Nests containing eggs were found in May and as late as August 4 in the sagebrush community.

Nighthawks, *Chordeiles minor* ssp., were seen with a frequency of 34.8 percent in the sagebrush community but were seldom seen in other areas. The Nuttall poor-will, *Phalaenoptilus n. nuttallii* (Audubon), was occasionally flushed in the shadscale community in August but was encountered only once in the sagebrush community.

Although ravens and sparrow hawks nested in the adjacent mountains they foraged throughout all the valley communities and are thus considered summer residents. During their nesting period the ravens made several trips to the valleys each day in search of food. After the young were able to fly the family groups would come down into White Valley about 5:00 to 6:00 a.m. and remain throughout the day, returning to the mountains about sundown. They were especially prevalent along roads where they fed on rabbits, rodents, and reptiles that were killed by passing automobiles. Sparrow hawks occurred most regularly near cultivated areas and were most abundant during late summer.

The horned lark, rock wren, *Salpinctes o. obsoletus* (Say), and the desert black-throated sparrow were the only species observed nesting the shadscale and associated edaphic communities (Table 19).

TABLE 19. Number and percentages of nesting, summer resident and transient minor influent birds. 1, Includes species observed in Tetradymia and Winterfat Communities; 2, Includes species observed at Tule Springs; 3, Percent of total species observed in all communities.

Communities	Nesting species		Summer residents		Transients		Total species[3]	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Shadscale[1]	3	9.4	16	50	16	50	32	61.5
Greasewood[2]	7	21.7	18	56.2	14	43.8	32	61.5
Sagebrush	5	14.8	21	61.8	13	38.2	34	65.4

Horned larks were most prevalent in the more open shadscale community and nested in the greasewood and sagebrush areas only where the vegetation was low and sparse. Their nests were always placed on the ground in a shallow excavation beneath some low-growing shrub. The only nest found in the greasewood community was beneath a small suaeda bush in an open sparsely vegetated area.

The breeding activities of the desert black-throated sparrow were almost entirely restricted to the teradymia community. Only one late nest, located July 13, was found within the greasewood area (Table 20). This species seems to prefer an open type of vegetation within which there are occasional larger shrubs. These larger shrubs were used as nest sites and as singing perches by the males. Nesting pairs were usually well isolated from each other. All nests found were more than 50 meters apart. Both males and females incubated the eggs and fed the young. After the brooding of the nestlings was no longer necessary, the male and female usually remained very close together when foraging for food, seldom getting more than a few feet apart. They would return to the nest with food at the same time and take their turn in feeding the young. After the young left the nest the family remained very close together and moved about as a group. Their feeding activities were restricted to the shrubs where they

TABLE 20. Nesting records of birds within communities of White Valley, 1940.

Dates	Community	Plant in which nest was located	Position of nest on plant	Number of eggs	Remarks	
					Eggs hatched	Young left nest
				DESERT BLACK-THROATED SPARROW		
April 22.....	Tetradymia	Ephedra	Southeast	4	April 30	May 11
May 8.....	"	Tetradymia	Northeast	4	Unknown	About May 30
" 12.....	"	Ephedra	North	3	May 20-21	?
" 19.....	"	Tetradymia	Northeast	?	4 young 3 to 4 days old	May 26
" 19.....	"	Sagebrush	"	3	May 31 and June 1	Young dead in nest June 10
" 21.....	Shadscale	Shadescale	"	3	Unknown	June 9
June 8.....	Tetradymia	"	"	3	All eggs failed to hatch	
July 13.....	Greasewood	Greasewood	North	3	Only 2 eggs hatched	One young found dead July 20
				HORNED LARK		
May 17.....	Shadscale	Beneath Shadscale	East	4	May 23	About June 5
" 28.....	"	Beneath Shadscale	"	4	Eggs unhatched June 2	
June 7.....	"	Beneath Winterfat	"	3	Eggs not hatched. Female caught in trap	
" 9.....	"	Beneath Shadscale	"	3	June 13	June 25
" 17.....	Greasewood	Beneath Suaeda	North	?	Nest empty when found	
				SAGE SPARROW		
May 14.....	Greasewood	Greasewood	North	4	May 21	June 3
" 17.....	"	"	"	3	May 21-22	June 2
" 17.....	"	"	East	?	Nest contained 3 young when found	
" 19.....	"	"	North	?	Nest contained 2 young when found	
				BREWER SPARROW		
May 14.....	Greasewood	Greasewood	North	4	May 19	Unknown
" 15.....	"	"	East	?	Nest contained 4 young when found	
" 19.....	"	"	North	?	Nest contained 3 young when found	
				GREAT BASIN SHRIKE		
May 16.....	Greasewood	Greasewood	Center of bush	0	Nest newly constructed	
" 20.....	"	"	"	1		
" 24.....	"	"	"	5		
" 25.....	"	"	"	6		
June 9.....	"	"	"	3	3 eggs hatched	
" 10.....	"	"	"	1	5 eggs hatched	
" 14.....	"	"	"	0	6 young	Nest empty June 28

foraged for insects. The breeding season of this species was very extended and probably more than one brood is produced. Nests containing eggs were found as early as April 22 and as late as July 13. The late nests contained fewer eggs and were less successful than the earlier ones (Table 20).

Rock wrens were found nesting only in the tetradymia community near the base of the mountains. One pair nested in a badger excavation and two others beneath large boulders.

The mockingbird, *Mimus polyglottos leucopterus* (Vigors), was never seen in the shadscale community and was only rarely encountered in other areas. It was seen most frequently in the sagebrush community where it occurred with a frequency of only 8.6 percent.

Sage thrashers, shrikes, sage sparrows, and Brewer sparrows, were only occasionally encountered outside the greasewood and sagebrush areas. The vegetation of these two communities is very similar in height, density, and form, and seemed to be preferred by these species. Nests of all but the sage thrasher were found, however, the activities and distribution of the adults and the occurrence of young sage thrashers indicated that this species also nests in these communities. Nesting sage sparrows and Brewer sparrows avoided the most dense vegetation and built their nests 10 to 18 inches above the ground in medium-sized shrubs which were well spaced. The only shrike nest found was located in the center of a large greasewood 2.5 feet above the ground and was so surrounded by upright branches that the incubating bird had difficulty in making a quick exit when the nest was approached.

The feeding activities of these sparrows and the sage thrasher were restricted to the shrubs where they fed on insects. Shrikes not only fed on insects, principally grasshoppers, but preyed on lizards as well. Their characteristic habit of impaling their prey was very much in evidence at the Desert Range Experiment Station where lizards (Utas) grasshoppers and sand crickets were found hanging

TABLE 21. Minor influent bird populations of a 4-hectare (10-acre) plot within the Shadscale Community.

Species	April			May					June				July			August			Sept.
	13	23	28	1	6	14	24	29	8	13	19	27	1	12	21	9	18	27	2
Sparrow Hawk	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	1	..	1
Horned Lark	4	3	5	3	..	4	3	3	3	2	..	5	4	3	..	3	2	5	3
Raven	..	..	2	..	1	..	1	..	..	2	..	..	..	..	3	1	..	..	2
Vesper Sparrow	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Black-throated Sparrow	1	2	1	4	2	..	..	1	..	..	3	..	..	..	..	..	..	..	..
Sage Sparrow	..	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	..
Chipping Sparrow	2	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Brewer Sparrow	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total	9	8	8	7	4	4	4	4	4	5	3	5	4	3	3	4	3	5	6

from the barbs along barbed wire fences. Grasshoppers were also found impaled on the thorns of greasewoods. The shrikes also fed on mice which had been caught in the writer's traps.

Summer resident species within the greasewood community which were restricted to the immediate vicinity of Tule Springs included the killdeer, *Charadrius vociferus vociferus* Linnaeus, the western yellow-throat, *Geothlypis trichas occidentalis* Brewster, the yellow-headed blackbird, *Xanthocephalus xanthocephalus* (Bonaparte), and the red-winged blackbird, *Agelaius phoeniceus* ssp. A pair of killdeers nested near the edge of the spring but their nest could not be located. Four young were first seen June 8 at which time they appeared to be several days old. The yellow-throats and blackbirds remained at the spring throughout the summer and their spring activities indicated that they might nest but no nests or young were ever observed. The vegetation growing in the spring was greatly disturbed by a small herd of cattle which frequented the area and which probably prevented these birds from nesting during the summer of 1940.

Bird populations were relatively low in all communities. The average summer population, as determined from actual counts on 4-hectare (10-acre) plots, varied from 10.6 per 10 hectares (25 acres) in the shadscale and 12.6 in the tetradymia to 27.0 in the greasewood community. Populations were greatest in the tetradymia and shadscale communities during the spring and early summer. A pronounced decrease occurred in the tetradymia community after the last part of June when the black-throated sparrows moved out (Table 22). This decrease coincided with a very rapid decline in the insect population (Fig. 9). The bird population of the shadscale community remained fairly constant throughout the summer being highest during April when several migrating species were present (Table 21). There was a general increase in bird population of the greasewoods during late summer (Table 23). The vegetation of this community was much taller and more dense than the vegetation of the shadscale and tetradymia communities and thus provided a greater amount of protection for the birds during hot summer months. The insect population of this community was also maintained at a more constant level (Fig. 9), so that the amount of food available to the birds was greater than in the other communities of White Valley.

Brewer blackbirds, *Euphagus c. cyanocephalus* (Wagler), vesper sparrows, *Pooecetes gramineus confinis* Baird, and the white-crowned sparrows, *Zonotrichia leucophrys* ssp., were the only transient species which occurred in all communities. Transient and vagrant species of the shadscale community comprised 59 percent of the total number of birds seen. Many of these such as the Arkansas kingbird, ash-throated flycatcher, *Myiarchus c. cinerascens* (Lawrence), Say phoebe, *Sayornis saya saya* Bonaparte, sage thrasher, shrike, yellow-headed blackbird, red-

TABLE 22. Minor influent bird populations of a 4-hectare (10-acre) plot within the Tetradymia Community.

Species	April		May								June					July			August				Sept.
	14	23	2	5	7	15	19	23	28	30	9	12	19	20	26	2	13	22	1	9	17	26	3
Horned Lark	...	...	...	...	...	...	...	...	...	...	...	1	...	3	...	...	2	1	2	1	1	1	...
Raven	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	1	1	...	...	...	...	...
Rock Wren	2	1	1	1	...	1	...	2	1	...	2	...	4	...	...	1	...	...	...	1	...	1	...
Desert Black-throated Sparrow	7	3	9	5	4	2	1	3	6	3	2	3	5	...	...	...	...	...	...	...	...	...	...
Sage Sparrow	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	...	1	...
Chipping Sparrow	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Brewer Sparrow	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	...	2
White-crowned Sparrow	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Total	12	4	11	6	4	3	1	5	7	3	4	4	9	5	0	1	3	2	3	4	2	3	2

TABLE 23. Minor influent bird populations of a 4-hectare (10-acre) plot within the Greasewood Community.

Species	April			May				June				July					August				Sept.
	16	23	28	7	13	16	24	1	8	14	26	2	10	13	18	26	5	12	18	27	4
Horned Lark	1	..	2	3	2	..	3	7	4	6	2	2	6	5	3	1	9	7	12	19	12
Sage Thrasher	..	..	..	..	..	1	1	..	..	..	1	1	..	..	..	..	..	3	..	..	2
Shrike	1	..	..	..	1	1	..	..	..	..	1	1	..	..	..	1	..	..	2	1	..
Vesper Sparrow	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..
Black-throated Sparrow	..	..	..	..	..	..	..	..	..	..	1	..	1	2	2	2	..	2	1	..	..
Sage Sparrow	5	2	4	2	2	2	..	1	5	1	..	4	4	6	2	7	5	2	3	..	5
Brewer Sparrow	3	2	1	2	3	3	1	2	1	3	1	1	..	..	1	1	1	..	..	1	1
Total	10	4	7	7	8	7	5	10	10	10	6	9	11	13	8	12	15	15	18	21	20

winged blackbird, cowbird, house finch, *Carpodacus mexicanus* ssp., pale goldfinch, *Spinus tristis pallidus* Mearns, lark sparrow, *Chondistes grammacus strigatus* Swainson, sage sparrow, chipping sparrow, *Spizella passerina arizonae* Coues, and Brewer sparrow are summer residents of other valley communities. Vagrants from adjacent mountain communities included the white-throated swift, *Aëronautes s. saxatalis* (Woodhouse), rufous hummingbird, *Selasphorus rufus* (Gmelin), and the violet-green swallow, *Tachycineta thalassina lepida* Mearns.

The springs within the greasewood community not only attracted such transient waterfowl and shorebirds as the Treganza great blue heron, *Ardea herodias treganzai* Court, common mallard, *Anas p. platyrhynchos* Linnaeus, sora rail, *Porzana carolina* (Linnaeus), and the western sandpiper, *Ereunetes mauri* Cabanis, but they were also frequented by a number of other species including the barn swallow, *Hirundo rustica erythrogaster* Boddaert, yellow warbler, *Dendroica aestiva* ssp., Audubon warbler, *Dendroica auduboni* ssp., long-tailed chat, *Icteria virens auricollis* Bonaparte, green-tailed towhee, *Oberholseria chlorura* (Audubon), savannah sparrow, *Passerculus sandwichensis nevadensis* Grinnell, and the song sparrow, *Melospiza melodia* ssp.

