RODENT POPULATIONS AND THEIR REACTIONS TO GRAZING INTENSITIES ON SAND SAGEBRUSH GRASSLANDS IN THE SOUTHERN GREAT PLAINS REGION

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Master of Science

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Syracuse, New York

1940

Submitted to the Faculty of the Graduate School of

the Oklahoma Agricultural and Mechanical College

in Partial Fulfillment of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

1950

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INTRODUCTION

Ecology may be defined as the science of the interrelation between living organisms and their environment, including both the physical and the biotic phases. In the realm of biological sciences probably no field, or concept of thought, has advanced as rapidly in the past twenty-five years as ecology. In ecological thinking we attempt to comprehend the entire organic unit with all its components as well as the influences of the inorganic world. Too often the task is beyond our capabilities but occasionally the panorama of unity is glimpsed, and these previews provide the stimuli for continued work in the field. It is hoped that this dissertation will become a part of the panorama.

The present treatise deals with rodent and rabbit populations on the sand sagebrush grasslands of the Southern Great Plains, with particular reference to the Southern Great Plains Experimental Range near Supply, Oklahoma. The primary objective of the work was to determine the species and populations of rodents and rabbits in a number of pastures, each of which has been under a different grazing program since December, 1941. Secondary objectives were to compare the populations in the various pastures, and to compare the data obtained in these investigations with data obtained in 1940 and 1941—prior to and immediately after the initiation of the grazing management programs.

The Southern Great Plains Experimental Range is under the jurisdiction of the United States Southern Great Plains Field Station, Bureau of Plant

Industry, Soils, and Agricultural Engineering, United States Department of Agriculture, Woodward, Oklahoma.

The work was performed from September, 1949, to February, 1950, a period of five months when full time was spent on the project. Additional field trips, from a single day to a week in length, were made from October, 1948, to May, 1950, to verify data or to investigate some particular phase of the work.

The Southern Great Plains Region includes about 130 million acres south of the Nebraska-Kansas and Wyoming-Colorado borders. It extends from the eastern slope of the Rocky Mountains in Colorado and New Mexico to about the 98th meridian in Kansas and Oklahoma. The boundary swings southwest in Texas to the southern border of New Mexico and includes the Texas Panhandle and adjacent areas of western Texas and eastern New Mexico (Fig.1). The region includes about a third of the area of the five states mentioned. It is a range country, with scattered dry-land farms, some irrigated areas, and during and after the great drought of the 1930's became a portion of the Dust Bowl. The drought emphasized the unwisdom of straight wheat production in the region, which had resulted from the first World War. A detailed study of the erosion problems in the Southern Great Plains has been made by Finnell (1939). Today much of the range land has again been diverted to wheat farming and only requires another severe drought to recreate the Dust Bowl. The climate of the region is marginal for farm crops and the area should essentially be range lands. The general aspect is a fairly level plain with shallow drainage channels often interspersed with rolling lands or steep broken areas. The principal rivers flow east or southeastward. Most of the region slopes gently from elevations of 5-6000 feet on the west to 2,000 feet or less on the east and south. The climate is exceedingly variable from month to month and year to year. Rainfall is comparatively light and infrequent, humidity is low, and there are high winds and rapid evaporation. The yearly precipitation, of which

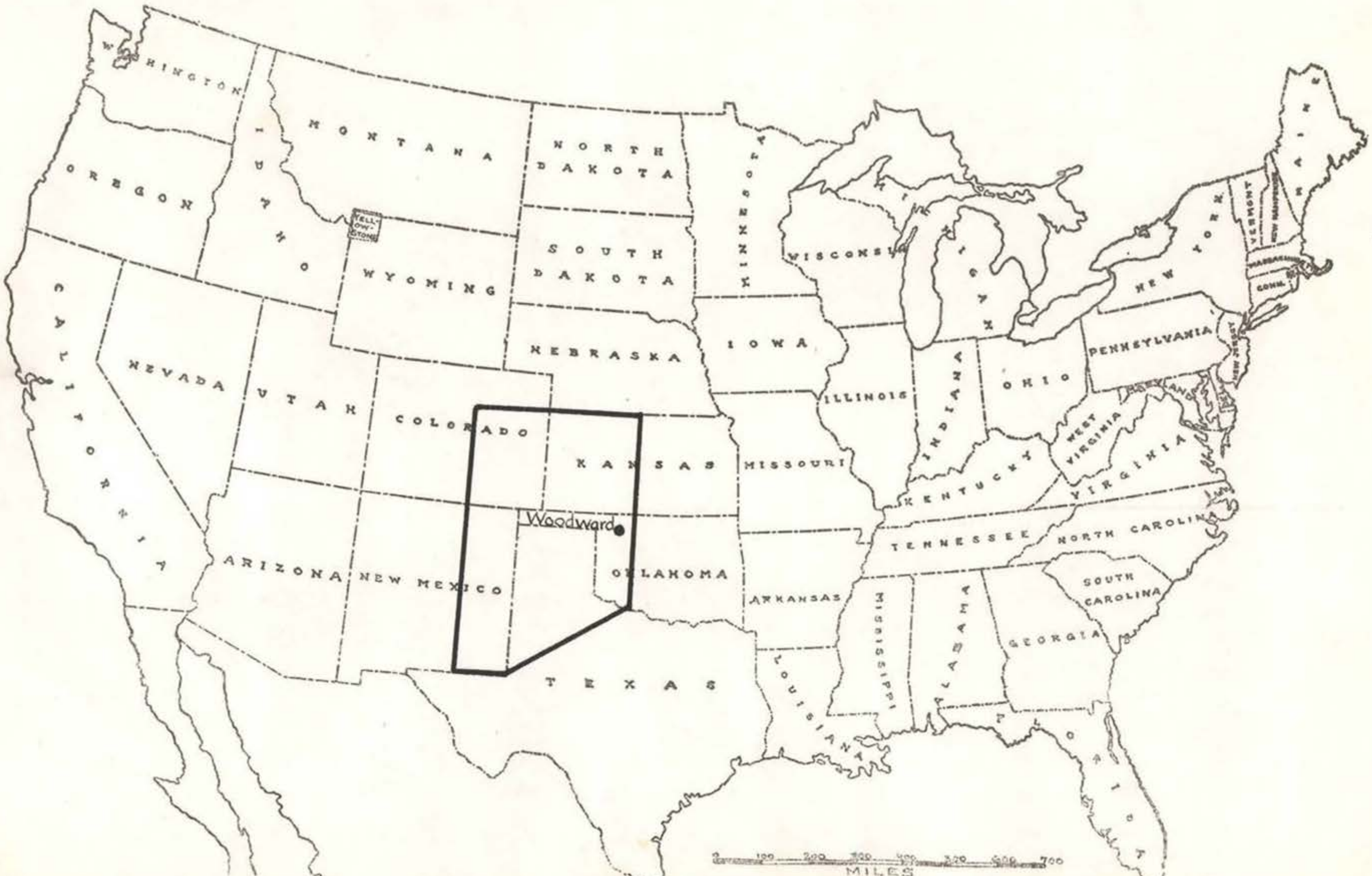

Fig. 1. Map of the United States showing the area of the Southern Great Plains Region and the location of Woodward, Oklahoma. Taken from "Grass, the Yearbook of Agriculture for 1948" (Savage, Costello 1948, p. 504).

about two-thirds falls during the active growing period, ranges from 10 to 17 inches in the west to 20 or more in the east. Much of the rainfall occurs either in torrents or light, ineffective showers; often hot weather and high winds further reduce the effectiveness of the rainfall. Drought periods, that occur periodically and which may occur nearly every year and last for several seasons or years, make dry-farming hazardous. The winters are generally mild with infrequent showers or severe snowstorms, and sharp fluctuations in temperature. The average yearly temperature ranges from 50 degrees in the north to 65 degrees in the south, with a summer mean usually above 70 degrees. The annual temperature variation may extend from 118 degrees to -30 degrees F. The frost-free season varies from 125 days on the higher slopes of Colorado to 200 days at the lower elevations in the southeast. The soils range from dune sand to heavy clay with the heavy, semi-heavy, and sandy soils adapted for cultivation and the loose sandy soils, heavy clays, and rough-broken land suitable for range. Savage and Costello (1948, pp. 503-506) have given a detailed description of the region.

The Southern Great Plains Region is outstanding in the production of feeder cattle which are fed on native grass alone, or with a limited supply or protein concentrates. Yearlong grazing of range land is a common practice in most of the region, especially with breeding herds. The cattle population on January 1, 1947, was eight per cent above the previous ten-year average (<u>loc</u>. <u>cit</u>. 1948, p. 504). This large population is certain to result in damage to the range resources in the event of drought unless supplements are provided.

Sand sagebrush grasslands of which there are about 600,000 acres in Oklahoma and 6,400,000 acres in Texas (Allred 1948, p. 4), constitute an important portion of the range lands in the Southern Great Plains and the condition, improvement and proper use of these lands are essential to the economics of the region. It is therefore proper that investigations be made of every sort of ecological problem on sand sagebrush grasslands. The Southern Great Plains Field Station has numerous experiments in process on the proper control and management of these ranges, and the investigations presented herein can be considered a part of this overall program to determine and improve proper range use.

Profound gratitude is expressed to Dr. Walter P. Taylor, Biologist, United States Fish and Wildlife Service, and Leader, Oklahoma Cooperative Wildlife Research Unit, under whose supervision the investigations were conducted. Grateful acknowledgement is extended also to D. A. Savage, Superintendent, and E. H. McIlvain, Range Ecologist, of the Southern Great Plains Field Station, United States Department of Agriculture, for their helpful suggestions and permission to use the facilities of the Station's Experimental Range at Supply, Oklahoma. Professor U. T. Waterfall, Botany Department, Oklahoma Agricultural and Mechanical College, assisted in identifying the flora of the area, as did various staff members of the Southern Great Plains Field Station. The identification of mammal species was checked by Professor Bryan P. Glass, Zoology Department, Oklahoma A. & M. College. Thanks are also extended to my colleagues, faculty members of the Oklahoma A. & M. College, and various personnel of the Soil Conservation Service, United States Department of Agriculture, who have given suggestions during the course of the study.

SUMMARY OF RESULTS OF PREVIOUS INVESTIGATIONS

A detailed summarization of literature on range rodents would result in a voluminous manuscript as there are numerous publications pertaining to these species. Most of the research, as reported in the literature, has been directed toward taxonomy and life histories studies. The excellent publication on the California ground squirrel, *Citellus beecheyi* (Richardson), by Linsdale (1946) is an example of one of the more detailed life history studies. An annotated bibliography of ecological life histories of range rodents, compiled by the writer at the Oklahoma Cooperative Wildlife Research Unit, Oklahoma Agricultural and Mechanical College, consisted of 94 references and these included only the major works available at the institution. Although the importance of a thorough literature review of range rodents is recognized, it is beyond the scope of this treatise, and only publications which are directly concerned with rodents and grasslands have been included.

One of the earliest works concerned with influences of rodents on the range was the study of the life history of the banner-tailed kangaroo rat, *Dipodomys spectabilis spectabilis* Merriam, by Vorhies and Taylor (1922). The studies were performed in New Mexico and Arizona, and the major objective was to determine the economic status of the banner-tailed kangaroo rat with reference to range forage. Emphasis was placed on den storage and dens were excavated and the stores measured qualitatively and quantitatively. Storage in each den varied from five grams (about 0.16 ounces) to 5,750 grams (12.67 pounds). Materials included several important forage plants of *Bouteloua* and Aristida, with B. rothrockii Vasey the most important species. Accessibility and abundance of plants had much to do with kinds of storage. It was concluded that the banner-tailed kangaroo rat was not of great economic importance, except locally, in ordinary seasons. During periods of extreme drought these animals could seriously affect the carrying capacity of a range for livestock.

Another publication, which was probably the first directed research in reference to a rodent species and its influence on range forage, was the study of damage to range grasses by the Zuni prairie dog, Cynomys gunnisoni zuniensis Hollister, by Taylor and Loftfield (1924). The procedure of the experiment was to either fence in the prairie dogs on a heavily infested area, or to permit free entry of prairie dogs while excluding cattle; to enclose a contiguous area of similar size, so that it could be held under total protection from cattle as well as prairie dogs; and by means of permanent quadrats to obtain quantitative information as to the vegetation actually destroyed under grazing (1) by prairie dogs alone and (2) by cattle alone (or cattle and prairie dogs together) in comparison with (3) the amount produced under total protection. The studies were performed on three different areas in Arizona in tall grass (wheat grass, Agropyron smithii Rydb.), short grass, and transition between Great Plains and Desert Grassland associations. Results of four years' experimentation in the tall grass showed that prairie dogs destroyed 69 per cent of the wheat grass and 99 per cent of the dropseed, Sporobolus cryptandrus (Torr.) A. Gray, or 80 per cent of the total potential annual production of forage. After one year, studies in short grass showed the rodents destroyed 83 per cent of the blue grama, B. gracilis (H.B.K.) Lag., crop, the most important forage grass of the region. The data demonstrated quite conclusively that in the region of the study prairie dogs were severe competitors of livestock for forage and that competition between rodents and livestock is greatly intensified during drought periods when the amount of forage is low.

Vorhies and Taylor (1933) made a study of the life histories and ecology of jack rabbits, Lepus alleni alleni Mearns and L. californicus eremicus (Allen), in relation to grazing in Arizona. Calculations indicated that 15 L. alleni ate as much valuable forage as one sheep, or 74 as much as one cow. The rabbit figures were doubled for L. californicus. In experimental plots on the Santa Rita Experimental Range jack rabbits were apparently responsible for holding the vegetation in a preclimax condition. Stomach analyses showed that 36 per cent of the food eaten by L. alleni was mesquite, and 45 per cent grasses; and for L. californicus, 56 per cent mesquite and 24 per cent grasses. It was estimated that jack rabbits consumed less than three per cent of the potential production of grass on the Santa Rita Range.

Further studies of jack rabbits in relation to grazing in Arizona were made by Taylor, Vorhies, and Lister (1935). Jack rabbit pellet counts were made in an area grazed during the summer and with a relatively small volume of grass; an area practically ungrazed and with a large volume of grass; and an area grazed continuously and with the least amount of grass. The data showed that jack rabbits preferred heavily grazed areas rather than ungrazed or lightly grazed areas. The preference may be due to a visibility factor or to vegetative composition as weeds were more numerous in the overgrazed area. It was pointed out that when overgrazing goes so far that very little valuable forage is left, then jack rabbit numbers decline.

Norris (1948, 1950) has reported on the results of exclosure studies in Black Grama Grassland and Mesquite-Snakeweed Type on the Jornada Experimental Range and the Southwestern Forest and Range Experiment Station, and the Experimental Ranch of the New Mexico College of Agriculture and Mechanic Arts, Las Cruces, New Mexico. In the Black Grama Grassland exclosures were made which (1) excluded rodents, rabbits, and cattle; (2) excluded cattle and rabbits but open to rodents; (3) excluded cattle but open to rodents and rabbits; and (4) open to rodents, rabbits, and cattle. Clip quadrats were run in each of the exclosures in 1940, 1941, 1942, 1947, and 1948 and the perennial grasses including black grama, B. eriopoda Torr., dropseed, Sporobolus sp., and threeawn, Aristida sp., were weighed. The yields of grasses showed no indication of beneficial results due to protection from rodents and rabbits. In the overgrazed Mesquite-Snakeweed Type exclosures were made which (1) excluded rodents and rabbits, (2) excluded rabbits and open to rodents, and (3) open to rodents and rabbits. Cattle were not included in the latter study. The results from quadrats on which the perennial grasses were clipped showed that rodents and rabbits can exert sufficient grazing pressure to hold deteriorated sites in a state of limited production indefinitely, even though the range is not used by cattle. It was concluded that rodent and rabbit control in good black grama grassland produced no benefits, and that benefits of extra forage from controlling rodents and rabbits even in deteriorated range would not balance control costs.

Fitch (1948a) has completed intensive studies of the California ground squirrel, Citellus beecheyi fisheri Merriam, on the San Joaquin Experimental Range, Madera County, California. Field observations and feeding of confined animals revealed that the average daily green food required per squirrel was 70 grams or about 4.7 pounds per month. By census methods the breeding population was determined as 2.3 squirrels per acre (based on five-year average), and the squirrels consumed approximately 10.8 pounds of green forage per acre each month during the late winter and spring when most direct competition with livestock occurred. Grass was but a small fraction of the diet, amounting to but 14.2 per cent in May and 3 per cent or less in all other months. The annual forb, broadleaf filaree, Erodium botrys Bertol, was the most important source of food based on 51,755 separate food items squirrels were observed to eat. Oak acorns were second in importance followed by yellow tarweed, Hemizonia virgata Gray. From enclosure studies it was concluded (loc cit., p. 529): ". . . that squirrel use in the population density of 12 per acre does not harmfully alter the composition of the forage crop, which shows only light utilization; that the annual forage yield under this degree of use is decreased, apparently in the neighborhood of one thousand pounds per acre; and that the quantity actually eaten by the squirrels is much less than that otherwise eliminated by them." The quotation is more pertinent when one considers that the normal breeding population was but 2.3 squirrels per acre.

From 1938 to 1942, inclusive, and in 1946, Fitch (1948) studied the Tulare kangaroo rat, Dipodomys heermanni tularensis (Merriam) on the San Joaquin Experimental Range, California, to ascertain the extent of competition between this species and livestock. Feeding data were obtained from cheek pouch contents of trapped animals, burrow caches, and siftings of discarded seed hulls from burrow mounds. Throughout the dry season, seeds of soft chess, Bromus mollis L., were the most important food, with foxtail fescue, Festuca megalura Nutt., filaree, E. botrys and E. cicutarium L'Her., and red brome, B. rubens L., following in that order. In winter the diet changed from seeds to green foliage material, mainly filaree. Fitch states (loc. cit., p. 15): ". . . that on California ranges of annual type forage (mixed filaree, soft chess, red brome, and foxtail fescue) heavy grazing intensity is economical and does not result in an undesirable alteration of the forage composition." (The inference apparently being that any forage loss by rodents was a direct loss of cattle forage.) Rainfall is uncertain on these ranges and hence some years little forage develops and the ranges become overstocked. At such times Fitch believes competition between livestock and rodents is intensified and a high kangaroo rat population may take a substantial portion of the short forage crop and cause heavy financial loss. Feeding experiments indicated that the annual food requirements of a kangaroo rat are about four pounds, dry weight, per acre. Eight kangaroo rats kept in a one-fourth acre enclosure (representing a population of 32 per acre) consumed 128 pounds of food in a year. This amount was but a small percentage of the usual forage crop and would have little effect on livestock production. Comparison of forage production within and outside the enclosure however showed the yield from the former was considerable less than from the outside control. The population of 32 kangaroo rats per acre reduced the yield 13.1 to 15.5 per cent of the total, during the growing season of about seven months. The reduction was three times as much as the animals could have eaten and was evidently caused by stunting of vegetation by eating plants early in the growing season, cutting and discarding portions of plants, and storing underground vegetation not used for food. All of these effects would be less important on open range. The most important effect of the kangaroo rats on the range, as determined by Fitch, was that during the growing season most of the principal forage species used by livestock also provided most of the food of the kangaroo rat.

Tappe (1941) made intensive studies of the Tulare kangaroo rat, Dipodomys heermanni tularensis (Merriam), in San Joaquin and San Benito Counties, California. Both study areas were heavily grazed by sheep and, although the kangaroo rats often noticeably depleted the vegetation along surface runways and burrow entrances, it appeared that the grazing and trampling effects of the sheep were the major factors in holding the areas in their low carrying capacities. During food shortages kangaroo rats, by cutting green vegetation and harvesting seeds, might affect the carrying capacity of an area for livestock enough to make the rats of adverse economic importance, but this is unlikely to occur on a properly grazed range. Cultivated crops grown adjacent to, or surrounded by, uncultivated areas of good kangaroo rat habitat may be damaged. Harmful effects of the Tulare kangaroo rat may be counter-balanced by its eating insects, particularly grasshoppers.

A study of range rodents in enclosures was made in the California annual forage type on the San Joaquin Experimental Range, California, by Fitch and Bentley (1949). Stockings in the enclosures were as follows: ½-acre pen, six ground squirrels; ¼-acre pen, eight pocket gophers; ¼-acre pen, eight kangaroo rats; and ½-acre pen, control. The rodent species were the California ground squirrel, Citellus beecheyi fisheri Merriam; pocket gopher, Thomomys bottae (Eydoux and Gervais); and the kangaroo rat, Dipodomys heermanni tularensis (Merriam). Stocking was about equal to maximum populations on favorable habitats and was several times greater than usual average populations for all sites on the range. Selective use of the plant species by the rodents had little effect on plant composition. The study showed high potential destructiveness for all three rodent species. Average amounts of herbage crops eliminated by the end of the green-forage season were: ground squirrels, 35 per cent; pocket gophers, 25 per cent; and kangaroo rats, 16 per cent. The actual estimated food consumption was less than ten per cent of the vegetation eliminated in each pen. The bulk was eliminated by stunting vegetation, cutting and discarding, trampling, and covering with soil. Competition between rodents and livestock was much more important during the green-forage season than during the dry-forage season. If each animal were to destroy herbage at the same rate as in the pens, a typical population of the three species could account for one-third or more of the annual forage crop. However, this does not occur for the amount destroyed by an individual rodent would be less where the different kinds of rodents were in competition with each other and with livestock for the use of the herbage, and where the vegetation was more closely grazed than in the pens.

Phillips (1936), working in Cleveland and McClain Counties, Oklahoma, compared populations of jack rabbits, Lepus californicus melanotis Mearns; cottontail rabbits, Sylvilagus floridanus alacer (Bangs); pocket gophers, Geomys breviceps llanensis Bailey; striped ground squirrels, Citellus tridecemlineatus texensis (Merriam); prairie deer-mice, Peromyscus maniculatus ssp. (probably an intergrade between P. maniculatus bairdi (Hoy and Kennicott) and P. maniculatus nebrascensis (Coues)); and cotton rats, Sigmodon hispidus texianus (Audubon and Bachman) in undisturbed areas, mowed hayfields, moderately overgrazed pastures, and heavily overgrazed pastures. Pellet counts indicated jack rabbits were most abundant in moderately overgrazed pastures and cottontails preferred the undisturbed grasslands. Mound counts showed pocket gophers more numerous in mowed hayfields and moderately grazed pastures, than in either heavily overgrazed or undisturbed areas. Ground squirrels occurred more often in mowed hayfields. Trapping showed deer-mice most numerous in moderately overgrazed grasslands and cotton rats were almost entirely restricted to undisturbed areas with abundant grass.

Trowbridge (1941) of the Fish and Wildlife Service, United Stated Department of Interior, began rodent and rabbit studies in Sand Sagebrush Grasslands on the Southern Great Plains Experimental Range near Supply, Oklahoma, in 1940. The objectives of the studies were to determine the rodent species and populations on the range, and the effects of rodents and rabbits on forage valuable to livestock. Trapping quadrats showed the small mammal population to be quite homogeneous on the vegetated sand dunes. Kangaroo rats, Dipodomys ordii richardsoni (Allen), and cottontail rabbits, Sylvilagus floridanus llanensis Blair, were considered very numerous; grasshopper mice, Onychomys leucogaster breviauritus Hollister, moderately numerous; wood rats, Neotoma micropus micropus Baird, and jack rabbits, Lepus californicus melanotis Mearns, numerous; pocket gophers, Geomys lutescens major Davis, common; and prairie deer-mice, Peromyscus maniculatus spp. (Wagner), and harvest mice, Reithrodontomys montanus griseus Bailey, rare. The abundance of kangaroo rats, pocket gophers and grasshopper mice seemed to be controlled by soil texture, cottontails and wood rats by cover, and jack rabbits by food. The average per acre populations of small rodents in late fall and early winter, based on trapping quadrats, was estimated as 25 kangaroo rats, 3 wood rats, 1 cottontail rabbit, 4 grasshopper mice, 1 pocket gopher, and 0.1 jack rabbits. Excluding pocket gophers the total rodent weight per acre was about 10.1 pounds, roughly 30 per cent of the estimated meat producing capacity of the land. (The data does not mean that rodents take 30 per cent of the feed which otherwise would be available for livestock as rodents consume large quantities of materials unavailable for stock; and, for much of their foods, are not in competition with livestock.)

In November and December of 1941, Trowbridge (1942) continued the rodent studies on the Southern Great Plains Experimental Range with similar objectives. It was found that populations of the smaller mammals had increased about 63 per cent over the 1940 populations, but jack rabbits, cottontail rabbits, and wood rats had decreased significantly. Per acre estimates of numbers on the sand dunes were: kangaroo rats, 36; grasshopper mice, 6; wood rats, 0.4; cottontail rabbits, 0.2; pocket mice, Perognathus flavus flavus Baird and P. hispidus paradoxus Merriam, 1; and cotton rats, Sigmodon hispidus texianus (Audubon and Bachman), 5. Despite the 63 per cent increase in total number of small rodents, the average weight per acre of rodents and rabbits altogether decreased 21 per cent from the 1940 level. The average food storage in dens by kangaroo rats declined about 50 per cent over 1940, and the amount of nest material decreased. Grasses formed 89.9 per cent of stored food materials, 96.9 per cent of nest materials, and occurred in over 60 per cent of kangaroo rat cheek pouches containing food. Certain plant species prominent in the foods of kangaroo rats in 1940 were barely represented in 1941. Hairy grama, Bouteloua hirsuta Lag., was found in 66 per cent of the cheek pouches containing food in 1940, but zero per cent in 1941. Sand dropseed, Sporobolus cryptandrus (Torr.) A. Gray, formed the bulk of the food caches and nest materials in 1941. During the year 1940-1941 no grazing occurred on the range and cotton rats increased in numbers; although none was taken from a continuously grazed control area.

In June of 1941 studies of a similar nature to those begun by Trowbridge were conducted on the Southern Great Plains Experimental Range by F. B. McMurry of the Fish and Wildlife Service (1942). With the limited data obtained, the following per acre small mammal populations were indicated on the sand sagebrush range: kangaroo rats, 8; cottontail rabbits, 0.5; grasshopper mice, 2; spotted ground squirrels, Citellus spilosoma major (Merriam), 0.25; Kansas pocket mice, 0.16; and jack rabbit, 0.05. No pocket gophers or wood rats were trapped. No species appeared to be of economic importance at the time the study was made. Food items in kangaroo rat cheek pouches showed they were feeding less heavily on the more important forage plants than they did the previous fall and winter. Weed seeds made up the bulk of the food material.

McMurry (1943) continued his studies in late May and early June of 1942. The data showed an increase in rodent numbers in all species over that of the June, 1941, level. He concluded that at this time there was little competition between kangaroo rats, pocket mice, and thirteen-lined ground squirrels, C. tridecemlineatus texensis (Merriam), and domestic livestock for valuable forage grasses and forbs. The insect destroying propensities of the spotted ground squirrel and grasshopper mouse tended to classify them as beneficial or neutral. The majority of the small rodents, exclusive of the kangaroo rats, were breeding at this time. The pastures on the range were opened to grazing in December, 1941, and since that time some differences in rodent numbers occurred, particularly with the cotton rat populations which decreased in the moderately and overgrazed pastures.

Cummings (1946) has reported on pocket gopher, Thomomys sp., studies on the Grand Mesa National Forest, Colorado. A series of four one-acre plots, replicated four times, were established as follows: (1) gophers and cattle present, (2) gophers present and cattle absent, (3) gophers absent and cattle present, (4) gophers and cattle absent. These treatments were accomplished by a combination of enclosure fences and rodent control (poisoning). Vegetative measurements and analyses, and interpretation of data thereon, were made by the Rocky Mountain Forest and Range Experiment Station, United States Forest Service, United States Department of Agriculture, Ft. Collins, Colorado. In 1941 gopher populations determined by complete trapping varied from 18.3 to 28 per acre. Data on populations for 1942 were obtained using six plots in each of three vegetative types. Populations in park-like areas were 25 to 35 per acre with an average of 30.5 for the 6 plots; in sagebrush type, 4 to 12 per acre with an average of 8.5 for the 6 plots; and in meadow land, 0.5 to 4 with an average of 2.3. Studies were made on the number of mounds of earth erected each day as an index to populations but this was found to vary considerably with seasonal variation in gopher activity and variations induced by rainfall, ground temperature and moisture, availability of food and of abandoned runways, and character of the soil. Extensive studies were made on the efficiency and costs of various controls, mainly poisoning. Control methods showed vegetable baits superior to grain baits but even with trained crews the cost was relatively high. The rodenticide 1080 dusted on vegetables such as sweet potatoes and carrots was very efficient. The average litter size was 3.5; the average ratio of females to males was 1.3 to 1; and the average ratio of immatures to adults was 1.3 to 1. Food habits as determined from items in cheek pouches of trapped animals showed forbs to be the preferred food, although a large number of items were not identified and some of these may have been grasses.

Doran (1948) has reported on the vegetative changes on the one-acre pocket gopher plots on the Grand Mesa National Forest, as described above under Cummings. Some of the tentative conclusions obtained were that pocket gophers did not affect plant vigor; plant density gained slightly when cattle were absent; weed density increased where pocket gophers were controlled, and decreased where present. The forage production was not materially increased by gopher control. The results showed that depleted range may require many years to recover even when completely protected from cattle and gophers, and gophers influence forage composition by utilization of weeds.

Studies of pocket gophers, Thomomys sp., in relation to range have been made on the Ochoco National Forest in Oregon by A. W. Moore of the Fish and Wildlife Service (Garlough 1937, pp. 305-306). Quarter-acre plots were protected and unprotected from the grazing of stock and game, with and without the presence of pocket gophers. The work was done from 1932 to 1937. In one of the study areas the sod had been destroyed by stock grazing and pocket gopher burrowing. Vegetative cover had been reduced to 0 to 30 per cent and erosion was occurring. On one plot in the absence of all grazing and pocket gophers, the density cover had reccovered from almost 0 to 30 per cent by 1936 and better sheep forage plants had returned. Another plot in a deteriorated area had a vegetative density of 2.5 per cent and grazing was permitted but gophers were excluded. By 1936 the density had increased to 20 per cent and again better sheep forage plants had returned. A third plot had a vegetative density of 20 per cent and grazing was excluded but gophers were present. During four years (1932-1936) the vegetative cover remained about the same in density but the vegetative composition was radically altered.

INFLUENCES OF RODENTS AND RABBITS ON RANGE LANDS

INTRODUCTION

The influences of rodents and rabbits on range lands have been presented as a separate section to show the complicated interrelationships of factors in an evaluation of the effects of rodents and rabbits on range lands. The information presented has been obtained from literature and field observations. The procedure has been to state a particular influence of rodents and/or rabbits on the environment and to give literature references thereto. No attempt has been made to evaluate the references or the importance of the influences; rather, the aim has been to point out that an individual influence does occur and should be considered in an evaluation of rodents and rabbits and range lands. Doubtlessly there are many influences not mentioned in this report but it is believed that all of the major ones recognized to date have been considered.

The influences of rodents and rabbits on range lands may be primarily divided into vegetative (effects on the plants) and edaphic (effects on the soil). Rodents and rabbits by their feeding, moving, storing, burrowing, nest building, and other activities exert influences on biotic communities which are frequently ignored and considered of little consequence. The diminutive size of these mammals is likely one of the salient reasons for the lack of recognition of their influences. One can readily see cattle in a pasture, but not the rodents and rabbits. Often the latter are underground as many are nocturnal and fossorial, others are resting in the shade under clumps of vegetation or in burrows, and some are actively working in vegetative cover too dense for human eyes to penetrate. The rodents and rabbits are present despite the lack of visible appearance and as the cattle are affecting the vegetation by trampling and feeding and the soil by defecation and urination, so are the rodents and rabbits affecting the grassland environment.

Probably the major factor in the magnitude of rodent and rabbit influences on range lands is their number. Many of them are small in size but abundant in numbers. Some of the data obtained in these investigations have indicated rodent populations of 60 or more individuals per acre—sixty individuals living, feeding, burrowing, breeding, defecating, trampling, and dying on a single acre of grassland. There is no doubt but that these individuals are influencing the environment.

VEGETATIVE

(1) Most rodents and rabbits directly reduce the amount of forage (leaves, flowers, and stalks) by feeding. All rodents living on range land feed to some extent on grasses and forbs, although the degree thereof varies with plant composition and species of rodent or rabbit. Vorhies and Taylor (1922) have indicated the foods of the banner-tailed kangaroo rat,[1] and (1933) the amount of forage consumed by jack rabbits. Bailey and Sperry (1929) have reported on the vegetative and animal foods of grasshopper mice based on stomach examinations and feeding of captive animals. Taylor and Loftfield (1924) by use of exclosures have demonstrated that the Zuni prairie dog destroyed 80 per cent of the potential forage in Wheat Grass Forage Type and 83 per cent in Blue Grama Type in Arizona. Buechner (1942) found that Brazos pocket gophers affected vegetation by feeding on roots in their burrows and by surface feeding on culms and blades of grasses. Cummings (1946) has shown from cheek pouch examinations that western pocket gophers eat forbs and grasses.

[1] Scientific names have been omitted in this section of the report and can be found in Appendix B.

Hawbecker (1947) determined the green forage consumption of the Nelson antelope ground squirrel. Fitch and Bentley (1949) by use of exclosures and captive animals have determined the amounts of forage consumed by the California ground squirrel, pocket gopher, and Tulare kangaroo rat.