Transient and vagran minor influent birds seen in the sagebrush community included the broad-tailed hummingbird, *Selasphorus p. platycercus* (Swainson), magpie, *Pica pica hudsonia* (Sabine), piñon jay, *Cyanocephalus cyanocephalus* (Wied), rock wren, mountain bluebird, *Sialia currucoides* (Bechstein), western gnatcatcher, *Polioptila caerulea amoenissima* Grinnell, green-tailed towhee, lark sparrow, chipping sparrow and the slate-colored fox sparrow, *Passerella iliaca schistacea* Baird.

Reptiles

Reptiles are very important and conspicuous seasonal minor influents within all the biotic communities studied. The following 6 species of lizards and 4 species of snakes were observed during the course of the investigation:

Collared Lizard, *Crotaphytus collaris baileyi* (Stejneger)
Leopard-lizard, *Crotaphytus wislizenii* Baird and Girard
Brown-shouldered Uta, *Uta s. stansburiana* (Baird and Girard)
Sagebrush Lizard, *Sceloporus g. graciosus* (Baird and Girard)
Desert Horned-toad, *Phrynosoma platyrhinos* Girard
Whip-tail Lizard, *Cnemidophorus t. tessellatus* (Say)
Striped Racer, *Coluber t. taeniatus* (Hallowell)
Gopher-snake, *Pituophis catenifer deserticola* Stejneger
Long-nosed Snake, *Rhinocheilus lecontei* Baird and Girard
Rattlesnake, *Crotalus viridis lutosus* (Klauber)

An attempt was made to estimate the relative abundance of the lizards by making counts within 0.4-hectare (1-acre) plots which were also used in making rodent population studies. The results of these counts for 3 communities in White Valley during the summer of 1940 are graphically represented in Figure 17, in terms of numbers of lizards per 10 hectares (25 acres). Although the results obtained include only those counts which were made during the morning and late afternoon hours in which the lizards were observed to be most active, they probably are lower than the actual total populations because most species tend to remain concealed beneath the shrubs and consequently escape observation. However these results do indicate relative differences in the abundance of the various species from one community to another and seasonal variations in the activity of the same species. Inasmuch as the vegetation of the greasewood community was much more dense than in other communities it is possible that more of the lizards were overlooked and their relative abundance within that community should be greater than the results obtained from this censusing method indicate. The data obtained indicate that the greatest lizard populations occurred in the tetradymia community where they varied from 91 lizards per 10 hectares in May to 29 in August with a summer average of 65.

The collared lizard was found only where there were large rocks and was consequently confined to the tetradymia and black sage communities. It was less numerous than any other lizard and was never observed within the census plots. The males were always well isolated indicating that they probably maintain individual territories of considerable size.

These lizards remained active throughout the day and were frequently seen on the top of large rocks even during the heat of the day when the surfaces of the rocks were very hot. Prolonged observations revealed that they do not remain on the exposed surface of these hot rocks for periods of more than 8 to 12 minutes at a time without moving into the shade.

The scarcity of these lizards and the difficulty involved in collecting them made it impossible to check very closely on their time of reproduction. Three females collected May 20 each contained 4 eggs varying from 9 to 12 mm. in length. No other females were collected until mid-July at which time they contained no eggs. The only young lizard seen was collected August 25. A captive female of a different subspecies, *Crotaphytus collaris collaris* (Say), which has a more southernly distribution than *baileyi,* is reported by Greenberg (1945) to have deposited 8 eggs May 14 after having been observed in copulation several times from April 15-23.

TABLE 24. Stomach contents of 8 specimens of *Crotaphytus collaris baileyi* (Stejneger).

	Percent of total volume	Frequency (Percent)
Brown-shouldered uta	36.6	25.0
Scorpion	9.2	12.5
Acrididae	3.0	12.5
Other Orthoptera	20.3	12.5
Tenebrionidae	3.8	12.5
Scarabaeidae	16.9	12.5
Curculionidae	4.8	25.0
Other Coleoptera	2.1	25.0
Coleoptera larvae	1.2	12.5
Unidentified insect fragments	2.1	25.0
Vegetation fragments	Trace	12.5

The collared lizard was found to feed primarily on other lizards and large insects (Table 24). The remains of brown-shouldered utas constituted 36.6 percent of the total food volume and occurred in 25 percent of the stomachs examined. Orthoptera made up 23.3 percent and coleoptera 28.8 percent of the total food from 8 stomachs.

The leopard-lizard is one of the most ecologically important lizards encountered because it occurred throughout all communities and because it feeds on such a variety of biotic components within the communities. It was not seen until April 26 and did not occur in any of the census plots until early May. It was most frequently observed in areas of fine gravel or sand and was most abundant within the census plots during late May, June, and July (Fig. 17). It was seen only infrequently before 7 o'clock in the morning and was most active from 9:00 a.m. until about noon and again during late afternoon.

This lizard moves very rapidly when frightened and on two occasions was observed to use only its hind legs when traveling at top speed. The ability and speed with which it moves about enables it to readily capture other lizards and the larger insects which form a large portion of its diet (Table 25). Lizards, primarily utas, constituted almost 25 percent of the total food volume and occurred in 30 percent of the stomachs examined. The stomach of one large female contained a whip-tail lizard 9 inches in length. Eight different species of lizards, including members of its own species and the horned-toad are listed by Van Denburgh (1922) as the prey of this lizard. The larger insects such as grasshoppers and beetles, especially tenebrionids, comprised 53.3 percent of the total food volume in 20 stomachs. Grasshoppers occurred in 48 percent of the stomachs and beetles in 52 percent. The hymenoptera and diptera consisted primarily of the larger forms such as wasps and asilids. Lizards kept in captivity would eat as many as 5 medium sized grasshoppers in rapid succession but would take them only if they were moving. They could be induced to take dead grasshoppers only if they were moved mechanically. A few fragments of vegetation and also a few pebbles were found in some of the stomachs examined but they were believed to have been accidentally ingested while the lizards were capturing insects. However, Merriam (1893) found that blossoms and plant leaves were eaten by this lizard during early spring.

TABLE 25. Stomach contents of 20 specimens of *Crotaphytus wislizenii* Baird and Girard.

	Percent of total volume	Frequency (Percent)
Lizards	22.6	30.0
Araneida	0.4	5.0
Acrididae	21.2	45.0
Other Orthoptera	1.3	5.0
Heteroptera	0.4	5.0
Cleridae	0.5	5.0
Tenebrionidae	25.8	30.0
Scarabaeidae	2.7	15.0
Curculionidae	1.6	5.0
Coleoptera larvae	0.2	5.0
Lepidoptera larvae	1.3	15.0
Formicidae	0.3	5.0
Other Hymenoptera	8.1	25.0
Asilidae	8.2	10.0
Other Diptera	2.3	15.0
Unidentified insect fragments	3.1	20.0
Vegetation fragments	Trace	10.0
Pebbles	...	30.0

Sexual dimorphism is very marked in the leopard-lizard, especially when the females are gravid. The males are usually smaller than the females and the ventral surface and the sides of the tail of the gravid females often become a deep salmon red in color with red spots occurring along the sides of the abdomen. Copulating pairs were observed in White Valley during the last week in May. Merriam (1893) found them copulating May 17 to 19 in the vicinity of the Escalante Desert. All females examined before May 20 contained eggs but no gravid females were found after the last of June (Table 26). The number of eggs per female varied from 4 to 5. The first newly hatched young were seen August 12, 1939 and August 11, 1940, after which dates they occurred rather frequently often being seen in greater abundance than the adults, especially within the shadscale community.

The brown-shouldered uta was consistently the most prevalent lizard in all communities. They were most numerous in gravelly areas where there was an abundance of large rocks and were consequently most abundant within the tetradymia community at the base of the House Range where they comprised 92 percent of the total lizard population in April and 63.6 percent of the average summer population. They became progressively less abundant from the base of the mountains to the valley floor.

The seasonal activity of the utas was longer than that of any other lizard encountered. They evidently came out of hibernation at an earlier date than most other species because they were most abundant during late April and early May whereas other species became most abundant during the latter part of May. They were also consistently more prevalent than other species during late summer. They likewise became active earlier in the day than most other species. During midsummer they were found to be active as early as 5:00 a.m., at which time other lizards were rarely seen. The reason for this interesting phenomenon is discussed later.

TABLE 26. Percentages of four species of gravid female lizards from April 15 to July 1, 1940.

Time of Year	Species			
	Uta	Horned-toad	Leopard-Lizard	Whip-tail Lizard
April 15	100.0	—	—	—
20	78.0	—	—	—
May 1	80.0	100.0	—	—
10	66.7	100.0	100.0	100.0
20	63.0	75.0	100.0	100.0
June 1	25.0	86.0	75.0	72.5
10	0	37.5	33.3	90.0
20	0	0	0	25.0

No gravid females were found after the first of June indicating that the breeding season of this species is earlier than that of other lizards (Table 26). Gravid females have been found as late as June 20 in areas farther north within the Great Basin (Taylor 1912). The number of eggs per female varied from 3 to 5 with an average of 4.1, which is less than for any other species of lizard examined. Young utas were first seen July 7, 1939 and July 1, 1940. Two individuals collected July 1, were each 53 mm. in length and had so recently emerged from the eggs that the yolk sacs were still visible through the skin of their abdomens. During late July and throughout August the young utas were very prevalent and were often seen in greater abundance than the adults.

TABLE 27. Stomach contents of 17 specimens of *Uta stansburiana stansburiana* (Baird & Girard).

	Percent of total volume	Frequency (Percent)
Acarina	0.6	11.7
Araneida	6.6	35.3
Acrididae	24.3	23.5
Homoptera	1.8	11.7
Hemiptera	6.7	52.9
Cleridae	1.8	17.6
Tenebrionidae	1.8	5.9
Scarabaeidae	3.6	11.7
Other Coleoptera	1.8	17.6
Coleoptera larva	6.6	23.5
Lepidoptera larvae	3.7	11.7
Formicidae	22.3	76.5
Other Hymenoptera	1.9	5.9
Diptera	2.4	11.7
Unidentified insect fragments	14.1	47.0

The brown-shouldered uta feeds on both terrestrial and shrub-inhabiting insects. Ants, principally, *Formica* sp. and *Camponotus* sp., occurred more frequently in the stomachs examined than any other kind of insects and constituted 22.3 percent of the total stomach contents (Table 27). Grasshopper nymphs made up a slightly higher percent of the total food volume than ants because of their size, but they occurred less frequently. Coleoptera larvae and adults occurred with about the same frequency as ants but their total volume was less. The hemiptera consisted primarily of plant bugs and pentatomids. The homoptera were chiefly cicadellids, but chermids and coccids also occurred in some stomachs. These soft-bodied heteroptera are probably digested at a faster rate than other insects with more chitinous exoskeletons, such as grasshoppers and beetles, and the chances of finding their remains in the lizard stomachs would be much less even though they may constitute a much greater percentage of the food eaten than the stomach analysis would indicate. Knowlton (1932) found as many as 83 beet leafhoppers in one uta stomach with an average of 12.79 for 86 stomachs. The occurrence of lepidoptera was low and only larvae were found. Other arthropods eaten included spiders and mites but they constituted a small part of the total food volume. Other investigations (Knowlton & Janes 1931, and Woodbury 1932) also indicate that the consumption of spiders is low.

Utas were observed feeding on grasshoppers and ants in the field, and when kept in captivity they readily ate small grasshoppers, leafhoppers, flies, and ants. This lizard is not only important in the biotic relationships of the community because of the variety of invertebrates upon which it feeds, but it is in turn preyed upon by other reptiles, by birds, and to a limited extent by mammals.

Sagebrush lizards occurred only in the greasewood and sagebrush communities. They usually remained within the larger shrubs and were seldom seen in the open. They were very hesitant about going from one shrub to another and would often remain within the same shrub until it was almost torn apart. The apparent relative abundance of this species was always low (Fig. 17). Inasmuch as this lizard was so restricted to the shrubs there would be a much greater chance for error in estimating its abundance than there would be in the case of other species which frequented open areas and which were found in communities where the cover was much less dense. Consequently the sagebrush lizards were probably much more abundant than the census method used would indicate. No quantitative data were obtained for the sagebrush community but general cruising observaitons indicated that this lizard was probably more abundant there, especially along the sides of ravines, than it was in the greasewood community.

TABLE 28. Stomach contents of 13 specimens of *Sceloporus graciosus graciosus* (Baird & Girard).