(2) Seeds of plants are frequently preferred foods of rodents and rabbits and their feeding thereby reduces the number of seeds available for natural revegetation. Of the rodents feeding primarily on seeds the kangaroo rats are one of the most important, although all rodents feed on seeds to a greater or lesser extent. Trowbridge (1941) by examination of cheek pouches found grass seeds an important food item of the Richardson kangaroo rat. Tappe (1941) believed dry seeds were the most important food of the Tulare kangaroo rat and this was verified by Fitch (1948), by examination of cheek pouch contents and siftings from burrow mounds. Bailey (1939) found that the Pacific pocket mouse fed on, and stored, seeds. Linsdale (1946) has reported on seed eating by the California ground squirrel, and Cahalane (1947) has stated that most of the harvest mouse's diet consists of seeds.

(3) Storage of seeds, propagules, and aerial portions of plants by rodents reduces the amount of forage and the potential sources of natural revegetation. Grinnell and Dixon (1918) have given numerous examples of the storage ability of a number of species of the California ground squirrels. Shaw (1934) has made an extensive study of the ability of the giant kangaroo rat as a storer and harvester of seeds. Vorhies and Taylor (1940) have pointed out the ability of the white-throated wood rat to store seeds, roots, and stalks of grasses and forbs; and Spencer and Spencer (1941) have also contributed to the data on the storage propensities of this species. Trowbridge (1941) measured the food caches of leaves, seeds, and stalks of plains wood rats and Richardson kangaroo rats. Tyron (1947) has discussed the storage of bulbs, roots, and green leaves by pocket gophers and Scheffer (1931) has substantiated these activities for the entire western group of pocket gophers.

(4) Rodents eliminate forage by utilizing it for construction of nests, frequently underground. Bailey (1908) stated that the nest of the desert harvest mouse was of grass. Vorhies and Taylor (1940) found that the nest proper of the white-throated wood rat was mainly of grass. Shaw (1924) in studying the home life and (1925) the hibernation of the Columbian ground squirrel found their nests to be of grasses and forbs. Trowbridge (1941) analyzed the nests of plains wood rats and Richardson kangaroo rats to determine quantities and species of plants utilized. Brown (1946) has mentioned the use of grasses and forbs in nests of the Nebraska deer mouse, gray harvest mouse, prairie harvest mouse, western upland meadow mouse, and thirteen-lined ground squirrel.

(5) Rodents and rabbits are disseminators of germules which germinate, ecise and thereby alter the composition of the plant community. Hawbecker (1940) found grain seeds sprouting and growing in surface caches of Santa Cruz kangaroo rats. Brown (1946) found seedlings of buffalo grass, Buchloe dactyloides (Nutt.) Engelm., and cactus growing from caches of the thirteen-lined ground squirrel, and buffalo grass seedlings from the caches of the Nebraska deer mouse. Furthermore, Brown (1947) has shown that 12.75 pounds of sand dropseed, Sporobolus cryptandrus (Torr.) A. Gray, seeds were deposited in black-tailed jack rabbit pellets on an acre of Natural Revegetative Type, and that seeds of certain plant species had a higher viability after passing through the digestive tract of rabbits.

(6) Rodents and rabbits by their effects on the soil may produce a better growth of forage. Grinnell (1923) noted patches of green forage on deteriorated range as markers of western pocket gopher mounds. Hawbecker (1944) concluded that the cultivating action of the giant kangaroo rat increased the amount of red-stemmed filaree, Erodium cicutarium L'Her., and red brome grass, Bromus rubens L., more than five times. Fautin (1946) stated that the chisel-toothed and Ord kangaroo rats may influence the growth of plants by altering the soil

and found that kangaroo rat and western pocket gopher burrows broke hardpan allowing the roots of winterfat, Eurotia lanata (Pursh) Moq., to penetrate the soil to greater depth and thus obtain sufficient moisture to support the plant.

(7) Rodents and rabbits by their feeding habits can stunt plant growth and reduce the quantity of forage. Fitch (1948) found that feeding by California ground squirrels produced a stunting effect on vegetation and considered the resultant loss of forage as important to livestock.

(8) Rodents and rabbits by feeding can alter the plant composition of a community. Taylor and Loftfield (1924) showed that the Zuni prairie dog was a primary factor in decreasing wheat grass, Agropyron smithii Rydb., and increasing blue grama, Bouteloua gracilis (H.B.K.) Lag. Schoffer (1931) has stated the possibility of western pocket gophers improving forage conditions by eliminating weeds. Vorhies and Taylor (1933) demonstrated that feeding on grasses by antelope and Arizona jack rabbits on overgrazed range favored the growth of weeds. Doran (1948) in studies of western pocket gophers inside and outside exclosures at Grand Mesa National Forest, Colorado, found weed density increased where gophers were absent and decreased when gophers were present. He concluded that gophers influenced composition by utilization of weeds. The most detailed account of range rodents and plant succession, substantiated with numerous references, has been made by Bond (1945).

(9) Rodents and rabbits by merely cutting and discarding vegetation tend to eliminate forage. Vorhies and Taylor (1933) have noted that jack rabbits cut and waste considerable grass, and antelope jack rabbits frequently feed by eating the lower succulent portion of grasses, leaving the upper 80 per cent of the stem lying on the ground. Fitch (1948) found that the amount of vegetation eaten by ground squirrels in enclosures was only 0.1 of the average quantity removed, and the other 0.9 was believed to have been removed by stunting effect, and cutting and discarding vegetation.

(10) Rodents and rabbits by their burrowing and depositing of spoil on the surface of the ground bury vegetation and thus deplete the total amount of forage. Grinnell (1923) has mentioned the burying of vegetation, particularly debris, by western pocket gophers. Buechner (1942) found in Tall Grass Vegetation that 0.2 per cent of the surface vegetation was denuded annually by spoil from Brazos pocket gopher mounds, and the figure was 4.4 per cent in Yaupon-Oak-Grass Area. Ellison (1946) found 3.5 per cent of the ground surface was covered by workings of the Moore pocket gopher on the Wasatch Plateau in Utah.

EDAPHIC

(1) Rodents by burrowing activities bring considerable quantities of soil to the surface and thus aid in mixing soil. Buechner (1942) found in a Tall Grass Area in Texas that Brazos pocket gophers brought 0.36 tons of soil to the surface per acre annually, and in Yaupon-Oak-Grass Area the amount was 7.08 tons per acre per year. Ellison (1946) in Utah determined that about five tons of soil was brought to the surface per acre per year by the Moore pocket gopher. Smith (1948) excavated the complete burrow system of a single pocket gopher and found that 70 cubic feet of earth had been moved in the construction of the burrow system. Grinnell (1923) computed that in Yosemite National Park, California, western pocket gophers made winter cores[2] amounting to 3.6 tons of earth per square mile. He has enumerated the following relations which seemed to exist between pocket gophers and their environment (<u>loc. cit.</u>, pp. 144-145).

> (1) The weathering of the substratum is hastened by the burrow systems carrying the air and the water and contained solvents to the subsoil particles and rock masses below.

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[2] A winter core consists of soil which the pocket gophers pack into tunnels made in the snow during the winter. In the spring those cores lie on the soil surface as long, winding cylinders.

(2) The sub-soil is comminuted and brought to the surface where it is exposed to further, and increased rate of, weathering.

(3) The loose earth brought up and piled on the surface of the ground thereby becomes available for transportation by wind and water; rain and melted snow carry it from the slopes down to fill up glacial depressions and to make meadows of them; and when these are full, the sediment is carried on still farther by the gathering streams to contribute to the upbuilding of the great and fertile valleys beyond the foothills.

(4) Water is conserved for the reason that snow melts more slowly on porous ground than on hard-packed soil or bare rock, so that the spring run-off is retarded and the supply to the streams below is distributed over a longer period of time; furthermore, the porous soil retains the water longer than packed ground and gives it up with corresponding slowness. Spring floods are less liable to occur and a more regular water supply is insured to the lowlands.

(5) A porous, moist soil produces a fuller vegetational cover—forest, brushland and meadow—and this again favors water conservation.

(6) The ground is rendered more fertile through the loosening of the soil as well as through the permeation of it by the tunnels themselves, thereby admitting both air and water to the roots of the plants; the mineral constituents of the soil become more readily available, and the rootlets are better able to penetrate the earth.

(7) The accumulated vegetational debris on the surface of the ground is eventually buried by the soil brought from below by the gophers, and becomes incorporated to form the humus content so favorable for the successful growth of most kinds of plants.

(2) The soil is enriched by the fecal and urine deposition of rodents and rabbits. Scheffer (1931) has pointed out that unused or spoiled food supplies, old nesting materials, and pellets of excreta are sealed in old galleries of western pocket gophers. Streator (1930) investigated Streator wood rat dens in California and found large quantities of pellets which were used for fertilizer by florists. Grinnell (1923) mentions that excreta of western pocket gophers are deposited in their tunnels. Greene and Reynard (1932) analyzed soil samples from dens of banner-tailed kangaroo rats and white-throated wood rats, and from unworked soil in the immediate vicinity of the dens. The soil from the dens contained a higher nitrate value due to excreta and materials carried into the burrows, and a higher carbonate value due to the breathing of the animals. The computed value of the nitrates on the Santa Rita Experimental Range, Arizona,

from rodent deposition in kangaroo rat burrows, was $31,500, and for the wood rat it was $50,000.

(3) Rodents and rabbits by burrowing provide better aeration of the soil. Grinnell (1923) has indicated the packing effect of heavier mammals and the consequent suffocation of plant roots, which is counteracted by the burrowing of rodents. Beuchner (1942) has mentioned the increased infiltration and percolation of water, and the aeration of soils from Brazos pocket gopher workings. Ellison (1946) believed loosening of soil and the formation of minor irregularities on the surface by the Moore pocket gopher increased rapidity of infiltration. Greene and Reynard (1932) have stated that aeration and water percolation are increased by burrowing rodents, and Greene and Murphy (1932) have given proof to the statement. The latter investigators determined the water holding capacity, moisture equivalent, and mechanical analysis of soil samples from burrows of banner-tailed kangaroo rats and white-throated wood rats, and from check samples. Wood rats had little effect on the physical condition of the soil but kangaroo rats increased moisture equivalent, water holding capacity, and produced a finer textured soil.

(4) Feeding by jack rabbits may stimulate plants to send out new shoots making a clump-like plant which tends to retard wind erosion. Vorhies and Taylor (1933) quote Aldous who pointed out that in the winter and spring on the Jornada Experimental Range, New Mexico, mesquite bark was a favorite food of jack rabbits. The mesquite, Prosopis glandulosa Torr., responded in the production of new shoots from below the sand and thus a clump was formed which increased in size and density preventing much shifting of sands on overgrazed ranges and allowing smaller annuals and perennials to take hold.

(5) Rodents and rabbits by their burrowing activity affect soil erosion. Ellison (1946) found the Moore pocket gopher was an agent of normal, not accelerated, erosion and it may retard erosion by aiding in revegetation of erosion-

pavement areas. Day (1931) has condemned prairie dogs and pocket gophers as agents of erosion. Kashkarov and Kurbatov (1930) found that feeding and digging by the long-toothed ground squirrel caused sand to move in the Kara-Kum desert of West Turkestan.

(6) Rodents and rabbits by dying contribute their bodies to the soil and serve as fertilizer. Taylor (1935) has shown a rodent and rabbit weight of 8.7 pounds per acre for the Santa Rita Experimental Range, Arizona. Trowbridge (1941) has computed the rabbit and rodent weight per acre on the Southern Great Plains Experimental Range, Oklahoma, as 10.1 pounds. These data are particularly impressive as there is a rapid turnover in populations of range rodents and the annual poundage of rodents which return to the soil would be higher than the weight per acre figures.

COMMENT

The influence of rodents and rabbits on range lands are varied and of fundamental importance as is evidenced by the material presented. Much qualitative work has been done on these ecological relationships but there is a dearth of quantitative data on the reactions of the various range rodent species on their environment. For edaphic influences the only important quantitative works are those of Greene and Reynard (1932), Greene and Murphy (1932), and Ellison (1946). Publications such as "Range Rodents and Plant Succession" by Bond (1945) which discuss and bring together literature references on a particular influence are of singular importance. The true value, or importance, of rodents and rabbits to range lands will be merely intelligent guessing (some previous work has not even been intelligent guessing) until we have sufficient quantitative, as well as qualitative, data to fully evaluate their position.

THE SOUTHERN GREAT PLAINS EXPERIMENTAL RANGE

INTRODUCTION

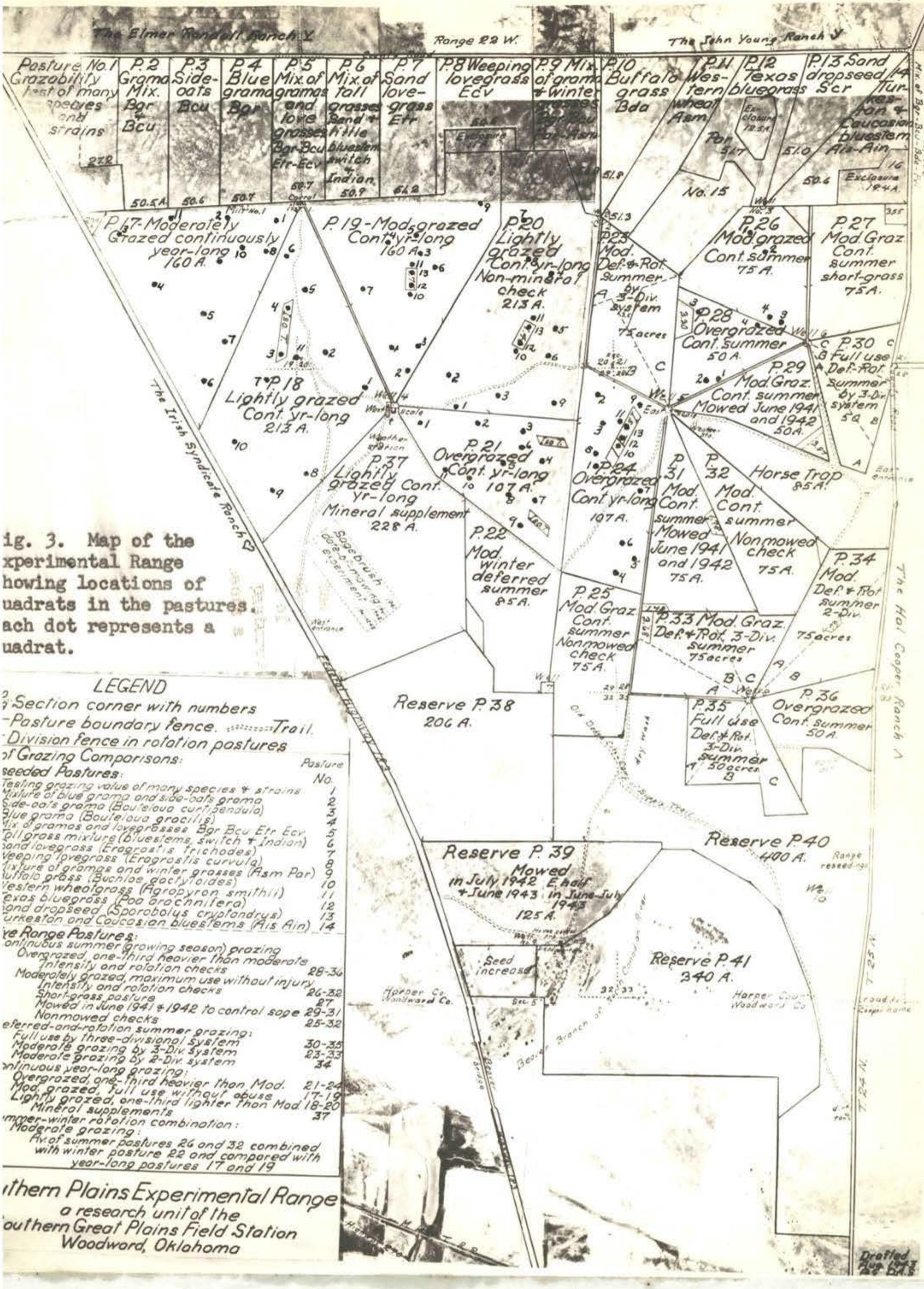
The Southern Great Plains Experimental Range is situated in northwestern Oklahoma about one mile north of the community of Supply, Woodward County (Fig. 2). The Harper-Woodward County line extends east-west through the south portion of the range and in one section the south boundary extends to the North Canadian (Beaver) River. United States Interstate Highway 183 forms the west boundary of the range (Fig. 3).

The lands, of 4,315 acres in extent, were acquired in 1940 by the Southern Great Plains Field Station, Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture, Woodward, Oklahoma, from the Irish Syndicate Ranch controlled by Mr. George S. Hovey, Kansas City, Missouri. At the time of acquisition the area was grazed as a single unit with no cross fences, and in 1941 it was divided into the present 42 pastures ranging in size from 50 to 200 acres (Fig. 3). Grazing studies were initiated in December, 1941, to determine how best to manage and graze native range and reseeded pastures to obtain maximum beef production while maintaining or improving the range forage. The results of these experiments are available (McIlvain, Savage, et al. 1949).