	Percent of total volume	Frequency (Percent)
Acrididae	24.8	46.1
Other Orthoptera	4.5	7.7
Homoptera	49.6	30.8
Hemiptera	1.6	7.7
Tenebrionidae	1.2	15.4
Scarabaeidae	4.1	23.1
Formicidae	4.1	100.0
Other Hymenoptera	4.0	15.4
Unidentified insect fragments	6.1	76.5

Unlike many of the other lizards, which spent most of their time on the ground or among rocks, this species spends most of its time within the vegetation and was often seen in the very tops of large shrubs. The fact that these lizards frequent the shrubs is very prominently reflected by the kinds of insects found in their stomachs. Insects from shrubs such as homoptera, hemiptera, and orthoptera composed the greater part of their stomach contents (Table 28). Although ground beetles were very numerous within the greasewood community, they formed less than 2 percent of the total food volume. Ants occurred in all stomachs examined but comprised only 4.1 percent of the total food volume.

Although the reproductive organs of only a few females were examined the results obtained indicate that the eggs of the sagebrush lizard are probably laid during May or early June. Two females collected May 15 both contained well-developed eggs. One of them was carrying 8 eggs, 8 mm. by 13 mm. in size and the other 7 eggs, 9 mm. by 13 mm. in size. Three females collected June 30 contained only ova about the size of a pin head and were assumed to have deposited their eggs. Taylor (1912) found that 2 females which were collected May 21 and May 25 in northern Nevada were still carrying eggs.

Desert horned-toads were consistently present in all communities throughout summer but were the least abundant species within the census plots. They had come out of hibernation prior to April 12 and their relative abundance remained fairly constant from April to August (Fig. 17).

They were never observed up in the shrubs and evidence that they are largely terrestrial in their activities is reflected in an analysis of their stomach contents. More than 55 percent of the total food volume from 16 stomachs consisted of ground beetles and ants (Table 29). Tenebrionids which are slow-moving and largely restricted to the ground were found in 56.3 percent of the stomachs and constituted 32.1 percent of the total food consumed. Ants occurred in all stomachs examined and made up 23.5 percent of the total food volume. As many as 181 ants were found in one stomach. Knowlton (1938) observed a mature horned-toad consume 64 ants within 30 minutes. Small pebbles which had probably been picked up by these lizards in the act of capturing insects occurred in almost half of the stomachs. Seventy-five percent of the specimens were infested with nematodes. As many as 50 nematodes were found in one stomach.

TABLE 29. Stomach contents of 16 specimens of *Phrynosoma platyrhinos* Girard.

	Percent of total volume	Frequency (Percent)
Araneida	0.1	6.2
Homoptera	0.1	6.2
Hemiptera	1.8	25.0
Meloidae	0.5	6.2
Coccinellidae	1.0	12.5
Tenebrionidae	32.1	56.2
Scarabaeidae	25.1	100.0
Curculionidae	5.0	12.5
Other Coleoptera	2.5	31.3
Coleoptera larvae	1.0	12.5
Coleoptera pupae	0.5	6.2
Lepidoptera larvae	5.2	25.0
Formicidae	23.5	100.0
Unidentified insect fragments	1.6	62.5
Vegetation fragments	Trace	25.0
Pebbles	....	43.8
Nematodes (parasites)	....	75.0

Egg-laying had begun during the last part of May and no gravid females were found after the middle of June (Table 26). The number of eggs per female varied from 4 to 9 with an average of 7.1, which is the greatest average number for any of the lizards encountered. The first young horned-toads were seen August 7 in 1939 and July 23, in 1940. These young still retained quite a large quantity of egg yolk within their abdominal cavities and their skin was soft and practically free of spines. Their bodies were also much less dorso-ventrally flattened than the adults.

The low temperatures which prevailed at night inactivated the horned-toads to a much greater degree than some of the other species of lizards. Individuals observed at 5:00 to 6:00 a.m. were almost immobile, even during midsummer. They were most active from 9:00 to 11:00 a.m. and again during the latter part of the afternoon. During midday they

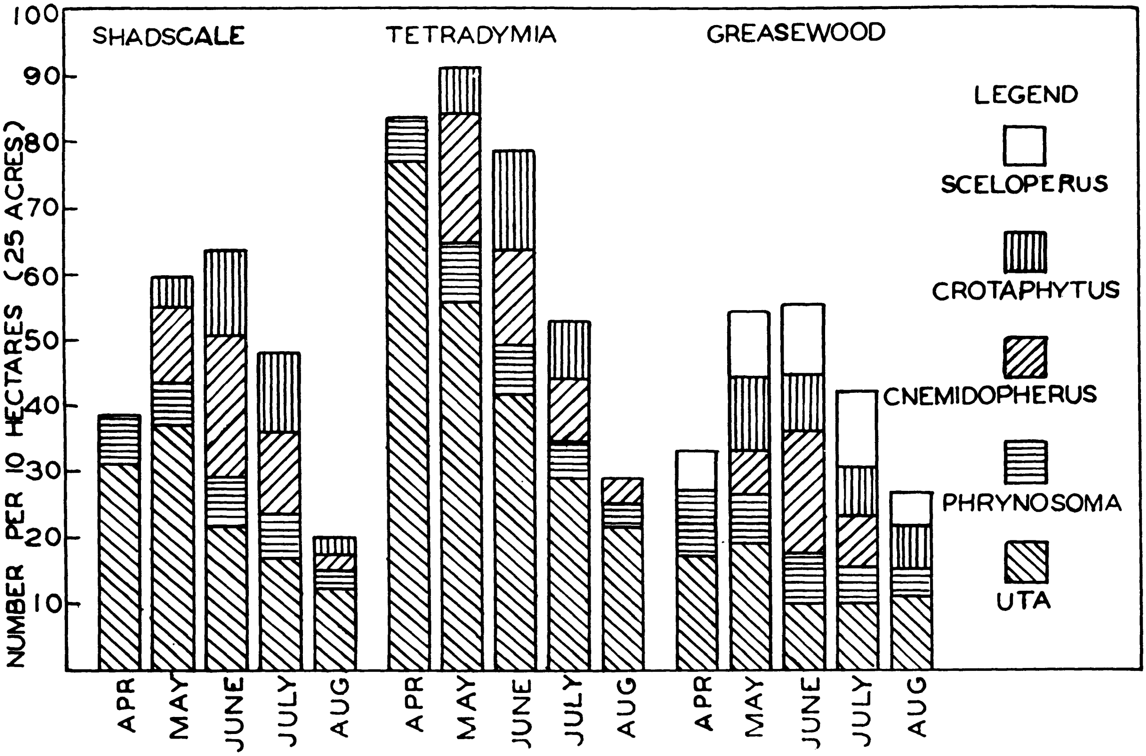

FIG. 17. Seasonal distribution and relative abundance of 5 species of lizards within 3 communities of White Valley, Millard County, Utah.

sought refuge beneath the shrubs or buried themselves in the loose sand. When pursued they attempted to escape beneath shrubs whose lower branches adhered closely to the surface of the ground. When beneath such shrubs they were difficult to extricate because of their posteriorly directed dorsal spines.

The whip-tail lizard is very widely distributed and occurred in all communities but was most abundant in the tetradymia and shadscale (Fig. 17). Their seasonal period of activity was relatively short. None were seen until April 20 and they were not recorded within the census plots until May. They became most abundant in the tetradymia community during late May but reached their maximum in June in the shadscale and greasewood communities. Very few were seen after the first part of August.

They were very rarely seen before 7:00 a.m. and were most active from 9:00 to 11:00 a.m. They usually moved about in a slow, stealthy, jerky manner, especially when they were foraging for food, but when frightened they moved so rapidly that it was sometimes necessary to flush them a second time to make sure of their identity. These sudden bursts of speed were usually of short duration after which the lizard would resume its jerky gait, bobbing its head up and down as it proceeded. Their activities are restricted to the ground as far as could be ascertained. They were seen in the open more frequently than most other lizards and when pursued they would seek refuge within rodents' burrows more often than beneath the shrubs.

By June 20 only 25 percent of the females were gravid (Table 26). Taylor (1912) observed this species copulating as late as June 10 in northern Nevada and Ruthven & Gaige (1915) report a gravid female being collected July 13 in Elko County, Nevada. The number of eggs per female varied from 5 to 9 with an average of 6.7. The first young whip-tails were seen August 3, 1939 and August 15, 1940. The first young collected varied from 105 mm. to 108 mm. in length and had brilliant bluish-green tails. By the first of September the tails of most of the young had assumed the brownish-grey color of the adults.

The food of this lizard consisted primarily of terrestrial insects but it also fed on insects from low-growing shrubs. Beetles were found in all stomachs examined and constituted more than 20 percent of the total food volume (Table 30). Insect larvae seem to be a favorite food item of this lizard since they comprised almost 50 percent of the total food volume of the stomachs examined. Ants had a low frequency of occurrence and were a minor item of food. Spiders constituted 4.1 percent of the total food volume which is a greater percentage than for any other species of lizard except the uta. Evidence that this species may feed on other small lizards is

TABLE 30. Stomach contents of 10 specimens of *Cnemidophorus tessellatus tessellatus* (Say).

	Percent of total volume	Frequency (Percent)
Araneida	4.1	30.0
Acrididae	13.4	40.0
Hemiptera	5.7	10.0
Tenebrionidae	9.0	60.0
Scarabaeidae	7.5	10.0
Curculionidae	4.5	20.0
Coleoptera larvae	18.2	90.0
Coleoptera pupae	1.6	10.0
Lepidoptera larvae	30.9	70.0
Formicidae	0.4	20.0
Other Hymenoptera	0.2	10.0
Unidentified insect fragments	4.5	70.0

reported by Ruthven & Gaige (1915) who collected a specimen August 14 which contained a recently hatched young of the same species. This lizard was observed feeding on flies and grasshoppers in the field and captive individuals readily ate grasshoppers, flies, and small beetles.

Although the striped racer was found in all communities, it was one of the least abundant snakes encountered. Only 6 individuals were observed and all but one were seen during April, May, and June. The other one was seen during early September. This snake moves very rapidly and was found to prey on lizards and insects. Only 3 stomachs were examined, one of which contained a large whip-tail lizard, another contained 2 utas, and the third one, from a snake only 17 inches in length, contained 2 grasshoppers and 3 tenebrionid beetles. One large racer was observed in the field in the act of trying to capture a whip-tail lizard but the lizard managed to escape. Little is known about the breeding habits of this snake. Woodbury (1931) reports that a gravid female kept in captivity had not deposited her eggs by August 12.

Another snake of minor importance because of its scarcity is the long-nosed snake. One specimen of this species was collected each year within the shadscale community. One of the snakes was kept in captivity for 7 days during which time it ate 2 utas and several grasshoppers. Tanner (1940) reports only 4 other records of this snake for Utah, all of which are for Washington County in the southwestern corner of the state.

The Great Basin gopher-snake occurred in all communities from the valley floor to the top of the Black Knolls but it was most abundant in the shadscale community where 54 percent of the total number seen were encountered. This species had emerged from hibernation before the writer's arrival in White Valley in early April. One small specimen, 15 inches in length was collected April 14 and the first adult specimen was seen April 23. Almost 50 percent of the total number seen were encountered during the month of May and 28.6 percent during July (Table 31). This snake is reported to be crepuscular or noctural (Klauber 1939 and Mosauer 1935) but, although the writer spent a considerable amount of time in making observations at night, he found none after dark. Seventy percent of the ones encountered were seen during late afternoon, usually after 6:00 p.m. One individual was collected at 2:30 p.m. after a rainstorm had occurred the night before. They were seen as early as 5:30 a.m. but were never encountered during midday.

The common name "gopher-snake" is very fitting for this species because it preys to a great extent upon ground squirrels which are locally referred to as "gophers." The stomach contents of only 3 specimens were examined but 2 of them contained ground squirrels. One of them had eaten a piute ground squirrel, the second one 2 antelope ground squirrels, and the third one a kangaroo rat. Captive gopher-snakes readily ate kangaroo rats and white-footed mice. As many as 3 mice were eaten by one snake within a period of 28 minutes. Captive snakes which had apparently eaten all that they desired would continue to kill any live mouse or kangaroo rat that was placed in their cages. Woodbury (1928) found a specimen with 9 mice in its stomach and Pack (1919) gives an account of a 3-foot specimen which had eaten 35 small mice.

No data were obtained as to the time of year that this snake reproduces, but according to the observations of Richardson (1915) and Ruthven & Gaige (1915), it must not deposit its eggs until late July or August.

TABLE 31. Frequency of occurrence of gopher-snakes and rattlesnakes from April 12 to August, inclusive.

Months	Percent of total number seen	
	Gopher-snakes	Rattlesnakes
April	14.2	0
May	47.6	27.8
June	4.8	16.7
July	28.6	33.3
August	4.8	22.2

Rattlesnakes were widespread throughout all communities but were encountered most frequently within the shadscale and tetradymia communities. They comprised 40.4 percent of the total snakes encountered and 78.9 percent of them occurred within the tetradymia and shadscale communities.

No rattlesnakes were found before May 6 although a special effort was made to locate them from April 12 up to that time. None had been previously seen by Civilian Conservation Corps personnel or a crew of surveyors who had been working in the field for more than a month before the arrival of the writer. Further evidence that they were just beginning to come out of hibernation about the first of May was obtained from a Civilian Conservation Corps foreman whose men had come into the vicinity of a den on May 7 and had killed 89 rattlesnakes during the day. They were most prevalent during

May and July (Table 31) and after the middle of June they were seen more frequently than gopher-snakes. They were still active in early September when the writer's observations were discontinued although their frequency of occurrence was less. All specimens of this species in the Museum of Vertebrate Zoology at the University of California, which have been collected in Nevada, were captured between May 11 and September 9 (Linsdale 1940). These dates agree very well with the observations of the writer, and seem to indicate the limits of the seasonal activity of this species.