PHYSIOGRAPHY AND GEOLOGY

The general physiography of the Experimental Range is of sand dunes from 5 to 40 feet in height and with their long axis north-south in direction. Small expanses of tight soil, seldom over three acres in area, are usually present

Fig. 2. Map showing locations of the communities of Supply, Woodward, and the Southern Great Plains Experimental Range.



ig. 3. Map of the xperimental Range howing locations of uadrats in the pastures. ach dot represents a uadrat.

between the dunes (Fig. 9). Out-croppings of Permian Red Beds on the Experimental Range and the emergence of the beds a few miles north of the range show that the dunes are lying on the Permian Red Beds which occupy much of western Oklahoma. The Permian Beds are of the following six formations in ascending order (Evans, 1931).

(1) The Blaine Formation is the lowest of the formations and is of four distinct beds of white to reddish white, massive, crystalline gypsum, separated by beds of red shale, and with beds of gray dolomite commonly at the bases of the three lower beds of gypsum. The formation is about 90 feet thick.

(2) The Dog Creek Formation is about 50 feet thick and of red shale, a few beds of soft red sand, and two or three beds of gypsum near the base of the formation.

(3) The Whitehorse Formation consists of about 250 feet of reddish buff sand, red to maroon shale, and a few gypsum beds. The lower 100 feet is entirely of sand in the Supply region. Another layer of sand, 25-30 feet thick, is near the top of the formation in the Cloud Chief Member.

(4) The Day Creek Formation has two layers of dolomite separated by a layer of brown shale.

(5) The Quartermaster Formation includes all the Permian Beds above the Day Creek dolomites and is composed of dark red or maroon shale, and red or red and white sandstone.

Figure 4 shows a type section of the Permian Beds taken north of Supply (it is quite possible the section may have been taken on the Experimental Range). The present sand dunes are on top of the uppermost layer of Quartermaster Formation and are Quaternary deposits (Snider 1917, p. 57) which have been washed down the rivers from high lands to the west.

Ware and Penfound (1949, p. 479-480) have described the formation of sand dunes along the north shore of the South Canadian River in central Oklahoma,

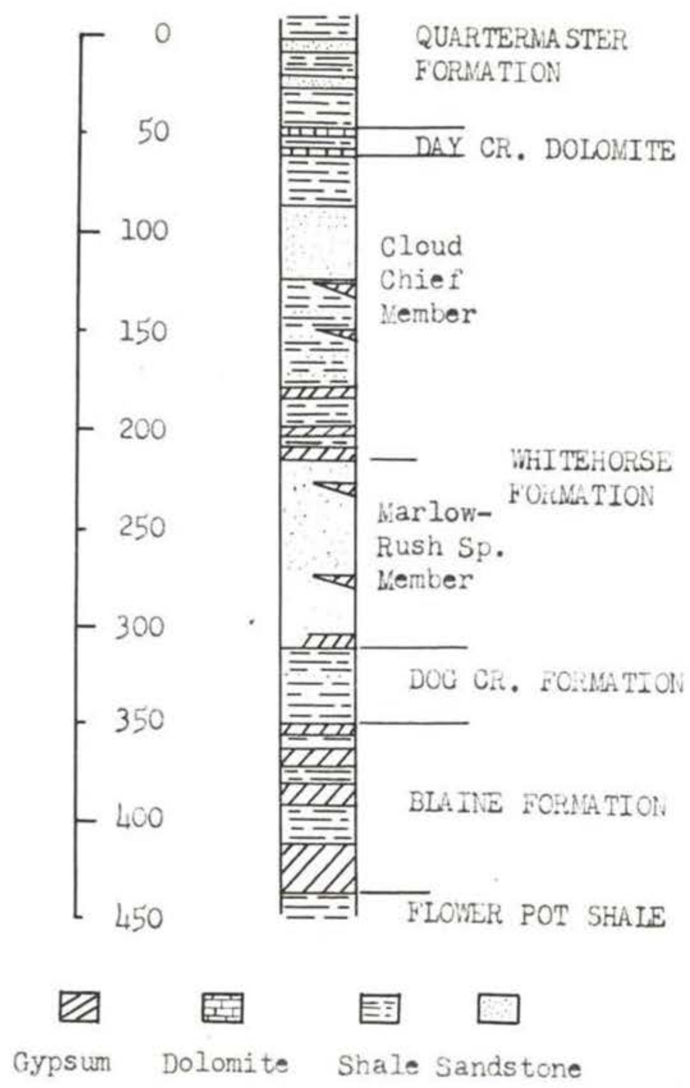


Fig. 4. Geologic section north of Supply, Oklahoma. Vertical scale in feet. The sand dune deposits of the Southern Great Plains Experimental Range lie on top of the uppermost layer of the Quartermaster Formation. (Taken from Evans 1931, p. 415.)

and their description is likely applicable to the formation of the dunes along the North Canadian River. The rivers in western Oklahoma are subject to great variations in depth and volume of water, usually drying in the summer to little or no flowage. With the lower water level the sands in the river channel are exposed and become dry. Winds in western Oklahoma are predominately from the southwest and usually have considerable velocity. Therefore the dry sands soon begin to move with the finer particles picked up by the wind and the coarser particles blown or rolled along. When an obstacle is met the coarser particles are deposited on or about the object while the finer particles form a diminishing trail on the leeward side. The small dune-like formations have been termed sand drifts. Further accumulation about the drifts results in dunes with a reversal in slopes—the windward slope becoming gradual and the leeward slope abrupt. Dunes may be formed directly without passing through the sand drift stage (Fig. 5). Almost any species of plant can cause a drift but sand dunes are formed principally by woody perennials. Cottonwood, Populus deltoides Marsh, was the most effective dune builder noted by Ware and Penfound. Along the north shore of the Cimmarron River (south of Waynoka) at the junction of United States Interstate Highway 281 and the river, salt cedar, Tamarix gallica L., is the principal plant in the formation of the dunes (Fig. 5). The wind blown sand is deposited around the saplings in typical dune formation, finally over-topping and killing the plants, and unless the slopes are vegetated effectively the dune becomes active. Perennial woody plants have persisted along the water courses of the streams of western Oklahoma for a considerable period of time and there is no apparent reason why Ware and Penfound's interpretations and observations would not be applicable to the sand dune areas along the north shores of the principal rivers in western Oklahoma, namely, the Salt Fork of the Arkansas, Cimarron, North Fork of the Canadian, Canadian, Washita, and North Fork of the Red River, although the location of the dunes on the south side of the North Fork of the

Fig. 5. Initial stages of sand dune formation along the north shore of the Cimarron River south of Waynoka, Oklahoma. The dunes are being formed by salt cedar, Tamarix gallica L., retarding the blowing sand and causing it to be deposited about the plants.

Red River is not readily explainable. The Quaternary sand dune areas are depicted in Figure 6.

SOILS

The soils of the Experimental Range are all sandy and have been derived from the dunes. Structurally they are loose on the dunes and fairly well bound in the low areas, 0.25 to 3.0 acres in extent, which lie between the dunes. Vegetation has tended to bind the soil and this influence diminishes with dune height. Patches of bare loose sand and clump-like vegetation occur on the upper slopes and tops of the high dunes. A detailed soils map of the Experimental Range and descriptions of the soil series are presented in Appendix A. Considerable information is given in this thesis regarding soils and soil types. It was thought that correlations might be found between the soil types and the rodent numbers and species. However, the investigator was not sufficiently trained in soil science to separate the various subdivisions of soils on the range.

CLIMATE

The statistical data for the climate in the vicinity of the Southern Great Plains Experimental Range are presented in Table 1. Buffalo is located about 18 miles north of the range and Woodward, 16 miles to the southeast. Generally the climate is of a continental type with pronounced seasonal ranges in temperature and precipitation. The average annual precipitation is about 25 inches; the average number of frost free days, 200; about 16 inches of precipitation occur from April to September; the average July temperature is 80 degrees F.; and the average January temperature is between 34 and 36 degrees F. During the period of study the days were clear and sunny with but three or four instances of precipitation. Strong winds are frequent in western Oklahoma and the rate of evaporation is correspondingly high.

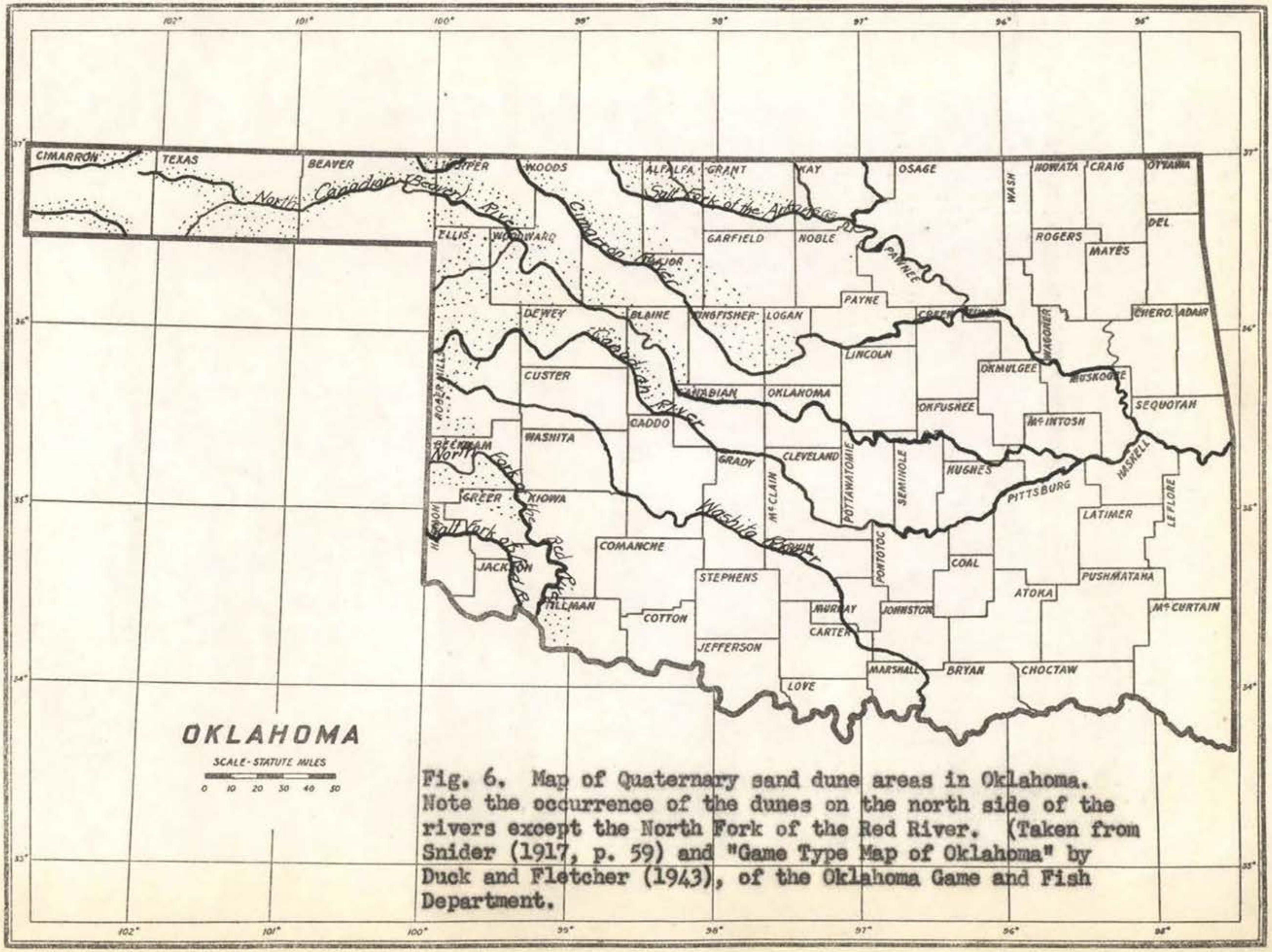


Fig. 6. Map of Quaternary sand dune areas in Oklahoma. Note the occurrence of the dunes on the north side of the rivers except the North Fork of the Red River. (Taken from Snider (1917, p. 59) and "Game Type Map of Oklahoma" by Duck and Fletcher (1943), of the Oklahoma Game and Fish Department.

Station and County	Buffalo, Harper Co.	Woodward, Woodward Co.	Supply, Woodward Co.
TEMPERATURE			
Length of record	24 years	34 years	
January average	35.6 °F.	36.0 °F.	
July average	82.8 °F.	82.1 °F.	
Maximum	115 °F.	115 °F.	
Minimum	-13 °F.	-18 °F.	
KILLING FROST AVERAGE DATE			
Length of record	24 years	33 years	
Last in spring	Apr. 10	Apr. 12	
First in fall	Nov. 17	Oct. 27	
Growing season	221 days	198 days	
AVERAGE PRECIPITATION			
Length of record	27 years	40 years	18 years
January	.55 inches	.59 inches	.43 inches
February	.77 inches	1.05 inches	.66 inches
March	1.43 inches	1.40 inches	1.04 inches
April	1.98 inches	2.42 inches	1.93 inches
May	3.12 inches	3.64 inches	3.04 inches
June	3.06 inches	3.43 inches	2.71 inches
July	2.12 inches	2.64 inches	2.00 inches
August	2.26 inches	2.60 inches	2.06 inches
September	2.46 inches	2.80 inches	2.02 inches
October	1.46 inches	2.17 inches	1.39 inches
November	1.24 inches	1.16 inches	1.82 inches
December	.81 inches	.79 inches	.61 inches
Annual	21.26 inches	25.14 inches	20.21 inches

Table 1. Climatic summary of data for the three stations nearest the Southern Great Plains Experimental Range. Taken from "Climate and Man," Yearbook of Agriculture for 1941, U. S. Dept. of Agri. pp. 1065-1074.

VEGETATION

The sand sagebrush grasslands have been classified as a unit and as a subdivision of a larger grouping by various ecologists who have studied the plant communities and biotic regions of Oklahoma and the grassland areas of the United States (Webb 1948). Most investigators have agreed that the climax expression of the area is grass. Probably the most appropriate appellation for the general vegetative type of western Oklahoma is Mixed Prairie Climax as used by Weaver and Clements (1938, p. 523) or Mixed-Grass Prairie-Plains as used by Carpenter (1940, p. 645). In both instances the term "mixed" refers to growth form as both the short grasses of the high plains and the tall grasses of the prairie are present. The region is a transition between the short grass plains of the west and the tall grass prairie to the east. Sand sagebrush grasslands are a sub-division of the Mixed Prairie Climax, and are merely an association superimposed over the original grassland by the appearance and movement of the sand dunes. In addition to many of the grass species of the Mixed Prairie Climax (little bluestem, Andropogon scoparius Michx.; indiangrass, Sorghastrum nutans (L.) Nash; switchgrass, Panicum virgatum L.; blue grama, Bouteloua gracilis (H.B.K.) Lag.; and hairy grama, Bouteloua hirsuta Lag.) sand sagebrush, Artemisia filifolia Torr., and psammophilous species of grasses like sand dropseed, Sporobolus cryptandrus (Torr.) A. Gray, sand paspalum, Paspalum stramineum Nash, and sand lovegrass, Eragrostis trichodes (Nutt.) Nash, are present. The sand sagebrush grasslands (Fig. 7) can be defined as an association of mixed grasses, sagebrush, and psammophilous species of grasses occurring on sand dune areas in the Mixed Prairie Climax.

Indications of vegetative succession on the sand sagebrush dunes have been obtained by observation, personal correspondence, interviews, and literature. The general successional trend seems to be as follows. Primary invaders are blowout grass, Redfieldia flexuosa (Thurb.) Vasey, big sandgrass, Calamovilfa

Fig. 7. Sand sagebrush grasslands on the Southern Great Plains Experimental Range. The plant in the foreground is the sand sagebrush, Artemisia filifolia Torr.

gigantea (Nutt.) Scribn., (Fig. 8) and forbs such as Reverchonia arenaria A. Gray, Oenothera latifolia (Rydb.) Munz, and Heliotropium convolvulaceum A. Gray, (Waterfall, 1948). Sand sagebrush may occur in the initial stages but usually it appears later in the succession. The second stage in the succession is characterized by greater dune stability and plants like sand lovegrass, sand dropseed, sagebrush, and additional forbs. The third stage is composed principally of sagebrush, sand lovegrass, sand dropseed, and little bluestem. The final stage is the mixed grasses of little bluestem, sand bluestem, indiangrass, blue grama, hairy grama, and switchgrass. Local variations of these sequences may occur. On the river floodplain the succession would advance beyond the mixed grass stage to a floodplain, or river bottomland, forest. The succession presented is for the sand dunes and does not apply to the areas of tighter soil between the dunes which on the Southern Great Plains Experimental Range are occupied by blue grama and horseweed, Eriogonum canadensis L. Grazing can, and does, vary the succession usually retarding the advance and tending to hold it in the earlier stages. Climate also exerts a tremendous influence on the succession and during drought years the short grass areas tend to occupy a larger area. With periods of greater rainfall the taller grasses become more dominant and the short grasses recede. At the present the sand lovegrass and sagebrush are the predominate species on the Experimental Range although for some years before acquisition of the property sand dropseed and blue grama were of greater importance.