Sixty-eight percent of the rattlesnakes were seen after 5:30 p.m. and 27 percent before 9:30 a.m. One was collected at 9:30 p.m. July 11, 1940. This specimen was in the open near a kangaroo rat mound and was presumably seeking food.

Rodents and small birds seem to be their main source of food. The stomach of one specimen contained 2 piute ground squirrels, one of which was partially digested and the other one just recently swallowed. Two others each contained one kangaroo rat, and a fourth one contained a horned lark. One individual was observed to successfully capture a vesper sparrow. Captive rattlesnakes would consume a kangaroo rat every 2 to 3 days, and they would eat freshly killed rats as well as live ones.

The time of reproduction in this species is apparently in late summer or early autumn. Two gravid females were collected May 10 and May 20. The first one contained 12 large ova which had not yet been shed into the uterus and the measurements of which were as follows: (2) 11 x 23 mm.; (2) 12 x 22 mm.; (1) 11 x 22 mm.; (2) 12 x 25 mm.; (2) 13 x 22 mm.; and (3) 12 x 23 mm. The second female contained 8 ova which varied in size from 15 x 32 mm. to 18 x 36 mm. Woodbury (1931) collected a female in August which contained 6 large ova and reports that the young are probably born in the autumn.

ENVIRONMENTAL RESPONSES OF THE BIOTA

PLANTS

As has been previously pointed out, the flora of the Northern Desert Shrub Biome is characterized by several species of dominant deciduous shrubs, accompanied by a few dominant grasses and a limited number of subdominant undershrubs and herbs. Eighty-one percent of the plants collected were perennials. Such a predominating percentage seems to reflect a greater survival value of this group in response to the xeric conditions to which they are subjected. Where the production of seed is the only way of insuring the existence of a species from one year to another the chances for its perpetuation are much less due to the possible shortage of sufficient moisture necessary for the maturing of the seed. This hazard was very obvious during the summer of 1940 when many of the plants failed to produce seed. Flowers were produced but drought prevented the seeds from maturing.

The annuals which do occur, usually reproduce very early in the spring when sufficient moisture is available to complete their life cycle. Many of the perennials, on the other hand, reproduce during the latter part of the summer when the second moist period of the year occurs. This is a rather hazardous time of the year for reproduction because of the variability of the precipitation and only perennials would have much of a chance of survival. During 1940 many of the little rabbitbrush failed to produce flowers because of the lack of moisture during July and August.

All of the dominant grasses are perennials. The only annual grass encountered was the introduced subdominant brome grass which matures its seeds before June. The survival value of grasses is decreased to a lower ebb than for some of the other herbaceous forms due to the coactions of herbivorous animals (both domestic and native) so that the hazards encountered in reproduction are even greater in this group. The capacity to send out new shoots from the more protected basal portion of these perennials is largely responsible for their continued survival under the conditions of heavy grazing and drought to which they have been subjected.

The dominant shrubs seem to have acquired their distinctive life-form in response to the arid climate to which they have been subjected. They all belong to herbaceous families which have acquired shrubby adaptations and are not dwarfed forms of larger shrubs and trees such as occur in the chaparral or alpine communities. Two species of ephedra were the only shrubby components encountered which did not belong to either the aster family (Asteraceae) or the goosefoot family (Chenopodiaceae). These two families comprised 49 percent of the total species identified and are all perennials except the Russian thistle, which is an introduced species. This shrubby life form makes possible the attainment of larger sized plants, by small increments of growth each year, than could be attained during the short period of time when sufficient moisture is available, if the entire plants were reproduced each year.

Two types of root systems are very characteristic of these xerophytic plants. The one is a long taproot which makes possible the utilization of deep soil moisture and the other is a widely branched system of roots near the surface which facilitates the rapid utilization of the limited amounts of periodic precipitation.

In response to the limited amount of available moisture, most of the plants are widely spaced, grow very slowly, are rather small, and cover only a small percentage of the area on which they occur. Such plants have been termed "drought evading plants" (Shantz 1927), because they evade early desiccation by delaying the eventual exhaustion of the available soil moisture through the above adaptations. Such spatial relations are not only characteristic of the shrubs but occur in most of the dominant grasses.

Conservation of water and the prevention of excessive water losses from transpiration is accomplished through morphological adaptations such as reduction in leaf surfaces, heavy cutinization of the epidermis, extreme pubescence of leaf surfaces, and the shedding of leaves. Bud sage and tetradymia shed practically all of their leaves very early in the summer and go into an apparent state of dormancy, appearing as if they were practically dead. The leaf surfaces of shadscale, winterfat, and sagebrush are relatively small and are so pubescent that these plants are gray to almost white in color. The leaf surface of the greasewood, suaeda, and gray molly is reduced by their linear proportions and the leaves of the greasewood are so heavily cutinized as to appear as if they were glazed. The ephedra and pickleweed leaves are reduced to mere scales and the stems function in photosynthesis. During extreme conditions of drought the transpiration surface of the ephedra plants is often reduced by the shedding of parts of the stems.

Physiological adaptations such as increased osmotic pressure values of the cell sap have been developed by many of the plants, thus enabling them to obtain moisture from the soil where moisture equivalent values are low or where the mineral content of the soil is high (Shantz 1916, Harris, J. H. *et al.* 1924). These studies show that the osmotic concentration of the cell sap of the dominant plants from different communities is inversely proportional to the available moisture. The cell sap of sagebrush, which grows where the greatest amount of moisture is available, has been found to have an average osmotic value of about 22 atmospheres whereas the cell sap of shadscale averages 43.6 atmospheres and sometimes exceeds 150 atmospheres where the moisture supply is lowest. Greasewood, growing in situations where underground water is available but where the salt content of the soil is apt to be higher, has a cell sap osmotic concentration intermediate between the above two, averaging about 30 atmospheres (Harris, J. A. *et al.* 1924). This correlation between osmotic concentration of plant tissue fluids and the availability of moisture has been further demonstrated by comparisons between the shrubs and the ephemeral herbs, always being considerably lower in the herbs which occur at the time of the year when the greatest amount of moisture is available.

MAMMALS

The survival value of any organism is dependent on its physiological and morphological adaptation to the environmental conditions to which it is subjected or to its ability to escape those conditions not favorable to its existence. The first type of response is more characteristic of plants because of their lack of motility and is manifest by morphological changes in life form and physiological adaptations such as have been described. Morphological and physiological adaptations also occur in animals but they are greatly augmented by adaptive types of behavior which enable them to evade the critical environmental extremes to which they are subjected.

The mammals in general are light in color in keeping with the general light tone of the sparse vegetation and the soil. Correlations between the pelage color of many different rodents and the color of the soil has been frequently observed in areas of sparse vegetation in southwestern Utah (Hardy, 1945) and in other parts of southwestern United States (Benson 1933, Dice and Blossom 1937, and Hooper 1941). Natural selection, resulting in the elimination of those individuals which do not blend into their backgrounds is thought to be an important factor responsible for such correlations (Benson 1933, and Dice and Blossom, 1937), but this protective coloration theory is discredited by others (Buxton, 1923, and Summer 1921 and 1925). As yet there is little experimental evidence as to what the causes may be. High temperatures and low humidities, which are often postulated to be responsible for pallid coloration, have been found to induce no detectable changes in various species when reared under controlled conditions for as many as twelve generations (Summer 1924).

Most mammals of the communities studied escape the hot summer temperatures by remaining under ground during the day. The high air and soil surface temperatures are not transmitted very far beneath the surface of the ground and relatively moderate and constant temperatures are quickly reached, as has been clearly shown by Vorhies (1945). The data presented in Table 32, compiled from Sinclair (1922), also shows that within a relatively short distance beneath the surface of the soil the temperatures are much lower and that the daily range in temperature at a depth of only 10 centimeters is less than one-eighth as great as at the surface.

TABLE 32. Soil temperature. From Sinclair, 1922. June 21, 1915 at Tucson, Arizona.

	Maximum °C	Time	Minimum °C	Time	Daily Range °C
Shelter.......	42.5	1:00 p.m.	11.0	4-5 a.m.	31.5
Soil 0.4 cm..	71.5	1:00 p.m.	15.0	4-5 a.m.	56.5
" 7.0 " .	44.1	4:30 p.m.	25.2	6:00 a.m.	18.9
" 10.0 " .	40.1	6:00 p.m.	26.3	6:30 a.m.	13.8
" 20.0 " .	33.4	9:00 p.m.	29.0	10:30 a.m.	4.4
" 30.0 " .	29.8	10:30 p.m.	27.8	12:00 n	2.0
" 45.0 " .	27.9	10:00 a.m.	27.8	2:00 p.m.	0.1

Sixty-eight percent of the mammals encountered were nocturnal. When the rodents are considered separately this response was even more striking, the percentages being 79 nocturnal and 21 diurnal. Although the diurnal species were active to a certain extent throughout the day yet there was a decrease in their activity during the midday hours. One diurnal species, the piute ground squirrel evades late summer high temperatures by aestivating. It remains within its burrow from July until the following February or March. The fact that the antelope ground squirrel remained active throughout the summer suggests the possibility of certain physiological differences and/or differences in the diets of these two species which are responsible for this difference in seasonal behavior.

Although the rabbits are crepuscular and nocturnal they remain above ground where they are exposed to the normal air temperatures throughout the day. They leave the more open areas during midday and go into areas where the tallest vegetation occurs and consequently where there is the greatest amount of shade. During the heat of the day they remain relatively inactive within their forms which were found to be almost invariably situated in the north and east sides of the shrubs where the maximum amount of shade is obtained during the hottest part of the day.

Temperature does not only alter the behavior of diurnal animals but it also has a pronounced effect on the time of activity of nocturnal species. Their time of activity tends to be progressively delayed until later hours of the night as the daily summer temperatures increase. During each month a limited number of trapping plots were visited every 2 hours during the night and the number of rodents caught was recorded. During May about 80 percent of the kangaroo rats were caught before 11:00 p.m., 32 percent of them being caught before 9:00 p.m. During July and August only 32 percent of them were caught before 11:00 p.m. The air temperatures most favorable for the activity of these rodents were apparently between 55° to 75° F., since that was the general range at which the greatest number were caught regardless of time of night or time of the season (Table 33).

TABLE 33. Kangaroo rat activity as indicated by number caught at different times of the night on 10 different plots from May to August, 1940.

Dates	Before 9:00 p.m.			9:00 to 11:00 p.m.			11:00 p.m. to 1:00 a.m.			After 1:00 a.m.		
	Temperature °F	Number	Percent of Total	Temperature °F	Number	Percent of Total	Temperature °F	Number	Percent of Total	Temperature °F	Number	Percent of Total
May 21	58	1	25	56	2	50	53	1	25	49	0	0
" 21	58	2	22	56	7	78	53	0	0	49	0	0
" 26	55	6	43	52	5	36	50	2	14	46	1	7
June 11	67	1	25	68	0	0	58	2	50	53	1	25
" 11	67	0	0	68	0	0	58	4	80	53	1	20
" 28	79	0	0	75	0	0	72	3	100	65	0	0
" 28	79	0	0	75	0	0	72	0	0	65	2	100
July 17	77	0	0	75	4	36	74	0	0	64	7	64
Aug. 11	79	0	0	76	0	0	73	0	0	60	4	100
" 11	79	0	0	76	0	0	73	0	0	60	3	100

The ability of mammals from arid regions to dispense with the ingestion of free water has caused considerable speculation but has received little scientific investigation and the role of metabolic water in desert animals has been grossly over-estimated. Since metabolic water is produced solely by the oxidation of proteins, fats, and carbohydrates, desert animals can presumably produce no more than aquatic ones. This metabolic water may be sufficient in certain insects and small rodents to meet their physiological needs but in most of the larger mammals it must be supplemented by free water. During the winter the problem is less serious because snow remains on the ground for considerable periods and can be utilized. Water losses from the surface of the body are also less during that time of the year due to lower temperatures and increased relative humidity. More metabolic water may also be available due to increased rates of metabolism for heat production. During the summer months just the converse is true. Less free water is available, water losses from the body are apt to be higher and the production of metabolic water lower. A certain amount of water is obtained from succulent plants by some mammals such as ground squirrels and rabbits and some from animal food by certain carnivorous species, but in the case of animals as large as the antelope and the coyote this supply is inadequate and must be supplemented by available sources of drinking water. Barnes (1929) postulates that the antelope may be able to persist without drinking water but such a hypothesis is very doubtful. Even in winter when snow is available antelopes usually seek out watering places about every four days (Rouse 1941). Although antelopes are often seen 40 to 50 miles from any known water supply they move very rapidly and can get to a water supply within a short time. There may also be seepages and small springs within their range which are unknown to man. Natural cavities in rocks filled with rainwater may also serve as a supply of drinking water for several weeks.

Many of the mammals are able to persist on the small quantities of water principally by conservation of the supply within their bodies. Most of the small rodents such as pocket mice, kangaroo mice and kangaroo rats feed on air-dry plant seeds and leaves and apparently persist almost entirely on metabolic water. Similar observations have been made on various species of Heteromyidae in other arid regions (Stephens 1906, Vorhies and Taylor 1922, Hall and Linsdale 1939, and Hawbecker 1940). Those factors which increase the rate of metabolic water production or conserve water within the body are of primary importance to animals in arid regions. Since an increase in the production of metabolic water necessitates an increase in the rate of metabolism it might appear as if an increased metabolic rate might be advantageous and characteristic of desert animals. However, factors directly concerned with increased rates of metabolism include increased rates of respiration, body temperature, and general activity. It is quite obvious that an increase in any one of these, to produce more metabolic water, would also increase the water loss from the body, and a vicious cycle would result. Evidence seems to indicate that on the whole the greatest economy of water is attained by animals kept on a dry diet where the rate of metabolism is lower and where the activity of the animal is reduced (Howell and Gersh 1935). Although metabolic water is very important, its increase to any appreciable degree through increased activity of the animal seems to be too expensive, by way of water losses, to be practical.

Diet is one factor which would seem to be of great importance in the water economy of mammals. Inasmuch as the end product of protein metabolism is urea, which is soluble and necessitates the presence of considerable amounts of water for its elimination, it would appear that desert animals would fare better on a diet low in nitrogenous constituents. Since carbohydrates will furnish approximately 55% of their weight (more or less in accordance with their hydrogen content) in metabolic water and fats more than their own weight, a diet high in these two constituents would be to the advantage of the desert mammals. Burr & Burr (1930) found that white rats on a fat-free diet required twice as much water as rats furnished 10 drops of lard per day, although the excess water was not eliminated through the kidneys. Vorhies (1945) reports a striking correlation between the food habits of several different species of rodents and the microclimates of their habitats. Those species, such as the kangaroo rat, which obtain practically no free water from the foods they consume, are strictly nocturnal and spend most of their time within a microclimate of their burrows which is less conducive to water losses from the body. Other species, such as the jack rabbit, which are subjected to environmental conditions conducive to greater degrees of desiccation, obtain sufficient water by feeding on more succulent plants.

Any factor which will reduce the rate of respiration and loss of water from the surface of the body would be of a distinct advantage to mammals in arid regions. Thus most of the rodents of such areas are active during only a small part of the day and at a time when it is coolest and the evaporating power of the air is lowest. During the hot part of the day they remain within their burrows where it is cool and where the underground moisture is not dissipated so rapidly. The work of Howell and Gersh (1935) suggests that the dry diet of kangaroo rats is conducive to lower respiratory rates and consequently to a reduction in water losses.

Secretions from oil glands of the kangaroo rats are very conspicuous and may play a part in preventing water losses from the surfaces of the body. When deprived of a sand bath the pelage of these animals assumes an oily and unkempt appearance within two or three days.

The feces of desert animals are very dry indicating an efficient reabsorption of water within the large intestines. Howell & Gersh (1935) have shown that water in the urine may be conserved for reutilization by kangaroo rats fed on dry diets through physiological means of reabsorption common to the kidney of other mammals, but supplemented by a marked increase in the reabsorptive powers of the large ducts of the renal papilla, and by a reabsorption of water in the bladder. This mechanism for water conservation and reutilization was exhibited only in kangaroo rats fed on dry diets and seems to be an adaptation that is peculiar to mammals living under arid conditions.

BIRDS

Many birds of the Great Basin have certain morphological and structural characteristics which serve to distinguish them from other birds, of even the same species, in other parts of the United States. Most of them are characterized by plain pallid colors which not only serve to reflect the sun's rays but also blend in with the general light colored soil and sparse vegetation thus affording protection where an adequate vegetation screen is lacking. Linsdale (1936) found a high positive correlation between the lining of the nests and coloration of nestling plumages (down) with the vegetation cover at the nest site and the general climatic ranges of the birds. The light colored plumage of the nestlings and adult birds may be the result of natural selection but the light colored nest linings appears to be largely a circumstantial matter. The materials used in lining the nests are usually dried grasses and light-colored vegetation fibers which are the most available materials for building nests in the communities concerned. Wool, which would not be present under natural conditions, was frequently found lining nests because it was readily accessible and apparently not because of any predilection on the part of the birds.

The nests of practically all species were placed on or near the surface of the ground due to the small size of the plants and most of them were located on the east or northeast side of the plants (Table 20). Such a position affords the greatest possible amount of protection from the sun during the hot afternoon hours and affords warmth during early morning hours which are usually chilly in such regions. Linsdale (1938) reports this same phenomenon in Nevada and attributes it to preferences on the part of the birds for the warmest side of the shrubs during the early morning hours when the nests are being constructed.

Long-range vision is very noticeable and is probably an important factor in the protection and social relations of these birds where the low-growing plants afford little protective cover and where the birds tend to be widely separated. This scattered distribution also necessitates a high development of the vocal powers in order that the birds may hear one another. Birds of central Nevada have been found to have much louder voices than those of the same species along the Pacific coast (Linsdale 1938a).

The flight of most species is very rapid and all species of passerine birds except the horned lark tend to fly low, seemingly to be within the protection of the low shrubs. This low-flying characteristic may not only be a means of evading enemies but it is also a means of evading the strong winds which are so prevalent in the area. Even ravens were observed to fly very low during strong winds and follow along ravines below the general level of the terrain.

The high temperatures are tolerated principally by seeking shade within the largest shrubs. Bird populations were higher in the greasewoods during the hotter part of the day than in the mornings and evenings because the birds coming in from the more open adjacent areas sought the shade of the larger greasewood shrubs during midday. In the open shadscale and tetradymia communities the bird populations decreased considerably after the nesting season when summer temperatures reached their maxima.

The lack of sweat glands in birds helps to prevent losses of water from their body surfaces. Water is also conserved by the excretion of nitrogenous waste materials in the form of semi-solid uric acid. When the end product of excretion is uric acid, approximately 53% of metabolic water has been found to be obtainable from nitrogenous oxidation, while with urea only 42% is thus obtainable (Howell and Gersh 1935).

Reptiles

Although reptiles are very characteristic of arid areas where temperatures often become high, they have few physiological adaptations which better enable them to withstand the high temperatures of such areas than mammals and birds. In fact their poikilothermic characteristics may be a handicap where daily and seasonal fluctuations in temperature are as great as they are in western Utah. Their seasonal and daily periods of activity are very short being affected by both high and low temperatures. Being so closely associated with the ground they are subjected to an environment where temperatures get much higher than the air temperatures and often reach 130° to 140° F. Experimental evidence indicates that most reptiles will succumb to such temperatures if exposed for only a few minutes and that diurnal species are no more heat-tolerant than nocturnal ones (Mosauer 1936). Most reptiles have been found to register marked discomfort at temperatures 5° F. above their optimum and exposure to higher temperatures causes death from a minute to an hour, the time element depending on the ground temperature, intensity of radiating capacity for color change and volume of the reptile. Cowles (1939) postulates the possibility of high temperatures and increased insolation, rather than cold, as being the chief element responsible for the disappearance of the Mesozoic reptilian fauna. The present day reptiles are able to persist only by altering their behavior so that they are not exposed to the daily temperature extremes. Lizards have an advantage over snakes because their body is elevated somewhat above the ground and their mode of locomotion enables them to move more quickly from one bit of cover to another.

The chromatophores of the skin function to a certain extent in thermo-regulation in reptiles but the degree of its effectiveness is not very great. The pigment cells are stimulated by both temperature and light with temperature being of primary importance. At low temperatures the melanophores expand and the skin is darkened thus facilitating a maximum amount of heat absorption and making it possible for the reptile to become active earlier in the day. At higher temperatures the melanophores contract causing the skin to become light and absorb less heat from the sun, thus extending the length of the reptiles' daily period of activity. The critical temperature for inducing the light phase in most iguanids is about 95° to 110° F. but may be as low as 77° F. in the uta (Atsatt 1939). In correlation with this experimental reaction of the uta, the writer found that this species became active much earlier in the morning than any other species of lizard. It was often active before 6:00 a.m. during the midsummer. Horned-toads encountered at such time of the day were practicaly immobile.

Since this thermo-regulator mechanism is of little use above the point where a maximum degree of blanching is induced, it is necessary for these animals to avoid the lethal daily temperatures by crawling into burrows, burrowing in the loose soil, and seeking shelter beneath rocks and vegetation. This evading reaction is very well reflected in the decreasing number of reptiles seen as the summer temperatures increased (Fig. 17).

Reptiles are morphologically and physiologically well adapted for water conservation which is very important to animals living in arid regions. Water losses from the body surfaces is reduced to a minimum in this group by their impervious integument and by very little water being excreted. The feces are eliminated as a dry mass containing practically no water and the urine is composed of an equally dry mass of uric acid and its salts which are insoluble and can be excreted in a solid form (Weese, 1917). These adaptations enable them to exist without the ingestion of free water. Their entire water requirements are met by the water contained in their food and by water which is produced as a result of the metabolic processes of the body. This protection against water loss is so effective that the reaction of the horned-toad in a gradient of the evaporating power of air has been found to be very indifferent unless the gradient is extremely steep (Weese, 1919a).

Invertebrates

The responses of the invertebrates to environmental factors was not as apparent as they were in the vertebrates but some rather detailed observations were made on a few of the more common species. Since ants were very abundant and exhibit very diversified habits, they were of particular interest. Among this group are both diurnal and nocturnal species. The harvester ant, a very widely distributed diurnal species, seems to be able to withstand much higher temperatures than many other species of ants, especially the honey ant, *Myrmecocystus mexicanus*

FIG. 18. Cone-shaped mound of the honey ant *(Myrmecocystus mexicanus navajo)* within the shadscale community. (July 14, 1940.)

navajo Whlr. which is crepuscular or nocturnal. The harvester ants emerged from their mounds about 7:30 a.m. during midsummer and were inactive only when the air temperatures exceeded 90° F.

The honey ant builds a funnel-shaped mound of small pebbles with an opening at the bottom of the funnel leading to a labyrinth of galleries extending 2 to 3 feet below the surface of the soil (Fig. 18). By remaining within these galleries they are able to avoid the high outside temperatures which they are unable to tolerate. When exposed to the direct rays of the sun at a temperature of 94° F. these ants were killed within 1 to 10 minutes. Their sensitivity to temperature was very markedly reflected in the time of their activity at different times of the year. During April they became active just before dark and the time of their activity was progressively delayed until a later hour of the night as the summer temperatures became higher. By midsummer they failed to emerge until near midnight. Observations were made on the time of emergence of these ants from their mounds at frequent intervals from April 19 to September 2, during which periods the position of the ants were recorded every 3 to 15 minutes and any significant changes in their position were recorded at the time that such changes occurred.

In presenting the data obtained from those observations the writer finds it convenient to divide the progress of the emergence of the ants from their mound into 3 stages. The first stage is the first appearance of the ants below the aperture of the funnel; the second stage, the occurrence of the ants above the aperture, but still remaining well toward the bottom of the funnel; and the third stage, their actual leaving of the mound.

As the season progressed and the daily temperatures became higher there was a definite tendency for the ants to delay the time of their emergence. The correlation between the time of their leaving the mound and the daily mean temperature during midsummer is not too close, the increased delay in the time of their leaving the burrow being much greater in proportion to the increase in daily mean temperature at that time than it had been earlier in the season (Fig. 19). Unfortunately the soil temperatures were not recorded and it may be that the ants were responding to the surface soil temperatures rather than to air temperatures. Since the surface soil temperatures rise considerably higher than the air temperatures during the day and drop more slowly during the night this may account for the longer delay of these ants in leaving their mounds during midsummer.

The air temperatures at which the ants first appeared below the aperture of the funnel varied from 58° F. to 88° F. with an average of 68° F. for the entire period of investigation. The air temperatures at the time they were in the bottom of the funnel varied from 56.4° F. to 83.5° F. with an average of 66.6° F. The air temperatures at the time they left the mound ranged from 52.2° F. to 70.5° F. with an average of 63.5° F.