Fig. 8. Big sandgrass, Calamovilfa gigantea (Nutt.) Scribn., established on bare sand dunes south of Waynoka, Oklahoma.

M E T H O D S

SUMMARY OF LITERATURE

Methods to obtain rodent species and populations on range lands have been (1) direct observation of the animals; (2) recording of animal sign such as dens, burrows, tracks, tail marks, scats, and so forth; (3) poisoning; (4) and trapping. Storer, Evans, and Palmer (1944) tested visual counts; poisoning; permanent and moving lines of snap traps; and live trapping, marking, releasing, and retrapping. They concluded that live trapping, marking, and releasing of individuals was the best method for studying the composition of rodent populations. Reinvasion of areas of depleted populations and the problem of determining resident vs. nonresident individuals were the factors involved in their decision. Phillips (1936) in studying the distribution of rodents in overgrazed and normal grasslands in Oklahoma used the pellet-spot count method, as devised by Vorhies and Taylor (1933), for rabbit concentrations; for pocket gophers, mound counts on transects; a similar method, presumably burrow counts, for ground squirrels; and snap trapping for deer mice and cotton rats. To determine comparative numbers of rodents in reference to types of soil in southwestern Utah, Hardy (1945) used trap lines of snap traps and of live traps. Smith (1940) used snap traps for rodent, and pellet counts for lagomorph, populations. Fitch (1948) in studies of the California ground squirrel on the San Joaquin Experimental Range tested various census methods such as counts of the numbers seen per minute of walking in different vegetative types; counts of the number seen per mile while driving an automobile; live trapping, marking, releasing, retrapping at intervals and the application of the "Lincoln

Index" to the data. In studying the Tulare kangaroo rat, Fitch (1948) used road counts, live trapping, and burrow counts with the first two considered quite satisfactory. Burrow counts were a poor criterion of kangaroo rat populations for the number of burrows varied with soil types and preceding population levels. Vorhies and Taylor (1933) in investigations of the life histories and ecology of jack rabbits tried numerous methods of counting these animals including censuses by automobile, rabbit drives, direct counts and application of jack rabbit-cow ratio, and pellet counts. Den counts and burrow mound counts of the banner-tailed kangaroo rat were used by Vorhies and Taylor (1922) to determine abundance. To ascertain rodent populations for evaluation of rodent pressure on the range Taylor (1930) has described the use of direct counts per unit area; trapping; poison bait spot counts; den counts; acre list counts; rodent cross-sections; and rodent pellet counts. Fautin (1946) in his studies of the biotic communities of the northern desert shrub biome in Utah used direct counts and pellet counts for relative densities of rabbits, and quadrat trapping with snap traps for small rodents. On the Jornada Experimental Range in New Mexico, Trowbridge (1942a) used car counts replicated many times to determine numbers of jack rabbits and cottontails, and quadrat and line trapping with snap traps for rodents. The data were evaluated statistically. Trowbridge (1941, 1942) tested line trapping and quadrat trapping with snap traps on the Southern Great Plains Experimental Range in Oklahoma and concluded that one-half acre quadrats of 27 traps each were suitable for population studies of small rodents, particularly kangaroo rats. Hayne (1949a) has presented an abstract study of strip census methods for estimating populations, and one on the calculation of size of home range (1949) which is pertinent to population studies. Methods of measuring small mammal populations have been analyzed experimentally by Stickel (1946a). It was concluded that errors involved in methods of snap trapping, and the current use of snap trap data, invalidated the usage thereof for determining actual population numbers, but it would be practical to use a snap trap quadrat technique to obtain a relative measure or index figure for small mammal populations. Bole (1939) has also analyzed the quadrat method of studying small mammal populations. Dice (1938) has presented census methods for mammals together with a good discussion of the difficulties involved in each. A similar paper has been done by the same author (1941) on methods of estimating populations of mammals. Both of these papers are excellent regarding the variables, difficulties, and problems of determining numbers of small rodents. Blair (1941) has described various techniques for the study of mammal, particularly rodent, populations. A summarization to compare methods and results of censusing and to draw conclusions upon comparative populations of small mammals has been presented by Mohr (1947).

Additional references to methods of determining rodent populations could be presented but they would have no very great significance. The principal points obtained from the review of literature on rodent populations are (1) that no method exists which will give absolute numbers of rodents, or even a single species thereof, on a given area; and (2) that almost any method properly used will give comparative rodent populations. The current method of determining absolute rodent populations is live trapping, marking, releasing, and recapturing individuals with the aim of determining the home ranges. This method combined with an adequate knowledge of the life history and ecology of the species probably will give the most accurate data on actual numbers of individuals present on a given area. To determine comparative or relative numbers of individuals a consistent system of trapping, or other method, used at intervals will give population data that can be used for comparison to show the effect of an environmental factor, or group of factors, on the rodent population. As there were about ten species of rodents on the Experimental Range for which no accurate census methods were available, and as Trowbridge had tested and evaluated a quadrat trapping method using snap traps on the range, the aim of the present study was primarily to obtain comparative population data.

INTRODUCTION

Preliminary reconnaissances of the pastures on the Experimental Range were made in October, 1949. The work consisted of walking through each of the pastures observing and noting plant species, plant associations, grazing intensities, animals, rodent sign, terrain, and soils. From these reconnaissances it was decided to confine most of the investigations to Pastures 19, 20, and 24 as a first group, and Pastures 17, 18, and 21 as a second group (Fig. 3). Trowbridge did most of his work in the latter three pastures. By dividing the six pastures into two groups of three each, each group consisted of a lightly grazed, a moderately grazed, and an overgrazed pasture. Quadrats were operated simultaneously in Pastures 19, 20, and 24; and Pastures 17, 18, and 21 were trapped individually. Different baits were used in each of the groups.

QUADRAT SITES

While making the reconnaissances of the pastures and immediately prior to trapping, each pasture was examined in regard to the placing of the quadrats (quadrat sites). The general terrain was of vegetated sand dunes with a maximum height of about 50 feet and small areas of tight soil between the dunes. These were classified as low, moderate, and high dunes with the low flat areas between the dunes making a fourth division. Low dunes were ten feet or less in height above the general level of the terrain. The soils on the low dunes were sandy and usually partially bound by organic matter and vegetation which was mainly of sand lovegrass and sagebrush, although frequently grasses of other species were well-represented. Moderate dunes were from 10 to 25 feet in elevation, were similar in character to the low dunes except the soil was looser, and had more exposed soil between the vegetation. The high dunes were over 25 feet in height. Loose sand was abundant and occurred in patches giving a clump-like appearance to the vegetation which was mainly sagebrush and sand lovegrass. The latter usually was growing in the clumps of sage on the high dunes. Flat areas were low flat areas between the dunes in which the soils were tightly bound, and blue grama and horseweed predominated. In selecting the quadrat sites an attempt was made to obtain a representative sample of the pasture. A topographic map (Fig. 9) was of material assistance in selecting quadrat sites and determining elevations of the dunes. Sites in Pastures 17, 18, and 21 were located as closely as possible to the sites used by Trowbridge (1942) in 1941.

After the quadrat sites were determined and during the operation of the quadrats data were taken on the vegetation, soils, and grazing intensity of each quadrat (Appendix C). Later the information was analyzed and categorized as follows. The vegetative crown densities, which were ocular estimates, were classified as light, moderate, and high. The soils were considered as tight, loose sand, and loose sand in patches. Grazing intensity was light, moderate, and overgrazed. All of these classifications were arbitrary and relative.

QUADRATS

Eleven quadrats were established in each of Pastures 19, 20, and 24, and two in cattle exclosures in each of these pastures. In Pastures 17, 18, and 21 eleven quadrats were operated in each pasture (Fig. 3). The quadrats were numbered.

A quadrat consisted of 27 traps placed in three lines. The lines were 52 feet apart and were composed of 9 traps each, with traps 26 feet apart in the lines. The lines of the quadrats were designated by letters A, B, and C, with B the middle line. Each trap location in the lines was numbered consecutively from one to nine and all catches within a quadrat were recorded by the combination of the line letter and trap number (Fig. 10). In establishing a quadrat all distances were paced and the traps set at the proper intervals regardless of rodent sign. A quadrat was 0.5 acres in area.

Fig. 9. Topographic map of the Southern Great Plains Experimental Range. The contour interval is five feet.

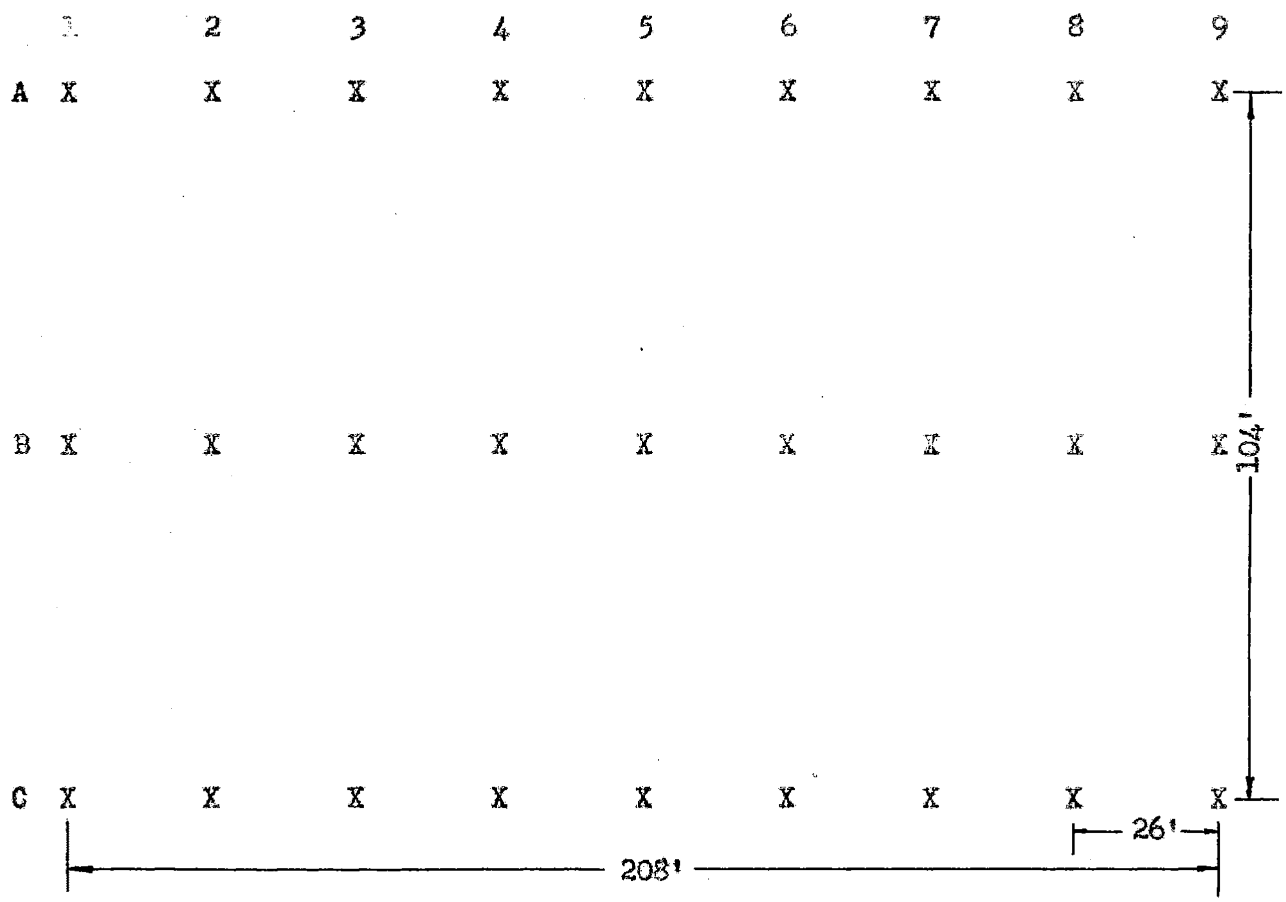


Fig. 10. Diagram of quadrat showing trap placement (X), dimensions, trap numbers, and line designations.

QUADRAT OPERATION

The quadrats were operated for five consecutive days and nights and were checked each day following a night of operation, except in Pasture 21 where due to illness of the operator the traps were not checked on one day. Operation consisted of visiting each trap; removing the captured animals; and rebaiting and resetting where necessary. The specimens were listed in a field notebook along with their sex, quadrat number, and trap site designation. Small price tags were affixed to a hind leg of each individual and the pasture number, quadrat number, and trap site location were written on the tag. Later these animals were measured, and the sex organs examined. Museum specimens were prepared of 83 individuals and these have been deposited in the Oklahoma A. and M. College Museum of Zoology.

TRAPS

For the five-day and -night trapping period, Victor rat traps (Fig. 11) were used exclusively. In five quadrats in each of Pastures 19, 20, and 24, Museum Special traps (Fig. 12) were substituted for the rat traps after the customary five-day and -night trapping period. The Museum Special traps were operated two consecutive days and nights.

BAITS

The traps in the quadrats in Pastures 19, 20, and 24 were baited with a paste bait mixture of about one cup of rolled oats, one heaping tablespoonful of peanut butter and a teaspoonful of melted bacon grease. The traps in Pastures 17, 18, and 21 were baited with a grain mixture of about equal parts of kaffir corn, milo maize, whole oats, and whole wheat. The grain mixture bait was the same as that used by Trowbridge who found this to be highly suitable, particularly for kangaroo rats.

Fig. 11. Victor rat trap baited with grain bait mixture and set in an overgrazed pasture. Note the height of the grasses in proportion to the size of the trap.

Fig. 12. Museum Special trap baited with grain bait mixture and set in an overgrazed pasture.

PRELIMINARY TRAPPING OPERATIONS IN A MODERATELY GRAZED AND AN OVERGRAZED PASTURE

PURPOSE

The first quadrat trapping was conducted in Pastures 26 and 28[1] (Fig. 3). The primary purpose of the trapping was to become familiar with the quadrat method of trapping, to learn the rodent species on the range, and to test the acceptance of a bait mixture. The two pastures had a difference in grazing intensity which it was thought might be reflected in the rodent populations.

DESCRIPTION OF PASTURE 26

Pasture 26 was classified as a moderately grazed, continuous, summer pasture by the Southern Great Plains Field Station. A reconnaissance of the pasture was made on October 10, 1949, and at that time the grazing intensity was light to moderate. The excellent growing seasons of 1948 and 1949 had produced sufficient forage to make the grazing intensity somewhat less than moderate, and according to the Grazing Service Range Use Classification (Stoddart and Smith 1943, p. 189) it would have been termed light. Grass fruiting stalks were abundant and the crown density of the grasses and forbs was moderate to high. Horseweed, Erigeron canadensis L., which was scarce in the overgrazed pastures on the range was relatively common in Pasture 26.

At the time of the reconnaissance the aspect of the vegetation consisted chiefly of the gray-green of sand sagebrush, Artemisia filifolia Torr., and

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[1] Pasture numbers are those of the Southern Great Plains Field Station as shown on the map, Figure 3.

the brown and tan fruiting stalks of the grasses. Common plants in the pasture were sand sagebrush; annual eriogonum, Eriogonum annuum Nutt.; and blue grama, Bouteloua gracilis (H.B.K.) Lag. Also present were sand bluestem, Andropogon hallii Hack.; little bluestem, A. scoparius Michx.; sideoats grama, B. curtipendula (Michx.); sand dropseed, Sporobolus cyptandrus (Torr.) A. Gray; sand lovegrass, Eragrostis trichodes (Nutt.) Nash; wild rye, Elymus canadensis L.; horseweed; showy gaillardia, Gaillardia pulchella Foug.; Fursh's plantain, Plantago purshii R. & S.; partridge pea, Chamaecrista fasciculata (Michx.) Greene; western ragweed, Ambrosia psilostachya DC.; daisy fleabane, Erigeron bellidiastrum Nutt.; Aplopappus divaricatus (Nutt.) A. Gray; Riddell's senecio, Senecio riddellii T. & G; Heterotheca subaxillaris (Lam.) Britt. & Rusby; broomweed, Gutierrezia dracunculoides (DC.) Blake; prickly pear, Opuntia sp.; and sand plum, Prunus angustifolia Marsh. No tree growth was present in the pasture.

Sand dunes in this pasture were low to moderate (5 to 20 feet) in elevation with gentle slopes. One high dune, about 35 feet elevation above the general level of the pasture, was located slightly north of the center of the pasture.

The soils were sandy and in general were bound by the roots of the vegetation and organic matter, especially on the low dunes and low areas of tight soil between the dunes. Loose sand was present on some of the moderate dunes and the high dune in the pasture. The soil types were Pratt fine sandy loam, Pratt loamy fine sand, and Tivoli loamy fine sand (Appendix A).

DESCRIPTION OF PASTURE 28

Pasture 28 has been categorized by the Southern Great Plains Field Station as overgrazed, continuous, summer pasture. The pasture, as a whole, was moderately overgrazed and probably would be classified as close in the Grazing Service classification. The grasses and forbs were not closely cropped and on the low areas between the dunes was a good stand of blue grama with some fruiting stalks. The general impression of the vegetation was of clumps of sand sagebrush with blue grama between the clumps on the low areas between the dunes, and mixed species of taller grasses in and between the sagebrush on the dunes. The taller grasses were often above the crown height of the sand sagebrush and fruiting stalks were sometimes present. The crown density of the grasses and forbs was light to moderate.

A reconnaissance of the pasture was made on October 10, 1949, and at that time the aspect consisted of the gray-green of sand sagebrush with scattered light gray stalks of annual eriogonum. Plants noted as common during the reconnaissance were blue grama, sand dropseed, annual eriogonum, and sand sagebrush. Also present were sand lovegrass; sand bluestem; little bluestem; sideoats grama; switchgrass, Panicum virgatum L.; sandbur, Cenchrus pauciflorus Benth.; western ragweed; showy gaillardia; loasa, Mentzelia stricta (Osterhout) G. W. Stevens; daisy fleabane; broomweed; Rocky Mountain bee plant, Cleome serrulata Pursh; and lespedeza, Lespedeza sp.

The dunes were low to moderate in height with one high dune, about 35 feet high, along the southeast fence line. Excepting the high dune, the dunes' slopes were moderate to gentle with the long axis usually north-south in direction.

The soils were sandy and of Pratt fine sandy loam and Tivoli loamy fine sand. Exposed loose sand was common on the high dune and a small "blow-out" was present on the east slope.

COMPARISON OF THE PASTURES

The pastures were essentially similar as regards soils and topography but differed in vegetation. Pasture 28 was moderately grazed to overgrazed and had a vegetative crown density of light to moderate. Pasture 26 was light to moderately grazed and had a crown density of high to moderate. Within the pastures the crown density and grazing intensity were inversely proportional to the height of the dune, decreasing as the dune height increased. A noticeable difference between the pastures was evidenced in the height of the grasses and the number of grass fruiting stalks, as the grasses were taller and there were more grass fruiting stalks in the moderately grazed pasture (Pasture 26). Annual plants were more abundant in Pasture 26 and horseweed, the lack of which is apparently an indicator of overgrazing, was present in Pasture 26 but not in Pasture 28. The differences in grazing intensities could be observed in walking through the pastures as it was comparatively easy to walk between the clumps of sagebrush in Pasture 28, whereas in Pasture 26 the dense grass and forb growth between the clumps made ambulatory progress difficult.

PROCEDURE

On October 10, 1949, and again on October 17, two trapping quadrats (Page 45) were established in Pasture 26 and two in Pasture 28, making a total of four quadrats per pasture. The quadrats were operated five consecutive days and nights, and Victor rat traps were employed. At the end of the trapping period of the four quadrats established on October 17, Museum Special traps were substituted for the rat traps. The Museum Special traps were operated two consecutive days and night.

The bait consisted of a paste mixture of rolled oats, peanut butter, and bacon grease and was placed directly on the bait pan of the trap.

The trapping operations consisted of 1296 trap nights.

DATA AND DISCUSSION

Tables 2 and 3 present the rodent catches per quadrat. In the moderately grazed pasture six genera of rodents and one of lagomorph were caught with the rat traps. The species trapped were kangaroo rat, Dipodomys ordii richardsoni Allen; spotted ground squirrel, Citellus spilosoma major Merriam; grasshopper

Quadrat No.	1	2	3	4	3	4
Dune Height	high	moderate	low	moderate	CATCHES WITH MUSEUM SPECIAL TRAPS	
Soil	loose sand in patches	loose sand	tight	loose sand		
Crown Density	moderate	high	high	moderate		
Grazing Intensity	moderate	moderate	moderate	moderate		
Dipodomys	6	1		6		
Onychomys	10	4		18		2
Citellus	1		1	3		
Peromyscus	1		1	2	1	1
Neotoma	2			2		
Sigmodon	1			1		
Sylvilagus		1		1		
Cryptotis					4	3
TOTALS	21	6	2	40	5	6

Table 2. Rodent catches from quadrats in Pasture 26, moderately grazed.

Quadrat No.	1	2	3	4	3	4
Dune Height	high	moderate	low	moderate	CATCHES WITH MUSEUM SPECIAL TRAPS	
Soil	loose sand in patches	loose sand	tight	loose sand		
Crown Density	light	light	light	light		
Grazing Intensity	overgrazed	overgrazed	overgrazed	overgrazed		
Dipodomys	11	5	4	4	1	
Onychomys	10	2	4	6	2	1
Citellus	1	2	1			
Peromyscus			1		2	
TOTALS	22	9	10	10	5	1

Table 3. Rodent catches from quadrats in Pasture 28, overgrazed.

mouse, Onychomys leucogaster brevicauritus Hollister; white-footed mouse, Peromyscus maniculatus nebrascensis (Coues); pack rat, Neotoma micropus micropus Baird; cotton rat, Sigmodon hispidus texianus (Audubon and Bachman); and cottontail rabbit, Sylvilagus floridanus llanensis Blair. One additional species of mammal, the least shrew, Cryptotis parva (Say), was caught with the Museum Special traps. In the following discussion all data refer to the trapping with the rat traps unless otherwise stated.

A comparison of the catches by quadrats in Pasture 26 shows that Quadrat 1 on the high dune had the highest rodent population (21) and also the greatest number of species (6). The two quadrats on moderate dunes had populations of six (including one cottontail rabbit) and eleven individuals, respectively, and the quadrat on the low dune had a population of but two rodents. The trapping with the Museum Special traps did not materially alter the proportions of these populations.

In Pasture 26, kangaroo rats were captured on all quadrats except that on the low dune with tight soil. The highest populations were taken on the high dune with considerable exposed loose sand, and from one of the moderate dunes on which the soil was much looser than on the other moderate dune and the low dune. A correlation may exist between amount of exposed loose sand and kangaroo rat populations. The catch of grasshopper mice was also largest on the high dune and lowest on the low dune with tight soil. As this species is not particularly adapted for digging it is doubtful if the amount of exposed loose sand would be a factor in its population distribution. There were no apparent correlations with the other species trapped. Spotted ground squirrels seemed to be quite evenly distributed throughout the pasture as was evidenced from the catch and burrow entrances of the animals. Catches of pack rats were probably associated with proximity of the quadrats to their dens which were scarce on the range, although usually one was present at or near each well. One cotton rat was caught on the high dune and it is surprising that this species was not taken on the other three quadrats which had a higher vegetative crown density. Cottontail rabbit sign was scattered in the pasture and no localization of population was noted.

Four genera of rodents were caught in the overgrazed pasture, Pasture 28. The species were kangaroo rat, spotted ground squirrel, grasshopper mouse, and white-footed mouse.

The quadrat on the high dune produced the highest population (22) and the low and two moderate dunes each had about the same number of catches (9, 10, and 10 respectively).

Kangaroo rats were caught in all the quadrats in Pasture 28 but the highest catch was from the quadrat on the high dune where there was considerable exposed loose sand. The quadrat on the low dune had a looser soil structure than the comparable low dune quadrat in Pasture 26, and this may account for the catches of kangaroo rats on the former. Grasshopper mice had a higher population on the high dune than on the low and moderate dunes, which strengthens the correlation noted in Pasture 26. Spotted ground squirrels and white-footed mice were relatively scattered and nothing specific as regards numbers or distribution was apparent from the data.

In comparing the catch of the four species common to both pastures, a higher population (51 as compared to 36) was obtained in the overgrazed pasture and the difference is attributable to higher populations of kangaroo rats and grasshopper mice.

No least shrews were taken with the Museum Special traps in Pasture 28 which would indicate that this species preferred the lighter grazed pasture with denser crown cover.

During the trapping period of five days and nights all the rodents on the quadrats were not caught as an examination of the quadrats after the trapping showed active burrows and fresh tracks. Undoubtedly some individuals were trapped whose home range was properly outside the quadrats. It is believed that the residual population on the quadrats probably balanced the influx of individuals whose home range was mainly outside the quadrat but were trapped in the quadrat. Each quadrat was 0.5 acres in area so the per acre populations for each dune height classification have been computed by multiplying the average species catches per quadrat by two. In each of the pastures there was but one high dune and a quadrat was placed on each of these high dunes. The remainder of the pastures was of low and moderate dunes in about equal portions. For each pasture the areas of the high dunes have been determined by using a grid of small squares; determining the total number of squares in the pasture; the number of squares represented by the high dune areas; and, finally, as the acreage of each pasture was known, a simple proportion gave the acreage of the high dune areas. The data for the low and moderate dunes have been treated as a unit. The total populations for each species in each of the pastures has been computed and are presented in Table 4. The accuracy of these data is far from satisfactory for the number of quadrats per pasture was too low. Probably the figures for cotton rat and the white-footed mouse populations are least reliable. It is believed that the data for kangaroo rats, grasshopper mice, spotted ground squirrels, and cottontail rabbits are approximately correct.

No particular difficulty was encountered in the operation of the quadrats and the bait mixture seemed to function satisfactorily. The low catch of rodents with the Museum Special traps would indicate that most resident individuals were caught during the five-day and -night trapping period when the rat traps were operated.

SUMMARY

Four rodent trapping quadrats were operated for five consecutive days and nights in an overgrazed pasture, and four in a moderately grazed pasture. Kangaroo rats, grasshopper mice, spotted ground squirrels, and white-footed mice

Species	Population Pasture 26 (75 acres)	Population Pasture 28 (50 acres)
Dipodomys	410	570
Onychomys	448	436
Citellus	100	100
Peromyscus	50	28
Neotoma	15	
Sigmodon	7	
Sylvilagus	42	
Cryptotis	499	
TOTALS	1,571	1,134

Table 4. Total rodent populations for Pasture 26, moderately grazed, and Pasture 28, overgrazed.

were the predominate rodents present. A comparison of the catches of these species showed a higher population (51 as compared with 36) in the overgrazed pasture. A positive correlation was noted between the amount of exposed loose sand and the population of kangaroo rats. A positive correlation was also noted between the height of dune and grasshopper mouse populations. The least shrew was caught in the moderately grazed pasture but not in the overgrazed pasture indicating its preference for a high vegetative crown density of grasses and forbs. The total populations for each pasture were computed assuming the quadrat catch was the total population of the quadrat area. Four quadrats per pasture are not considered adequate to give sufficient data on which to base populations. The work was primarily conducted to acquaint the investigator with the method of quadrat trapping.

STUDY OF A LIGHTLY GRAZED, A MODERATELY GRAZED, AND AN OVERGRAZED PASTURE

INTRODUCTION

Except for replicates, each of the pastures on the Southern Great Plains Experimental Range has been under a different grazing program since 1941 and the soils and vegetation have had eight years to become adjusted to the individual grazing intensities. The establishment and maintenance of these conditions in the pastures offered a promising opportunity to study the effects of the grazing intensities on rodent species and numbers. As a logical approach to the problem quadrats were operated in a lightly grazed, a moderately grazed, and an overgrazed pasture.

For purposes of orientation, the sequence of presentation will be as follows: a brief discussion of the methods; presentation of collected data from each of the pastures; a comparison of the rodent populations in the pastures; and, finally, a comparison of populations in cattle exclosures in each of the pastures with the populations immediately outside the exclosures. A brief summary has been compiled at the end of each section.

METHODS

For comparison of the populations nine quadrats were operated in each pasture. In addition two quadrats per pasture were operated immediately adjacent to cattle exclosures and two within each of these exclosures. The data obtained from the quadrats immediately adjacent to the exclosures have been incorporated with the original nine quadrats to determine rodent populations in the pastures.

Thus, eleven quadrats per pasture were available for total population studies and for comparisons.

The quadrat locations were selected with the viewpoint of securing a fair comparison of the data from the pastures and an attempt was made to obtain a representative sample of each pasture as regards soil conditions, floristic composition, and height of dunes. As soil conditions and floristic composition were correlated with dune height, the latter was a satisfactory criterion for locating quadrats. Quadrats were established on high dunes, moderate dunes, low dunes, and low flat areas between dunes.

The pastures trapped were Pasture 19 (moderately grazed, continuous, yearlong), Pasture 20 (lightly grazed, continuous, yearlong), and Pasture 24 (overgrazed, continuous, yearlong). The size, shape, and location of each pasture are shown in Figure 3.

The quadrats were the typical half-acre, 27 rat trap quadrats (Page 45). Each quadrat was operated five consecutive days and nights after which Museum Special traps were substituted for the rat traps in five of the quadrats. The bait used was the paste mixture of rolled oats, bacon grease, and peanut butter. Three quadrats were operated simultaneously in each pasture for three trapping periods, and four (the two in the exclosures and the two immediately outside) quadrats during a final period. The locations of the quadrats are shown in Figure 3. The data for individual quadrats, including a description of the quadrat, the catches by trap inspection periods, and the catches in each of the traps, are given in the data sheets (Appendix C). The trapping operation extended from October 30 to November 24, 1949.

PASTURE 19 (MODERATELY GRAZED)

Description of Pasture

Pasture 19 was classified and managed by the Southern Great Plains Field Station as a moderately grazed, continuous, yearlong pasture. It was 160 acres in area and its location is as shown on the map, Figure 3. Reconnaissances of the pasture were made on September 27 and October 23, and the conditions described below prevailed on these dates.

Grazing intensity was moderate to light and in many localized areas the pasture was more lightly grazed than moderately grazed. The pasture definitely had a heavier grazing intensity than the lightly grazed Pasture 20 and was less heavily grazed than the overgrazed Pasture 24. Grass fruiting stalks were abundant and the grass showed very little cropping. Based on the Grazing Service classification of range use, Pasture 19 would probably have been classified as light.

The dunes and overall aspect on October 23 was mainly of the tan-colored, dried sand lovegrass and the gray-green of the sagebrush, with the former color predominating. On the lower elevations between the dunes sand lovegrass was absent, and the aspect was principally of the gray-green of the sage, the dark brown of dried horseweed, and the brown, and gray coloration of dried fruiting stalks of various grasses, principally blue grama. On September 27, the low areas between the dunes were readily distinguishable by the yellow-green color of the horseweed. Also, at that time the light gray color of annual eriogonum and the purple-tan color of sand lovegrass fruiting stalks were conspicuous.

Plants commonly noted in the pasture were sand lovegrass, sand bluestem, little bluestem, blue grama, sagebrush and horseweed. Also present were indiangrass; switchgrass; sideoats grama; sand dropseed; annual eriogonum; broomweed (near Well 4); yucca; showy gaillardia; Riddell's senecio; partridge pea; western ragweed; daisy fleabane; sand plum; dew flower, Commelina erecta L.; Queens root, Stillingia sylvatica L.; Aplopappus divaricatus (Nutt.) A. Gray; and Baptisia sp. No tree growth was present.

The soil was predominately loose sand with the amount of exposed sand between the vegetation greater on the higher dunes in the north and west portions of the pasture. The loose sand was important for sand lovegrass, which was the dominant grass, requires such a site (Hoover, Hein *et al*. 1948, p. 671). Between the dunes the soil was sandy but tight and had a higher amount of organic matter. The soil types in the pasture were Pratt fine sandy loam, Pratt loamy fine sand, Tivoli loamy fine sand, Tivoli sand, and Albion sandy loam (Appendix A).

The high dunes were in the north and northwest sections of the pasture with more moderate dunes in the northeast and east. Sizeable areas of low flat terrain with relatively tight soils were present in the south and central sections (Fig. 9).

Data and Discussion

The data for each quadrat operated in Pasture 19, exclusive of the two quadrats in the exclosure and the Museum Special trap data, are presented in Table 5. The dune height categories of flat, low, moderate, and high may be characterized as follows: Flat areas were low flat areas between the dunes in which the soil was tightly bound, and blue grama and horseweed were the dominant plant species. Low dunes were dunes ten feet or less in height above the general level of the terrain, the sandy soil was bound in some places and loose in others, and the vegetation was mainly sagebrush and sand lovegrass although frequently grasses of other species were well-represented. Moderate dunes were ten to twenty-five feet in elevation, were similar in character to the low dunes except the soil was looser, and there was more exposed soil between the vegetation. The high dunes were over twenty-five feet in height, loose sand was abundant and occurred in patches giving a "clump-like" appearance to the vegetation in which sagebrush and sand lovegrass predominated.

As recorded the crown density of the vegetation was an ocular estimate and was classified as light, moderate, and high. The light crown densities invariably prevailed on the high dunes where the loose sand was present in patches. The moderate crown density was mainly associated with the moderate dunes, although frequently these dunes had a high crown density, particularly the lower dunes within this category. The low dunes had a high crown density, mainly of sand lovegrass, and little or no soil could be seen except by parting the grass.