There was a considerable variation in the length of the 3 different designated stages at different times of the summer. The range in the time of their appearance below the aperture of the funnel amounted to 2 hours and 12 minutes; the time of their aggregation above the aperture of the funnel was 2 hours and 36 minutes; whereas the range of the time of their leaving the mound amounted to 4 hours and 34 minutes. Thus the length of time the ants remained at each of the designated points varied at different times during the summer. From April 18 to the last part of May, when the daily mean temperatures did not rise above 70° F., the interval from the time the ants first appeared below the aperture until they left the mound ranged from 12 to 40 minutes with an average of 31 minutes. From the first part of August until September 2 the range was from 1 hour and 22 minutes to 1 hour and 25 minutes with an average of 1 hour and 23 minutes. During the early part of the summer the ants left their mound soon after emerging into the base of the funnel, the average time, up to the last of May being 15 minutes with a range of 6 to 24 minutes. During midsummer they remained within

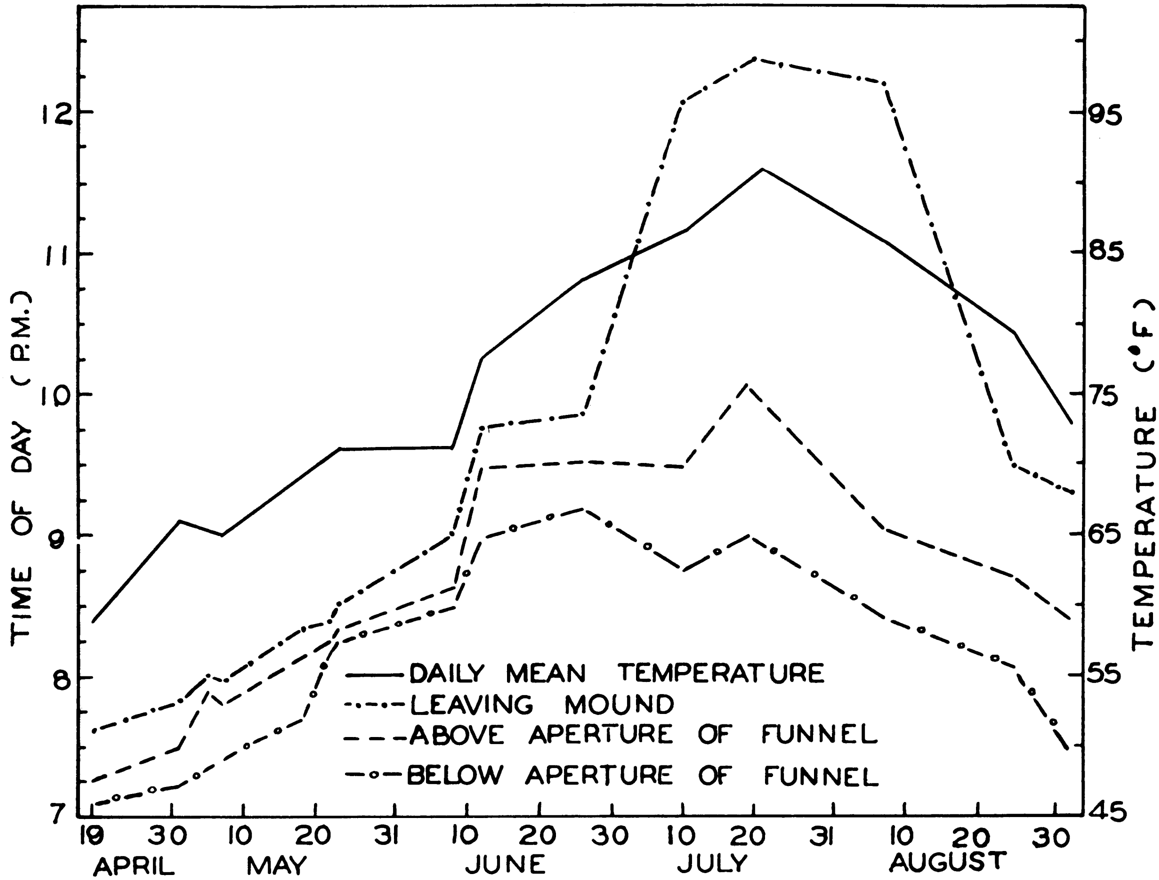

FIG. 19. Activity of the honey ant *(Myrmecocystus mexicanus navajo)* in relation to daily mean temperatures.

the funnel for 16 minutes to 2 hours and 44 minutes with an average of 1 hour and 25 minutes while during the latter part of the season they remained within the funnel only 51 minutes.

A great many species of invertebrates are strictly nocturnal and escape the high temperatures during the day by remaining in burrows or beneath rocks and vegetation. The large tenebrionid beetles were both diurnal and nocturnal but were most active during the cooler hours of the day. Such diurnal species as grasshoppers were usually found during the hottest part of the day on the shady side of the plants and oriented along the longitudinal axis of the stems parallel with the rays of the sun.

Water losses in insects are reduced to a minimum by their chitinous exoskeleton and by the excretion of a dry urine in which uric acid is the sole nitrogenous constituent. The large black tenebrionids which are so characteristic of the communities studied are particularly well protected against water loss. Their elytra is fused together forming a very impervious armor. Experiments by Weese (1919) indicate that these insects lose little or no water from their body surfaces since they exhibit no definite reaction to either low or high relative humidities when subjected to a gradient ranging from 6 to 98%.

The water supply of insects is obtained from the food they ingest and from physiological metabolic processes. Certain tenebrionids are known to live throughout their natural lives without any inhibition of water (Babcock 1912).

SUMMARY

Many of the plant communities of western Utah have received a considerable amount of attention because of their significance as indicators of soil conditions in relation to the economic pursuits of man, but no previous attempt has been made to investigate the total biotic components and analyze their bio-ecological relationships. This study was undertaken for that purpose and an attempt was made to investigate the biotic constituents from the standpoint of their distribution, relative abundance, interactions and environmental responses.

The shadscale association and its related communities were studied in White Valley which is located in Millard County, 65 miles west of Delta, Utah. The sagebrush community was studied in Fernow

Valley located about 15 miles west of Levan, Utah in the eastern part of Juab County.

Field observations were made from June to September, 1939 and from April to September, 1940. Quantitative methods were employed in studying both the plants and animals of the various communities, supplemented by general cruising observations. The principal plant components for each community were calculated in terms of percent of the total floral composition, frequency of occurrence in quadrat samples taken, and percent of the total ground surface covered. One square meter samples of the invertebrate populations were taken every 7 to 10 days by making 50 sweeps with an insect net 30 centimeters in diameter. The frequency with which the larger vertebrates were seen or heard, together with the frequency with which their "signs" in the form of scat, tracks, and dens or nests were encountered, were used as indices of their relative abundance. Estimates of the bird and rabbit populations were made by counting the number of individuals within 4-hectare (10-acre) sample plots. The relative abundance of the smaller rodents was determined by trapping 0.4-hectare (1-acre) and 0.2-hectare (0.5-acre) plots for 4 consecutive nights. The relative abundance of lizards was estimated by making counts within the same plots that were utilized for trapping rodents. Daily records of temperature, relative humidity and evaporation which were kept while the field work was in progress were supplemented by climatic data from government weather stations located within shadscale and sagebrush areas throughout western Utah.

The biotic communities of the Great Basin region occurring at elevations below the piñon-juniper woodland and extending from the Palouse prairie areas of southern Idaho and southeastern Washington to about 37 degrees south latitude, where they merge in the Southern Desert Scrub Biome in southern Utah, are designated as constituting the Northern Desert Shrub Biome. The term "Northern" is used to denote a semi-desert climate and to differentiate it from the more arid desert of southwestern United States. The "Atriplex-Artemisia Association" of Clements is divided into two separate associations, sagebrush and shadscale, on the basis of differences in available moisture, distribution of the dominant plants and composition of the various biotic components.

The sagebrush community occurs along the windward bases of mountains or in valleys where the precipitation is greater and/or where the soil is deep, more permeable, and relatively saline-free, whereas the shadscale and its closely related communities occupy the more xeric areas where the soil is often impregnated with mineral salts. Temperature conditions are very similar in both associations ranging from a maximum of 115° F. to a minimum of —28° F. with an annual mean of 49.9° F. in the sagebrush areas, as compared with a maximum of 110° F. to a minimum of —30° F. with an anuual mean of 49.5° F. in the shadscale areas. Annual precipitation is about 100 percent greater in the sagebrush area than in shadscale areas, with an average of 14.84 inches in the former as compared with 7.95 inches in the latter. The distribution of the precipitation throughout the year is much the same for both associations and most of it occurs in the form of snow. June is the driest month of the year although very little precipitation may fall during July in some years.

Considerable variation occurs in the composition of the shadscale association with the result that a number of distinct edaphic biotic communities, designated as faciations, were differentiated on the basis of the deletion or addition of one or more dominants. These variations seem to be the result of differences in the availability of soil moisture which is altered by the texture and mineral content of the soil.

The shadscale, tetradymia, greasewood, and sagebrush communities were studied most intensively and are described in greatest detail. The plants and invertebrates are regarded as constituting the biotic matrix of the various communities. The relationships of the vertebrate animals to the biotic matrix, together with their interactions and environmental responses, are described as far as they are understood.

Each community is characterized by rather sharp boundaries, by one or two rather widely spaced dominant deciduous shrubs, accompanied by several dominant grasses, and a limited number of subdominant under-shrubs and herbs. Except for a small portion of the lowest part of the valley floor in White Valley, which consists of a barren playa, so heavily impregnated with mineral salts that no plant life can exist and which is fringed in some places by a border of pickleweed, the greater part of the floor is occupied by the greasewood faciation. As this community extends towards the outer edges of the valley floor, shadscale becomes increasingly abundant and in some places an ecotone is formed between the two communities. The shadscale association extends from the upper border of the valley floor toward the base of the mountains and occupies a much greater part of White Valley than any other community. The principal dominants of this community include shadscale, winterfat, bud sage, Indian rice grass, and galleta grass. As this community approached the base of the mountains a new dominant *Tetradymia glabrata* became very prevalent in some areas. The tetradymia faciation thus occurred as a discontinuous narrow band at the base of the mountains where the soil was coarse in texture, well-drained and where there were usually many large boulders. The winterfat faciation was also edaphic in nature and often occurred as "islands" within the shadscale community where the soil was sandy. This community has probably been greatly reduced in extent by the grazing of domestic animals because winterfat, the principal dominant, is utilized to a great extent as forage for sheep. The black sage community occurred on a series of black lava rock knolls where the soil was shallow and very coarse in texture. The subdominant little rabbitbrush was very widespread and in some areas where the soil was very shallow or where the characteristic dominant shrubs had been disturbed or depleted, it formed a developmental community (associes) of considerable extent.

Arachnids, tenebrionid beetles and ants were very prevalent and conspicuous members of the ground society in most communities. The invertebrates of the dominant shrubs varied greatly in abundance and species from one community to another. They were consistently most abundant in the sagebrush and greasewood communities and least abundant in the shadscale. Maximum invertebrate populations occurred during the month of May in all communities except the greasewood, after which they declined as the summer temperatures increased. Invertebrate populations of the greasewood community remained fairly constant during midsummer and reached a maximum about the middle of June when populations of other communities were beginning to decline. The greatest fluctuation occurred in the tetradymia community where the dominant plants produced profuse inflorescences that attracted numerous small hemiptera during early May. Following a very high population level, which exceeded that of any other community during May, the abundance of insects declined very rapidly as the tetradymia matured its seeds and shed most of its leaves in response to the xeric conditions to which it was subjected.

Most of the major influent mammals, such as the badger, coyote, and antelope ranged throughout all communities. Although continuous predator control measures are exerted against the coyote by stockmen and government agencies, it continues to be very prevalent and was the most ecologically important major influent in all communities. It was most abundant in the greasewood and sagebrush communities where there was the greatest amount of cover and where its basic food supply (rabbits) was most abundant. Its coactions are far-reaching because it is active throughout the year and because it feeds on such a variety of biotic components from insects to the largest mammals. The badger has been greatly reduced in numbers through the predator control activities of man but it still is an important major influent because it feeds on many of the prevalent rodents and because its burrows are utilized by so many other species of animals such as the burrowing owl, cottontail rabbits, foxes, coyotes, and many of the smaller animals of the community. The distribution of the burrowing owl seemed to be practically dependent on badger excavations.

The major influent birds also ranged throughout all communities. The most important species observed included the Swainson hawk, marsh hawk, prairie falcon, and the burrowing owl. The burrowing owl was most prevalent in the shadscale community. So pronounced were the effects of this owl within the community that rodent populations within the vicinity of its burrows were practically nil.

The smaller vertebrates were much more numerous and although many of them occurred in all the biotic communities they varied in abundance from one community to another. Heteromyidae, consisting of 3 species of pocket mice, 2 of kangaroo rats, and one kangaroo mouse, were very prevalent throughout all communities. *Perognathus parvus* was restricted to the sagebrush community; *Perognathus formosus* occurred only in the black sage and tetradymia communities; and *Perognathus longimembris* was most prevalent in the shadscale community. *Dipodomys microps* occurred in all communities, but was most abundant in the shadscale and tetradymia communities where it constituted 80.6 and 60.9 percent respectively of the total rodent populations. *Dipodomys ordii* occurred in all communities except the black sage and was more abundant than *D. microps* in the greasewood and sagebrush communities. The kangaroo mouse occurred in several communities of White Valley but was never abundant, being most prevalent in the winterfat community. The piute ground squirrel was most prevalent in the vicinity of Tule Springs in the greasewood community and in the sagebrush community whereas the antelope ground squirrel was most prevalent in the shadscale community. Chipmunks were never abundant and occurred only in the sagebrush community. The pocket gopher occurred in most communities except where the soil was shallow and rocky but it was never abundant, being most prevalent in the greasewood community in the vicinity of Tule Springs. The number of grasshopper mice trapped was very low, although this species occurred in most of the communities of White Valley. The harvest mouse occurred only in the greasewood, shadscale-greasewood ecotone, and sagebrush community, being most prevalent in the greasewoods. *Peromyscus maniculatus* occurred in all communities but was largely replaced by an ecological equivalent, *Peromyscus crinitus*, in the black sage community, the latter species being restricted to the black sage. The pack rat was present only in the black sage and tetradymia communities where large boulders and cliffs provided adequate sites for its dens. Jack rabbits were widespread but were most abundant in the greasewood and sagebrush communities. Cottontail rabbits were largely restricted to the tetradymia and black-sage communities where large rocks and ravines were present.