Grazing intensity likewise was based on ocular estimate and for Pasture 19 was considered light in all quadrats. Likely the grazing intensity in Pasture 19 would have little or no effect on the rodent population as it appeared to be too light to cause a radical difference in environment from an ungrazed area. The factor of height of dune, as evidenced by density of crown canopy and amount of loose sand between the vegetation, was a more variable and stronger influence than the grazing intensity. It was evident that the successional considerations could be easily confused with grazing intensity for on casual observation of the high dunes there was abundant loose, exposed soil and the vegetation was in clumps which would indicate a high grazing intensity. However, upon closer examination it was found that the grasses growing in the clumps of sagebrush were ungrazed and the fruiting stalks protruded well above the tops of the sagebrush.

The exposed soil between the vegetation on the high dunes (Fig. 12a) has not returned to grass since the dunes were active, and the grass has not been eliminated by grazing---it was never present except in and among the sagebrush. The slowness to completely restock the high dunes with vegetation may be due to a deficiency of moisture, a physical effect of moving sand, rodent activity, a lack of time since the dune was stabilized, or a combination of these factors. There is little stored food in the seed of sand lovegrass and its inability to germinate and survive sufficiently long to get roots down to minerals and water may be a cause in delaying vegetative growth on these high dunes. In the clumps of sagebrush on the high dunes, grasses, particularly sand lovegrass, were present and persisting. Apparently the sagebrush produced an environment suitable for the establishment of the grasses, and this environment was sufficiently

Fig. 12a. Exposed loose sand between the vegetation on a high dune in Pasture 24 which was overgrazed. The grass growing in the clumps of sagebrush is sand lovegrass.

different from the adjoining bare areas to allow the growth of grasses. Availability of grass seed was not of critical importance as the sand lovegrass fruited prolifically and seed was abundant. In the exposed patches the abrasive action of wind blowing loose sand and covering germinating vegetation might be a factor retarding plant growth. Rodent activity definitely must contribute to the delay in complete revegetation of the higher dunes. Kangaroo rats have a relatively high population on these dunes and are active foragers for grass seeds; make runways by trampling vegetation; and throw considerable quantities of loose sand out of their burrows (Fig. 13) which provides soil for blowing and covering vegetation. All of these activities contribute to the condition of loose sand in patches between the vegetation and retard the growth of vegetation on these patches. Likely the high dunes were last to be stabilized and they might revegetate completely given sufficient time, although the elimination of the kangaroo rats probably would accelerate the process.

The following species of rodents were taken with the rat traps: kangaroo rat, Dipodomys ordii richardsoni Allen; grasshopper mouse, Onychomys leucogaster breviauritus Hollister; cotton rat, Sigmodon hispidus texianus (Audubon and Bachman); spotted ground squirrel, Citellus spilosoma major Merriam; white-footed mouse, Peromyscus maniculatus nebrascensis Mearns, harvest mouse, Reithrodontomys montanus griseus Bailey; and pack rat, Neotoma micropus micropus Baird. The only additional mammal species caught with the Museum Special traps was the least shrew, Cryptotis parva Say. Pocket gophers were present in the pasture but no studies were conducted on this species. The thirteen-lined ground squirrel, Citellus tridecemlineatus Mitchell, occurred on the range but no specimens were caught and they undoubtedly were in hibernation during most of the trapping period. Cottontail rabbits occurred in the pasture but none was caught. Jack rabbits were probably present but none was taken and this species was very scarce over the entire range. No pocket mice were taken in Pasture 19 although two species were known to be present on the range.

Fig. 13. Entrance to kangaroo rat burrow showing the exposed loose sand which has been thrown out of the burrow by the animal. The loose sand is typical of the high dunes.

Quadrat No.	1	2	3	4	5	6	7	8	9	10	11	TOTALS
Dune Height	moderate	low	moderate	moderate	low	moderate	high	flat	moderate	flat	flat	
Soil	loose sand	loose sand	loose sand	loose sand	loose sand	loose sand	loose sand in patches	tight	loose sand	tight	tight	
Crown Density	moderate	high	moderate	moderate	high	moderate	light	high	moderate	moderate	moderate	
Grazing Intensity	light	light	light	light	light	light	light	light	light	light	light	
Dipodomys	6	7	7	8	3	10	19	1	10	3	6	80
Onychomys	7	3	3	10	6	12	4	2	9	3	5	64
Sigmodon		2			1	2			1			6
Peromyscus					1							1
Citellus		1										1
Reithrodontomys								1		1	1	3
Neotoma											1	1
X				2								2
TOTALS	13	13	10	20	11	24	23	4	20	7	13	158

Table 5. Rodent catches per quadrat for eleven quadrats operated in Pasture 19. The species category "X" signifies a specimen whose species was not known as the entire animal was not present in the trap, i.e. usually a tail, foot, fur, etc. was present.

Numerically the two most important rodent species taken with the rat traps were the kangaroo rat and grasshopper mouse. On the eleven quadrats they each had an incidence of 100 per cent and comprised 51 per cent and 41 per cent respectively of all the individuals caught. The two species combined formed 92 per cent of all rodents taken in the quadrats.

The data of the catches with the Museum Special traps are presented in Table 6. The rat trap data for the kangaroo rat, grasshopper mouse, cotton rat, pack rat, and spotted ground squirrel seem to be relatively accurate as shown by the failure of the Museum Specials to catch many of these species. The rat traps did not give an accurate sample of the populations of the smaller rodents such as the white-footed mouse, harvest mouse, and least shrew. The reason for this discrepancy was due to the small size of these animals and their consequent failure to trip the larger less delicate rat traps, as compared with the Museum Specials. The combination of the data for the quadrats in which both Museum Specials and rat traps were operated appeared to give reasonable quadrat populations for these smaller mammals. The data from the Museum Specials and the rat traps for all the quadrats present a reasonable account of the rodent species present and their relative and actual populations.

The discussion from hereon will be limited to the data from the five-day and -night trapping period of the eleven quadrats in the pasture using rat traps, unless otherwise indicated. Of the eleven quadrats, three were on flat areas, two on low dunes, five on moderate dunes, and one on a high dune. From an examination of the topography in the field and of a topographic map of the range the dune areas on which the quadrats were located were a fair sample of the pasture as a whole; and the data have been used directly for computations. All the rodents, even of the five major species taken with the rat traps, were not removed from the quadrats after the five-day and -night trapping period. However, it was not unlikely that the residual population about balanced the

Quadrat No.	2	3	4	8	10	TOTALS
Dune Height	low	moderate	moderate	flat	flat	
Soil	loose sand	loose sand	loose sand	tight	tight	
Crown Density	high	moderate	moderate	high	moderate	
Grazing Intensity	light	light	light	light	light	
Dipodomys		1	3			4
Onychomys	2		4	1	3	10
Sigmodon			1			1
Peromyscus			2	1		3
Reithrodontomys		3	6	2	5	16
Cryptotis	3	2			1	6
X				2		2
TOTALS	5	6	16	6	9	42

Table 6. Mammal catches with Museum Special traps substituted for rat traps which had been operated five consecutive days and nights. The Museum Specials were operated two days and nights.

influx from surrounding areas and compensated for those individuals caught but whose home ranges were principally outside the quadrat area.

In as much as very few individuals of kangaroo rats, grasshopper mice, cotton rats, ground squirrels, and pack rats were taken in the Museum Special traps it was believed that these species were adequately represented by the catches with the rat traps. As the quadrats were 0.5 acres in area, and the quadrat sites were representative of the terrain, the populations per acre for these species have been ascertained by computing the average catch per quadrat and multiplying by two to convert to a per acre basis. The populations of white-footed mice, harvest mice, and least shrews were not adequately represented by the catches with the rat traps as was evidenced by the high catch of these species when the Museum Special traps were substituted for the rat traps. The Museum Specials were operated only two days and nights for the rat traps, which had been operated five days and nights, had served as bait stations; and it was thought that the catch in the two days and nights period was adequate. In Pasture 19 five of the quadrats (exclusive of one in the cattle exclosure) had Museum Special traps substituted for the rat traps after the five-day and -night trapping period. The sites of these quadrats were one low dune, two moderate dunes, and two low flat areas between dunes. These sites were fairly representative of the terrain in the pasture and have been considered a representative sample. To obtain the populations of white-footed mice, harvest mice, and least shrews, the average number of catches of these species using the rat traps and Museum Specials in the five quadrats have been determined.

The pasture populations were computed by multiplying the per acre catch by the number of acres (160) in the pasture. The populations per acre and for the pasture are presented in Table 7. The average population per acre of the eight mammal species (seven Rodentia and one Insectivora) was 39.2 individuals. These data would most likely represent a minimum rodent population as no pocket gophers

Species	Average number per acre	Pasture Populations
Dipodomys	14.6	2,336
Onychomys	11.6	1,856
Reithrodontomys	7.2	1,152
Cryptotis	2.4	384
Peromyscus	1.6	256
Sigmodon	1.0	160
Neotoma	0.2	32
Citellus	0.2	32
X	0.4	64
TOTALS	39.2	6,272

Table 7. The species per acre populations are based on the rat trap catches from eleven quadrats for kangaroo rat, grasshopper mouse, cotton rat, ground squirrel and pack rat, and on the Museum Special catches and the rat trap catches for the white-footed mouse, harvest mouse, and least shrew.

were included in the study, no pocket mice were secured, and many of the ground squirrels were in hibernation. It safely can be stated that the rodent population (exclusive of the least shrew) in this moderately to lightly grazed pasture was between 40 and 50 individuals per acre.

Within the pasture the highest populations taken with the rat traps were on the high dunes and the lowest in the low flat areas between the dunes, although Quadrat 11 was an exception. The high catch of 13 individuals in Quadrat 11 was due to a take of eight individuals from three traps in one corner of the quadrat where a slight rise in the ground occurred and there was exposed loose sand between the vegetation. Excluding these three traps, only five individuals were trapped from Quadrat 11. The highest population of kangaroo rats was 38 per acre taken from a high dune and the lowest was two per acre from a flat area. This would indicate the kangaroo rats preferred the higher dunes with a light to moderate crown canopy and abundant loose sand. The affinity of kangaroo rats for loose sand in patches and a moderate to light crown canopy was further evidenced by high catches at the east end of Quadrat 7 and from line A of Quadrat 2. These two locations had more exposed sand and a lower crown density than the rest of their respective quadrats. Conversely few kangaroo rats were trapped from the low flat areas with tight soil. No particular difference was noted on the moderate and low dunes where the kangaroo rat populations varied from 6 to 20 per acre and averaged 14.6 for the seven quadrats.

No correlation was noted with the grasshopper mice and they seemed to have a universal distribution. Cotton rats were allied to the lower dunes with a dense vegetative crown canopy, as was demonstrated in lines C of Quadrats 2 and 5 where catches of this species were made under these conditions. As only one ground squirrel was taken this was hardly sufficient to compute data. Most of these individuals were in hibernation. The catch of one pack rat would seem about proper for the houses of these individuals were very scarce on the range except at the buildings about the wells. No particular correlations were noted with the white-footed mice, harvest mice, and least shrews, although there was a tendency to catch the latter two species in areas of high crown density.

Summary

Eleven rat trap quadrats were operated in a moderately grazed pasture for five days and nights, after which Museum Special traps were substituted in five of the quadrats and continued in operation two days and nights. Seven species of rodents and one of insectivores were caught. Kangaroo rats and grasshopper mice comprised 92 per cent of all catches. The rat traps functioned satisfactorily for taking all but the smaller rodents, as was evidenced by relatively high catches of small rodents with the Museum Special traps and low catches of the larger species such as the kangaroo rat. Per acre and pasture populations were computed using both rat trap and Museum Special trap data. The per acre population was 39.2 individuals which was low as no pocket gophers were included in the study. The rodent population per acre in this moderately grazed pasture was from 40 to 50 individuals per acre. The highest populations of kangaroo rats were caught on the high dunes with a light vegetative crown density and abundant loose sand. The lowest populations of kangaroo rats and of all rodents as a group were taken from low flat areas of tight soil. Grasshopper mice had a wide-spread distribution. Cotton rats, harvest mice, and least shrews were allied to a dense vegetative crown canopy.

PASTURE 20 (LIGHTLY GRAZED)

Description of Pasture

The pasture was managed as a lightly grazed, continuous, yearlong pasture. It was 213 acres in extent and the map in Figure 3 shows the location with reference to the other pastures. Reconnaissances were made on September 28 and October 28, 1949.

The category "lightly grazed" aptly applied to this pasture as there were numerous grass fruiting stalks, a dense vegetative crown canopy, and very little evidence of cropping by livestock. A real difference existed between Pasture 19 (moderately grazed) and Pasture 20 (lightly grazed) as regards density and height of grasses and forbs. The major portion of Pasture 20 was more closely allied to the pastures to the east where the soils were tighter, loose sand was less common, and consequently less sand lovegrass was present. Pasture 19 was predominately sagebrush and sand lovegrass; loose sand was common, frequently exposed between vegetative crown canopy; and the pasture was definitely allied with Pastures 17 and 18 to the west. The south and southeast portions of Pasture 20 had loose sand plus sand lovegrass, and was similar to the western pastures. Thus, Pasture 20 was a transition between the loose sand and lovegrass pastures to the west and the pastures with a little tighter soil, less sand lovegrass, and more blue grama to the east.

The aspect on the dunes on September 28 was of the purplish-tan fruiting stalks of sand lovegrass, gray-green of sagebrush, and brown and tan of grass fruiting stalks. In the area between the dunes the yellow-green of horseweed and the light gray stalks of annual eriogonum were obvious. On October 28 the dunes showed the tan-colored dried fruiting stalks of sand lovegrass, the gray-green of the sagebrush, and the brown and tan fruiting stalks of other grasses. In the low areas between the dunes the horseweed had become dark brown and was less conspicuous. The browns, tans, and grays of the fruiting stalks of grasses, scattered gray-green clumps of sagebrush, and the light gray stalks of annual eriogonum characterized the low areas on October 28 and for the rest of the winter.

The plant species in the pasture noted as common were sand lovegrass, sand bluestem, little bluestem, blue grama, sand dropseed, horseweed, annual eriogonum, and sagebrush. Also present were switchgrass; indiangrass; Riddell's senecio; partridge pea; western daisy fleabane; western ragweed; sand plum; broomweed (near Well 4); sedge, _Cyperus schweinitzii_ Torr.; _Aplopappus divaricatus_; _Heterotheca subaxillaris_ (Lam.) Britt. and Rusby. Tree growth was absent.

The dunes were generally low to moderate in elevation with high dunes in the south, southeast, and central sections of the pasture. Soils were typically sandy and loose on the dunes, becoming tighter on the low dunes and definitely tight on the areas between the dunes. Soil types were Pratt fine sandy loam, Pratt loamy fine sand, Tivoli loamy fine sand, Tivoli sand, and Albion sandy loam. Tivoli loamy fine sand was most common, with Albion sandy loam in the northeast, Pratt fine sandy loam near Well 4, and Tivoli sand on the high and moderately high dunes in the south-central portion of the pasture. The Pratt loamy fine sand was represented in relatively small scattered patches.

Data and Discussion

The data for the eleven quadrats are presented in Table 8. Dune height, crown density, soil, and grazing classifications have been explained previously. Of the eleven quadrats two were on high dunes, six on moderate dunes, two on low dunes, and one on a low flat area. The quadrat sites reflected the terrain of the pasture except for the low flat area which was present in a greater proportion than the single quadrat would indicate.

The soil conditions were allied to the dune heights, being tight on low areas between the dunes, loose sand on low and moderate dunes, and loose sand in patches on the high dunes. Vegetative crown density, which consisted of sagebrush, dry grasses, and dry forbs, was high on five of the dunes, moderate on four, and light on two. All the low dunes, the low flat area between the dunes, and two of the six moderate dunes had a high crown density. The light crown densities were on the higher dunes. Grazing was very light on all the quadrats and according to the Grazing Service classification of range use would have been considered "slight."

The following mammal species were caught with the rat traps: kangaroo rat, grasshopper mouse, cotton rat, spotted ground squirrel, white-footed mouse, plains pocket mouse, silky pocket mouse, pack rat, pocket gopher, cottontail

Quadrat No.	1	2	3	4	5	6	7	8	9	10	11	TOTALS
Dune Height	moderate	low	moderate	moderate	low	moderate	moderate	flat	high	moderate	high	
Soil	loose sand	loose sand	loose sand	loose sand	loose sand	loose sand	loose sand	tight	loose sand in patches	loose sand	loose sand	
Crown Density	moderate	high	moderate	high	high	high	moderate	high	light	moderate	light	
Grazing Intensity	light	light	light	light	light	light	light	light	light	light	light	
Dipodomys	12	9	9	8	7	9	8		9	5	8	84
Onychomys	6	2	4	5	3	7	4	2	6	2	3	44
Sigmodon				5	8	4	1			2		20
Citellus	1		1									2
Peromyscus	1			1				1				3
Perognathus f.				1								1
Perognathus h.								1				1
Neotoma						1	1					2
Geomys									1			1
Sylvilagus											1	1
X									1	1		2
TOTALS	20	11	14	20	18	21	14	4	17	10	12	161

Table 8. Small mammal catches per quadrat for the eleven quadrats operated with rat traps in Pasture 20.

rabbit, and harvest mouse (Fig. 14). The only additional species caught with the Museum Special traps was the least shrew.