Passerine bird populations were low and the resident species few in number. Populations were highest in April and May in the shadscale and tetradymia communities and in August in the greasewood community.

Reptiles were very conspicuous minor influents from April to August but their ecological importance is limited by their short seasonal period of activity. This group consisted of 6 species of lizards and 4 species of snakes. The brown-shouldered uta was not only the most abundant lizard but it had the longest daily and seasonal periods of activity and occurred in all communities, being most numerous in the tetradymia community during April and May. The collared lizard was restricted to the tetradymia and blacksage communities, whereas the sagebrush lizard occurred only in the sagebrush and greasewood communities. All other lizards occurred in most of the communities but they varied in abundance from one community to another. The utas began depositing their eggs soon after the middle of April and had completed their egg-laying activities in early June when most of the other lizards were just beginning to lay their eggs. The food of most lizards consisted primarily of insects. Terrestrial insects, such as ants and ground beetles, constituted the greater part of the diet of the strictly terrestrial species such as utas and horned-toads, whereas homoptera and hemiptera were most frequently eaten by the shrub-inhabiting sagebrush lizard. The leopard-lizard and collared lizard were found to be carnivorous as well as insectivorous and fed to a considerable extent on utas. The gopher-snake and rattlesnake were the most prevalent snakes and both were most abundant in the shadscale and tetradymia communities. Gopher-snakes were encountered almost a month earlier than rattlesnakes but both species were most prevalent during May and late July.

Soil texture seemed to be a very important factor in the determination of the distribution of many of the biotic components. It not only influenced the composition of the plant life but also had a pronounced effect on the distribution of many of the animals. The kangaroo mouse and one species of kangaroo rat *(Dipodomys ordii)* were most frequently encountered in areas of fine gravel and sandy soils, whereas *Dipodomys microps* and *Peromyscus crinitus* were most abundent where the soil was very coarse in texture. The brown-shouldered uta was most abundant in the tetradymia community where the soil consisted principally of coarse gravel, whereas the leopard-lizard was most prevalent in sandy areas. The pack rat, long-tailed pocket mouse *(Perognathus formosus)*, rock wren, and the collared lizard were restricted to those communities where the soil was very rocky and where there was an abundance of large boulders.

The height, density, and general vegetative form of the dominant plants also influences the composition of many of the biotic communities. The dominants of the greasewood and sagebrush communities are very similar in vegetative form, height, and density and many of the vertebrate components of these communities were more nearly alike, although the communities studied were more than 100 miles apart, than were the components of the greasewood and shadscale communities which were adjacent to each other in White Valley. Coyotes and jack rabbits were much more prevalent within the greasewood and sagebrush communities than in any other. The harvest mouse and sagebrush lizard were never encountered elsewhere; and the shrike, sage thrasher, sage sparrow, and Brewer sparrow were found nesting in no other community. The greater amount of cover of the greasewood community was utilized to a great extent by various animals to escape the high midday temperatures. Rabbit and bird counts tended to be higher during midday than they were in the morning and evening hours, and total bird populations increased as the summer progressed and the daily temperatures became higher.

Those animals which were nocturnal or which lived in burrows, such as kangaroo rats and the burrowing owl, were most abundant in the more open communities such as shadscale, winterfat and tetradymia. In such communities the scattered dominants were more important as sources of food than as cover. The feeding habits of the kangaroo rats suggest that the presence of shadscale may be a very important factor in their distribution and abundance. Only a very limited number of resident birds occurred in such communities. The principal species was the desert horned lark which nested on the ground and found adequate protection for its nest beneath the low, scattered dominant shrubs of the shadscale and winterfat communities. The desert black-throated sparrow, on the other hand, was largely restricted to the tetradymia community where there was a combination of taller shrubs interspersed among the shorter ones. It nested regularly only in that community and utilized the taller shrubs as singing perches and nesting sites.

The rodents are among the most ecologically important minor influents of the biome. They constitute the principal food supply of the predatory mammals, birds and reptiles; they influence the growth and distribution of certain dominant and subdominant plants; and their burrows are utilized by many reptiles and invertebrates as avenues of escape from their natural enemies and as a means of avoiding lethal temperatures during midsummer. Their interactions not only include the consumption and storage of leaves and seeds, but through their burrowing activities and underground deposition of stored plant materials and excrement, they alter the chemical and physical composition of the soil to the extent that very noticeable changes are produced in the growth and distribution of certain plants.

Morphological adaptations of the plants in response to the xeric climatic conditions to which they are subjected were very pronounced. The dominants are all perennials, are widely spaced, and have shallow fibrous root systems which are supplemented by a long taproot in some species. The conservation of water is accomplished through morphological adaptations such as reduced leaf surfaces, heavy cutinization of the epidermis, extreme pubescence of the leaf surfaces, and defoliation during the dry summer season.

Most of the animals are characterized by morphological and physiological adaptations or by adaptive types of behavior which enable them to tolerate or evade the high temperatures, low humidity and lack of drinking water. Prevention of water losses from the body surfaces is reduced to a minimum by the chitinous exoskeleton of the diurnal insects; by the

(Continued on Page 307)

APPENDIX A

Distributional list of mammals, birds, and reptiles. The species listed for the shadscale community also occurred throughout the minor edaphic communities of the shadscale area in White Valley and adjacent areas.

	Shad-scale	Tetra-dymia	Grease-wood	Sage-brush
MAMMALS				
Black-nosed Bat *Myotis subulatus melanorhinus* (Merriam)	X	X	X	
Pallid Big Brown Bat *Eptesicus fuscus pallidus* Young			X	X
Desert Pallid Bat *Antrozous pallidus pallidus* (LeConte)	X			
Mexican Free-tailed Bat *Tadarida mexicana* (Saussure)	X	X		
Nevada Long-tailed Weasel *Mustela frenata nevadensis* Hall	X		X	
Great Basin Spotted Skunk *Spilogale gracilis saxatilis* Merriam	X	X		
Badger *Taxidea taxus* ssp	X	X	X	X
Kit Fox *Vulpes macrotis* ssp	X			
Coyote *Canis latrans lestes* Merriam	X	X	X	X
Bobcat *Lynx rufus* ssp	X	X		
Piute Ground Squirrel *Citellus townsendi mollis* (Kennicott)	X	X	X	X
Antelope Ground Squirrel *Citellus leucurus leucurus* (Merriam)	X	X	X	X
Wasatch Chipmunk *Eutamias minimus consobrinus* (Allen)				X
Pocket Gopher *Thomomys bottae centralis* Hall	X	X	X	
Nevada Pocket Mouse *Perognathus longimembris nevadensis* Merriam	X	X	X	
Long-tailed Pocket Mouse *Perognathus formosus formsus* Merriam		X		
Great Basin Pocket Mouse *Perognathus parvus olivaceus* Merriam				X
Kangaroo Rat *Dipodomys microps bonnevillei* Goldman	X	X	X	X
Kangaroo Rat *Dipodomys ordii celeripes* Durrant and Hall	X	X	X	X
Kangaroo Mouse *Microdipodops megacephalus paululus* Hall and Durrant	X	X	X	
Grasshopper Mouse *Onychomys leucogaster brevicaudus* Merriam	X	X	X	
Harvest Mouse *Reithrodontomys megalotis megalotis* (Baird)			X	X
White-footed Mouse *Peromyscus maniculatus sonoriensis* (LeConte)	X	X	X	X
White-footed Mouse *Peromyscus crinitus pergracilis* Goldman		X		
Desert Pack Rat *Neotoma lepida lepida* Thomas		X		
Black-tailed Desert Jack Rabbit *Lepus californicus deserticola* Mearns	X	X	X	X
Cottontail Rabbit *Sylvilagus nuttallii grangeri* (Allen)	X	X		X
Pronghorned Antelope *Antilocapra americana americana* (Ord)	X	X	X	X
BIRDS				
*SPECIES OBSERVED ONLY AT TULE SPRINGS IN THE GREASEWOOD COMMUNITY.				
*Treganza Great Blue Heron *Ardea herodias treganzai* Court			X	
*Common Mallard *Anas platyrhynchos platyrhynchos* Linnaeus			X	
Western Turkey Vulture *Cathartes aura teter* Friedmann	X	X	X	X
Sharp-shinned Hawk *Accipiter striatus velox* (Wilson)	X		X	
Cooper Hawk *Accipiter cooperii* (Bonaparte)			X	X
Western Red-tailed Hawk *Buteo jamaicensis calurus* Cassin	X		X	X
Swainson Hawk *Buteo swainsoni* Bonaparte	X	X	X	X
Golden Eagle *Aquila chrysaëtos canadensis* (Linnaeus)	X		X	X
Southern Bald Eagle *Haliaeetus leucocephalus leucocephalus* (Linnaeus)	X			X
Marsh Hawk *Circus cyaneus hudsonius* (Linnaeus)	X	X	X	X
Prairie Falcon *Falco mexicanus* Schlegel	X	X	X	X
Eastern Sparrow Hawk *Falco sparverius sparverius* Linnaeus	X	X	X	
*Sora Rail *Porzana carolina* (Linnaeus)			X	
*Killdeer *Charadrius vociferus vociferus* Linnaeus			X	
*Western Sandpiper *Ereunetes mauri* Cabanis			X	
Western Mourning Dove *Zenaidura macroura marginella* (Woodhouse)	X	X	X	X
Western Burrowing Owl *Speotyto cunicularia hypugaea* (Bonaparte)	X	X	X	
Long-eared Owl *Asio otus wilsonianus* (Lesson)				X
Nighthawk *Chordeiles minor* ssp	X		X	X
Nuttall Poor-will *Phalaenoptilus nuttallii nuttallii* (Audubon)	X	X		X
Western White-throated Swift *Aëronautes saxatalis saxatalis* (Woodhouse)	X	X		
Broad-tailed Hummingbird *Selasphorus platycercus platycercus* (Swainson)	X	X		X
Rufous Hummingbird *Selasphorus rufus* (Gmelin)	X			
Arkansas Kingbird *Tyrannus verticalis* Say	X	X	X	X
Ash-throated Flycatcher *Myiarchus cinerascens cinerascens* (Lawrence)	X	X		
Say Phoebe *Sayornis saya saya* Bonaparte	X	X		X
Great Salt Lake Horned Lark *Otocoris alpestris utahensis* Behle	X	X	X	X
Violet-green Swallow *Tachycineta thalassina lepida* Mearns	X	X		
*Barn Swallow *Hirundo rustica erythrogaster* Boddaert			X	
American Magpie *Pica pica hudsonia* (Sabine)				X
American Raven *Corvus corax sinuatus* Wagler	X	X	X	X
Piñon Jay *Cyanocephalus cyanocephalus* (Wied)				X
Rock Wren *Salpinctes obsoletus obsoletus* (Say)		X		X
Western Mockingbird *Mimus polyglottos leucopterus* (Vigors)			X	X
Sage Thrasher *Oreoscoptes montanus* (Townsend)	X	X	X	X
Mountain Bluebird *Sialia currucoides* (Bechstein)				X
Western Gnatcatcher *Polioptila caerulea amoenissima* Grinnell				X
Great Basin Shrike *Lanius ludovicianus nevadensis* Miller	X	X	X	X

	Shad-scale	Tetra-dymia	Grease-wood	Sage-brush
BIRDS				
*Yellow Warbler				
Dendroica aestiva ssp.			X	
*Northern Audubon Warbler				
Dendroica auduboni ssp.			X	
*Western Yellow-throat				
Geothlypis trichas occidentalis Brewster			X	
*Long-tailed Chat				
Icteria virens auricollis Bonaparte			X	
English Sparrow				
Passer domesticus domesticus (Linnaeus)	X			
Yellow-headed Blackbird				
Xanthocephalus xanthocephalus (Bonaparte)	X		X	
Red-winged Blackbird				
Agelaius phoeniceus ssp.	X		X	
Brewer Blackbird				
Euphagus cyanocephalus cyanocephalus (Wagler)	X	X	X	X
Nevada Cowbird				
Molothrus ater artemisiae Grinnell	X		X	
House Finch				
Carpodacus mexicanus ssp.	X			
Pale Goldfinch				
Spinus tristis pallidus Mearns	X	X		
Green-tailed Towhee				
Oberholseria chlorura (Audubon)			X	X
Lark Bunting				
Calamospiza melanocorys Stejneger	X		X	
*Nevada Savannah Sparrow				
Passerculus sandwichensis nevadensis Grinnell			X	
Western Vesper Sparrow				
Pooecetes gramineus confinis Baird	X	X	X	X
Western Lark Sparrow				
Chondestes grammacus strigatus Swainson	X	X		X
Desert Black-throated Sparrow				
Amphispiza bilineata deserticola Ridgway	X	X	X	X
Northern Sage Sparrow				
Amphispiza belli nevadensis (Ridgway)	X	X	X	X
Western Chipping Sparrow				
Spizella passerina arizonae Coues	X	X		X
Brewer Sparrow				
Spizella breweri breweri Cassin	X	X	X	X
White-crowned Sparrow				
Zonotrichia leucophrys ssp.	X	X	X	X
Slate-colored Fox Sparrow				
Passerella iliaca schistacea Baird				X
*Song Sparrow				
Melospiza melodia ssp.			X	
REPTILES				
Collared Lizard				
Crotaphytus collaris baileyi (Stejneger)		X		
Leopard-lizard				
Crotaphytus wislizenii Baird & Girard	X	X	X	X
Brown-shouldered Uta				
Uta stansburiana stansburiana (Baird & Girard)	X	X	X	X
Sagebrush Lizard				
Sceloporus graciosus graciosus (Baird & Girard)			X	X
Desert Horned-toad				
Phrynosoma platyrhinos Girard	X	X	X	X
Whip-tail Lizard				
Cnemidophorus tessellatus tessellatus (Say)	X	X	X	X
Striped Racer				
Coluber taeniatus taeniatus (Hallowell)	X	X	X	X
Gopher-snake				
Pituophis catenifer deserticola Stejneger	X	X	X	X
Long-nosed Snake				
Rhinocheilus lecontei Baird & Girard	X			
Rattlesnake				
Crotalus viridis lutosus (Klauber)	X	X	X	X

APPENDIX B

Distributional list of identified invertebrates collected in quantitative samples.

	Shad-scale	Tetra-dymia	Grease-wood	Sage-brush
ARANEIDA				
Argiopidae—				
Araneus carbonarius (C. Koch)	X	X		
Araneus sp.	X		X	
Metepeira foxi Gertsch & Ivie	X	X	X	
Metepeira sp.		X	X	X
Dictynidae—				
Dictyna reticulata Gertsch & Ivie			X	X
Dictyna sp.	X	X	X	
Oxyopidae—				
Oxyopes rufipes Banks		X	X	X
Salticidae—				
Dendryphantes sp.	X		X	X
Evarcha hoyi (Peckham)	X		X	
Habrocestum sp.			X	
Icius sp.				X
Pellenes sp.	X	X	X	X
Phidippus formosus Peckham			X	
Phidippus sp.		X	X	X
Sassacus papenhoei Peckham			X	
Titanebo sp.		X		
Theridiidae—				
Euryopsis scriptipes Banks			X	
Thomisidae—				
Misumenops celer (Hentz)	X	X	X	
Misumenops sp.	X	X	X	
Philodromus virescens Thorell			X	X
Philodromus sp.	X		X	X
Xysticus cunctator Thorell				X
Xysticus sp.			X	X
ACARINA				
Caeculidae—				
Caeculus nigripes Bks.	X	X		
Erythraeidae—				
Atomus arvensis Bks.	X	X		X
Atomus lepidonotus Bks.	X			
Erythraeus sp.	X	X	X	
Tetranychidae—				
Bryobia praetiosa Koch		X	X	
Trombibiidae—				
Trombidium sp.			X	
COLLEMBOLA				
Deuterosminthurus sp.		X		
Sminthurus sp.	X	X		
ORTHOPTERA				
Acrididae—				
Aeoloplus tenuipennis tenuipennis Scudder	X	X	X	
Melanoplus complanatipes canonicus Scudder				X
Melanoplus mexicanus mexicanus (Saussure)				X
Melanoplus sp.		X	X	X
Trimerotropis gracilis gracilis (Thomas)				X
Trimerotropis pallidipennis pallidipennis (Burm.)	X			X
Xanthippus lateritius Saussure	X	X		
THYSANOPTERA				
Anaphothrips sp.		X		
Frankliniella occidentalis Perg.		X		
Thrips sp.			X	

	Shad-scale	Tetra-dymia	Grease-wood	Sage-brush
HEMIPTERA				
Anthocoridae—				
Orius tristicolor (White)	X	X	X	X
Corizidae—				
Corizus viridicatus Uhler				X
Lygaeidae—				
Geocoris sp.			X	
Nysius californicus Stal	X	X	X	
Nysius ericae (Schilling)		X		
Miridae—				
Adelphocorus superbus Uhl.		X	X	
Chlamydatus uniformis Uhl.				X
Europiella decolor (Uhl.)				X
Europiella sp.				X
Lopidea (n. sp.)				X
Lygus elisus Van D.		X		X
Lygus sp.		X		
Megalopsallus rubropictus Kgnt.			X	
Megalopsallus sp.		X	X	
Parhenicus sp.			X	
Phyllopidea sp.	X			
Psallus pictipes (Van D.)		X	X	
Psallus sp. (No. 1)	X	X	X	
Psallus sp. (No. 2)		X		
Rhinacloa forticornis Reut.			X	
Sthenarus humeralis Van D.			X	
Strongylocoris (n. sp.)	X	X		X
Tuponia sp.				X
Nabidae—				
Nabis alternatus Parshley	X	X	X	X
Pentatomidae—				
Chlorochroa sayi Uhl.			X	
Thyanata custator (Fabr.)				X
Thyanata rugulosa (Say)			X	X
Piesmidae—				
Piesma depressa McAtee			X	
Piesma explanata McAtee			X	X
Reduviidae—				
Sinea sp.			X	X
Zelus socius Uhl.			X	
HOMOPTERA				
Aphididae—				
Aphis bonnevillensis Knlt.			X	
Epameibaphis frigidae (Oest.)	X			
Cercopidae—				
Clastoptera brunnea Ball				X
Chermidae—				
Paratrioza cockerelli (Sulc.)		X		
Cicadellidae—				
Aceratagallia cinerea (O. & B.)	X	X		
Acinopterus sp. (No. 1)			X	
Acinopterus sp. (No. 2)				X
Athysanus frigidus Ball				X
Ballana sp.				X
Ceratagallia artemisia Oman	X	X		X
Ceratagallia dondia (Oman)		X	X	
Empoasca nigra typhlocyboides G. & B.				X
Empoasca sp. (*nigra* group)		X	X	X
Empoasca sp. (*aspersa* group)			X	X
Errhomus aridus (Ball)	X	X		X
Eutettix insanus Ball	X			
Eutettix tenellus (Baker)	X		X	
Exitianus obscurinervis (Stal.)	X	X		X
Nesosteles neglectus (DeL. & D.)		X	X	
Norvellina clarivada (Van D.)			X	
Ophiola clavata (Ball)			X	X
Xerophloea viridis (F.)				X
Cicadidae—				
Neoplatypedia constricta Dan's				X
Platypedia lutea Dan's			X	

	Shad-scale	Tetra-dymia	Grease-wood	Sage-brush
Coccidae—				
Orthezia sp. (near *artemisiae*)	X		X	
Fulgoridae—				
Deserta bipunctata Ball	X			X
Hysteropterum cornutum Mel.			X	X
Oecleus fulvidorsum Ball	X			
Oeclidius nanus Van D.		X		
Oliarus sp.			X	
Orgerius minor Ball	X			
Scolops uhleri marginatus Ball	X		X	
Membracidae—				
Enchenopa permutata Van D.			X	
Psyllidae—				
Aphalara sp.				X
COLEOPTERA				
Anthicidae—				
Anthicus sp.	X		X	X
Chrysomelidae—				
Chaetocnema sp.				X
Monoxia sp.	X	X	X	X
Pachybrachis sp.	X	X	X	X
Phyllotreta sp.			X	X
Cleridae—				
Hydnocera discoidea Lec.	X			
Hydnocera scabra Lec.	X		X	X
Hydnocera sp.		X		
Coccinellidae—				
Exochomus septentrionis Ws.	X			
Hippodamia apicalis Csy.				X
Hippodamia convergens Guer.			X	
Hippodamia sp.				X
Hyperaspis fastidiosa Csy.			X	
Hyperaspis fimbriolata (Melsh)				X
Hyperaspis lateralis montanica Csy.				X
Hyperaspis pleuralis aterrima Csy.	X			
Hyperaspis taeniata Lec.				X
Hyperaspis sp.			X	
Scymnus sp.				X
Curculionidae—				
Apion sordidum Smith				X
Cercopeus artemisiae Pierce		X		X
Eupagoderes varius Lec.	X	X		
Promecotarsus densus Csy.				X
Dermestidae—				
Cryptorhopalum sp.			X	
Meloidae—				
Epicauta maculata (Say)				X
Melyridae—				
Attalus sp.	X		X	X
Dasytastes ruficollis (Ulke)	X	X		
Listrus sp.		X	X	X
Trichochrous sp.		X	X	
Mordellidae—				
Mordellistena commata Lec.			X	
Mordellistena aspersa Melsh	X			
LEPIDOPTERA				
Coleophoridae (Pupae)		X		X
Ethmiidae (Larvae)		X		
Gelechiidae (Larvae)	X		X	
Geometridae (Larvae)			X	X
Olethreutidae (Larvae)		X	X	
Phalaenidae (Larvae)			X	
Pterophoridae (Larvae)				X
Pyraustidae (Larvae)		X		
DIPTERA				
Agromyzidae—				
Agromyza sp. (*virens* Lw. group)			X	
Agromyza sp.	X		X	
Leucopis sp.	X		X	

	Shad-scale	Tetra-dymia	Grease-wood	Sage-brush
DIPTERA				
Anthomyiidae—				
Hylemya sp.		X	X	
Asilidae—				
Cyrtopogon sp.				X
Bombyliidae—				
Geron sp. (No. 1)	X	X	X	X
Geron sp. (No. 2)				X
Mythicomyia sp.				X
Ceratopogonidae—				
Culicoides variipennis (Coq.)			X	
Chironomidae—				
Spaniotoma sp.			X	
Chloropidae—				
Madiza sp.		X		
Oscinella sp.	X	X	X	
Culicidae—				
Aedes sp.			X	
Drosophilidae—				
Scaptomyza graminum Fallén			X	
Empididae—				
Drapetis sp.	X		X	
Ephydridae—				
Hydrellia sp.		X	X	X
Otitidae—				
Euxesta nitidiventris Lw.	X	X	X	X
Euxesta (Probably new species)	X	X	X	
Rhagionidae—				
Chrysopilus sp.		X		
Sapromyzidae—				
Caliope variceps (Cog.)	X			
Sarcophagidae—				
Eumacronychia sp.?		X		
Scenopinidae—				
Scenopinus sp. (near *nubilipes* Say)	X		X	
Scenopinus sp.			X	
Tachinidae—				
Plagia americana Coq.			X	
Zenillia sp.			X	
Trypetidae—				
Trypanea abstersa Lw.			X	
Trypanea sp.		X		

	Shad-scale	Tetra-dymia	Grease-wood	Sage-brush
HYMENOPTERA				
Callimomidae—				
Callimome sp.		X		
Chalcididae—				
Haltichella sp.		X		
Elachertidae—				
Elachertus sp.				X
Encyrtidae—				
Anagyrus sp.	X		X	
Chalcaspis phenacocci Ashm.			X	X
Copidosoma sp.			X	
Eulophidae—				
Euderus sp.			X	
Eurytomidae—				
Eurytoma sp.			X	
Rileya sp.		X		
Halictidae—				
Halictus (*Chloralictus*) *sparsus* Robt.	X			
Microgasteridae—				
Halticoptera sp.			X	X
Pteromalidae—				X
Scelionidae—				
Leptacis sp.		X		
Platygaster sp.		X	X	X
Tetrastichidae—				
Tetrastichus sp.			X	
Formicidae—				
Camponotus (*Myrmentoma*) sp.			X	X
Crematogaster (*Acrocoelia*) sp.	X	X		
Dorymyrmex pyramicus (Roger)	X	X		
Formica fusca L. var.			X	
Formica manni Whlr.			X	
Formica neogagates Emery			X	
Formica neogagates lasioides var. *vetula* Whlr.			X	
Formica obtusopilosa Emery			X	X
Formica sp.				X
Iridomyrmex sp.				X
Leptothorax rugatulus Emery			X	
Leptothorax (n. sp.)	X	X		
Monomorium minimum (Buckley)			X	X
Myrmecocystus mexicanus navajo Whlr.	X	X		
Myrmecocystus sp.	X	X		
Tapinoma sessile (Say)		X	X	

impervious integument of the reptiles; by the lack of sweat glands in birds; and the profuse secretion by oil glands in the kangaroo rats. Conservation of water is facilitated by the excretion of the waste materials from the kidneys in the form of uric acid in insects, reptiles, and birds, and by effective reabsorption of water in the renal papilla of kangaroo rats. The majority of the mammals are nocturnal, and remain within burrows during the day in a microclimate which is less conducive to water losses from their body surfaces. The diurnal animals become less active during the hotter hours of the day and even some of the nocturnal species such as the kangaroo rats and honey ants were found to delay their time of emergence from their burrows until later hours of the night as daily summer temperatures increased.

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