Ten species of mammals were taken but only three—the kangaroo rat, grasshopper mouse, and cotton rat—in quantity. The kangaroo rats comprised 52 per cent of the total catch of 161 and had an incidence of 90 per cent; the grasshopper mice were 27 per cent of the total catch and had an incidence of 100 per cent; and the cotton rats, 12 per cent and had an incidence of 50 per cent. The three species comprised 91 per cent of all the individuals caught.

Kangaroo rats were present in all quadrats except Quadrat 8 which was on a low flat area with tight soil. The high dunes with loose sand in patches did not have the highest kangaroo rat catches as was exhibited in Pasture 20. The kangaroo rat catches on the two high dunes were nine and eight, and the average kangaroo rat catch per quadrat from the low and moderate dunes was 8.4. No explanation was apparent for the relatively low populations on the high dunes. The relatively high populations on the low dunes were due to small areas within the quadrats where the crown density was light to moderate and exposed loose sand was present. The kangaroo rat catches from these quadrats were taken from such localized areas. No particular correlations were noted with the catches of grasshopper mice other than they seemed to have a uniform, wide-spread distribution. Cotton rats were predominately taken on the dunes with loose sand and a high crown density. While these animals preferred dense vegetative cover, they were not taken on low flat areas with tight soil and a high crown density. A high catch (10) of harvest mice was taken with the Museum Special traps from Quadrat 4 which was on a moderate dune of about 15 feet in height and had a high crown density. This quadrat had a total catch of 36 individuals using the rat traps and Museum Special, which would indicate a population of 72 per acre. As a whole the quadrat catches showed a more wide-spread distribution of rodents with less variation between quadrats than in Pasture 19.

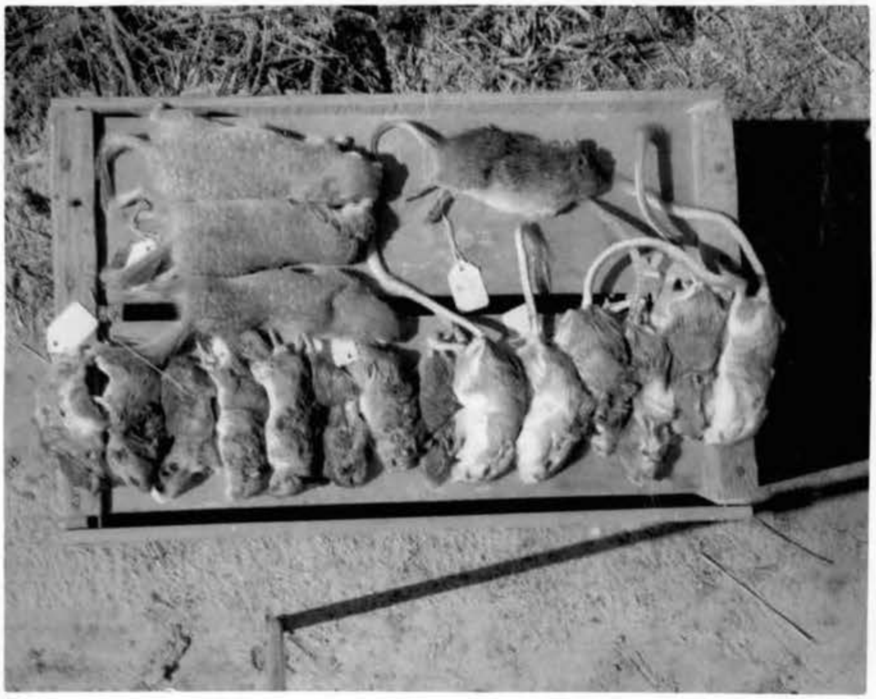

Fig. 14. A typical catch of rodents from a pasture. Included in the photograph are spotted ground squirrels (upper left), cotton rat (upper right), kangaroo rats (lower right), grasshopper mice (lower center), and white-footed mice (lower left).

From the data obtained with the Museum Special traps (Table 9), the rat trap catches for the five-day and -night period gave satisfactory results for kangaroo rats, grasshopper mice, cotton rats, spotted ground squirrels, and pack rats. Harvest mice and the least shrew were not truly represented by the rat trap catches as was evidenced by a relatively high catch after substitution of the Museum Special traps. The single plains pocket mouse taken with a rat trap in Quadrat 8 was the only individual of the species taken during the entire period of study. Evidently the traps, types of bait, or methods employed were not suitable for catching this species. It is likely, also, that low temperatures had an effect in keeping the pocket mice inactive. The single catch has been used in the computations of the populations. The catch of a single specimen of silky pocket mouse in a rat trap was also unusual. The species was taken in other pastures with the Museum Special traps, although only the one individual was trapped in Pasture 20. The catch of a pocket gopher definitely did not represent the status of this species as it is predominately fossorial and normally not taken in surface trapping. The record was not used for population computations. The catches of white-footed mice with the Museum Specials indicated a satisfactory sample was obtained with the rat traps. This condition was contradictory to that found in other pastures. The data from the eleven quadrats in which the rat traps were operated have been used for computations of populations of the white-footed mouse.

A sufficient number of quadrats were not placed on the low flat areas between the dunes in the pastures. Therefore, to compute the populations the data from the single quadrat on the low flat area have been doubled and the total number of quadrats considered as 12. This procedure applies to those species in which the catches with the rat traps have been used for the computations. As each quadrat was 0.5 acre the average population per acre for each species has been computed by averaging the catch of the 12 quadrats and

Quadrat No.	1	2	4	8	11	TOTALS
Dune Height	moderate	low	moderate	flat	high	
Soil	loose sand	loose sand	loose sand	tight	loose sand	
Crown Density	moderate	high	high	high	light	
Grazing Intensity	light	light	light	light	light	
Dipodomys	1				1	2
Onychomys		1	3	1		5
Reithrodontomys	1	3	10			14
Sigmodon			1			1
Cryptotis			2			2
X	1				1	2
TOTALS	3	4	16	1	2	26

Table 9. Mammal catches in Pasture 20 from the Museum Special traps substituted for the rat traps. The rat traps had been in operation five days and nights, and the Museum Specials were operated two days and nights.

multiplying by two. The catches per acre for the species are presented in Table 10. For the harvest mouse and least shrew the per acre catches have been computed on the catches with the Museum Special traps from the five quadrats in which they were substituted for the rat traps. Neither the harvest mouse or least shrew were taken in the rat traps on any of the quadrats where the Museum Specials were substituted.

The computed rodent population, inclusive of the least shrew and cottontail rabbit, was 34.5 individuals per acre. As no pocket gophers were included in the study and most of the spermophiles were in hibernation the rodent population was considered to have been 35 to 40 per acre. The total pasture population of small mammals was 7,349 individuals in this lightly grazed pasture.

Summary

Eleven quadrats were operated with rat traps in the lightly grazed Pasture 20 and Museum Special traps were substituted in five of these. The rat traps were operated five consecutive days and nights and the Museum Specials two days and nights. The paste bait mixture of peanut butter, rolled oats, and bacon grease was used. Ten species of rodents, one of insectivore, and one of lagomorph were caught. Kangaroo rats, grasshopper mice, and cotton rats comprised 91 per cent of the total catches with the rat traps. Museum Special trap catches indicated a high population of harvest mice and ten were taken from a single quadrat. The lowest rodent populations were on low flat areas. A uniform population was present on the high, moderate, and low dunes. No correlation existed between high catches of kangaroo rats and high dunes. Grasshopper mice occurred uniformly over the entire pasture. A high vegetative crown density was correlated with cotton rat and harvest mouse populations. The average population of rodents was determined as 35 to 40 per acre, which was lower than in the moderately grazed Pasture 19.

Species	Average number per acre	Pasture populations
Dipodomys	14.0	2,982
Onychomys	7.7	1,640
Reithrodontomys	5.6	1,193
Sigmodon	3.3	703
Cryptotis	0.8	170
Peromyscus	0.7	149
Citellus	0.3	64
Neotoma	0.3	64
Perognathus h.	0.3	64
Perognathus f.	0.2	43
Sylvilagus	0.2	43
X	1.1	234
TOTALS	34.5	7,349

Table 10. The species per acre populations are based on catches from eleven quadrats which have been weighted to twelve quadrats to compensate for a discrepancy between quadrat sites and terrain. The data for harvest mice and least shrews are based on the catches with Museum Special traps.

PASTURE 24 (OVERGRAZED)

Description of Pasture

Pasture 24 was managed as an overgrazed, continuous, yearlong pasture. It comprised 107 acres; for location see the map, Figure 3.

Due to the favorable growing seasons of 1948 and 1949 the intensity of grazing in Pasture 24 was not as severe as was desired, and the Grazing Service category of "close" would more aptly describe conditions existing in the fall of 1949. Nevertheless it was more heavily grazed than the light and moderately grazed Pastures 19 and 20 as was evidenced by more bare soil, fewer fruiting stalks of grasses, fewer annuals, and closer cropping of grasses. The sand lovegrass was well utilized on the dunes with a noticeable reduction of its crown canopy. Moderate and high dunes, and the accompanying sand lovegrass, were fewer in this pasture than in Pastures 17, 18, and 19. Flat areas and low dunes with blue grama, sagebrush, and horseweed were common thus allying the pasture with Pastures 26 and 28.

The aspect on the dunes on September 30 was the gray-green of the sagebrush, purplish-tan of sand lovegrass, tans and browns of grass fruiting stalks, and light gray of isolated stalks of annual eriogonum. In the low areas between the dunes the yellow-green of horseweed predominated. Later in the season the sand lovegrass became tan in color and the horseweed turned brown.

The following plant species were common in the pasture: sand lovegrass, blue grama, sand bluestem, little bluestem, sand dropseed, annual eriogonum, horseweed, and sagebrush. Also noted were wild ryegrass; indiangrass; showy gaillardia; western daisy fleabane; *Aplopappus divaricatus*; loasa, *Mentzelia stricta* (Osterhout) G. W. Stevens; and prickly pear cactus, *Opuntia* sp.

The terrain consisted principally of low dunes and low flat areas between dunes with a few high dunes and moderate dunes in the northwest and north, and moderate dunes in the southwest.

Soils were sandy with considerable areas of tight soil between the dunes and on some of the low dunes. On moderate and high dunes the soil was of loose sand. Tivoli loamy fine sand was the predominate soil type with an area of Pratt loamy fine sand extending northwest-southeast through the pasture, and on which blue grama and sagebrush predominated. One relatively small area each of Pratt fine sandy loam and Tivoli sand were present.

Data and Discussion

In accordance with the studies in Pastures 19 and 20, eleven quadrats were operated in Pasture 24, exclusive of the two quadrats in the cattle exclosure. Of the eleven quadrats three were on high dunes, four on moderate dunes, three on low dunes, and one on a low flat area between the dunes. Field reconnaissances and examination of a topographic map indicated that the quadrat sites were representative of the terrain in the pasture and consequently have been used directly in population computations. The high dunes had the customary loose sand in patches and the amount of exposed loose sand decreased with the heights of the dunes. All the moderate dunes had loose sand but not in patches as on the high dunes. The low dunes had a moderately tight soil and the soil in the quadrat on the low flat area was definitely tight. Crown density was moderate to light on all but the quadrat on the low flat area where it was high. Grazing intensity was moderate to heavy but was light on Quadrat 8.

The following mammal species were taken in the pasture: kangaroo rat, grasshopper mouse, cotton rat, spotted ground squirrel, white-footed mouse, harvest mouse, silky pocket mouse, least shrew, eastern mole, Scalopus aquaticus intermedius (Elliot), and cottontail rabbit. Table 11 presents the catches for the eleven quadrats using the rat traps. The kangaroo rat was the most abundant species having an incidence of 100 per cent, and the 93 individuals caught represented 63 per cent of the total rat trap catch on the eleven quadrats. Grasshopper mice were second in numerical importance, had an incidence of 100

Quadrat No.	1	2	3	4	5	6	7	8	9	10	11	TOTALS
Dune Height	moderate	low	low	low	moderate	moderate	moderate	flat	high	high	high	
Soil	loose sand	moderate tight	moderate tight	loose sand	loose sand	loose sand	loose sand	tight	loose sand in patches	loose sand in patches	loose sand	
Crown Density	moderate	moderate	moderate	moderate	moderate	moderate	light	high	light	moderate	moderate	
Grazing Intensity	over-grazed	over-grazed	moderate	over-grazed	over-grazed	over-grazed	over-grazed	light	moderate	over-grazed	over-grazed	
Dipodomys	5	2	1	11	10	9	9	1	15	20	10	93
Onychomys	4	5	3	5	3	6	4	1	4	4	1	40
Sigmodon								1				1
Citellus	2	1	1						1	1		6
Peromyscus		1										1
Reithrodontomys									1			1
Scalopus					1							1
Sylvilagus						1						1
X										2	1	3
TOTALS	11	9	5	16	14	16	13	3	21	27	12	147

Table 11. Rodent catches with rat traps from eleven quadrats operated five days and nights in Pasture 24.

per cent, and a catch of 40 which was 27 per cent of the total catch. The kangaroo rats and grasshopper mice, combined, formed 90 per cent of all the mammals caught with the rat traps during the five-day and -night trapping period.

The highest numbers of kangaroo rats were caught from quadrats on the high dunes and the lowest numbers from the low dunes and low flat areas between the dunes. This correlation was probably allied with the amount of loose sand being greatest on the high dunes, and progressively less with a decrease in dune height. The grasshopper mice were found on all the quadrats and seemed to have a widespread distribution. Harvest mice were taken in all five quadrats operated with Museum Special traps and their distribution and population could not be correlated with high vegetative crown density. The highest rodent population trapped with both rat traps and Museum Special traps was 36 individuals from Quadrat 10 located on a high dune.

The data for the catches with the Museum Special traps from the five quadrats (exclusive of the one quadrat in the cattle exclosure) are given in Table 12. Kangaroo rats, grasshopper mice, cotton rats, spotted ground squirrels, and white-footed mice were adequately represented in the catches with the rat traps, as a low catch of these animals resulted from the substitution of the Museum Special traps. A seemingly high catch of grasshopper mice was obtained with the Museum Special traps but it was probably due to the indefinite home range of the species and its wandering tendency. The rat trap catches of the above mentioned species have been used directly for average per acre and pasture population computations. The catches with the Museum Specials showed the harvest mouse, least shrew, and silky pocket mouse were not adequately represented in the rat trap data. Therefore, the data from the Museum Special traps have been used to determine average catch per quadrat and populations of these species. The catch of the mole was not included in the computations as the single catch did not give an accurate sample of the species.

Quadrat No.	1	2	6	8	10	TOTALS
Dune Height	moderate	low	moderate	flat	high	
Soil	loose sand	moderate tight	loose sand	tight	loose sand in patches	
Crown Density	moderate	moderate	moderate	high	moderate	
Grazing Intensity	over-grazed	over-grazed	over-grazed	light	over-grazed	
Dipodomys					3	3
Onychomys	1	3	4	1	1	10
Reithrodontomys	1	1	6	1	2	11
Cryptotis			1			1
Perognathus f.			2			2
X					3	3
TOTALS	2	4	13	2	9	30

Table 12. Catches in Pasture 24 with Museum Special traps operated two days and nights subsequent to operating rat traps five days and nights at the same locations.

Table 13 presents the average species catch per acre and the total populations in the pasture. The average number of individuals per acre was 33.1. Populations of least shrews and cottontail rabbits have been included but not of pocket gophers and ground squirrels. The rodent population on the overgrazed Pasture 24 was probably 35 to 40 per acre.

Summary

Eleven quadrats were operated five days and nights with rat traps in an overgrazed pasture; after which Museum Special traps were substituted in five of the quadrats and operated two days and nights. A paste bait was used. Seven species of rodents, two of insectivores, and one of lagomorph were caught. Kangaroo rats and grasshopper mice comprised 90 per cent of the rat trap catches. The Museum Special trapping showed a moderately high population of harvest mice which could not be correlated with high vegetative crown density. The rat traps were not adequate to obtain representative populations of the smaller rodents. High kangaroo rat populations were correlated with high dunes. Grasshopper mice had a universal distribution. The rodent population was 35 to 40 individuals per acre in this overgrazed pasture.

Species	Average number per acre	Pasture populations
Dipodomys	16.9	1,808
Onychomys	7.2	770
Reithrodontomys	4.4	471
Citellus	1.1	118
Perognathus f.	0.8	86
Cryptotis	0.4	43
Sigmodon	0.2	21
Peromyscus	0.2	21
Sylvilagus	0.2	21
X	1.7	182
TOTALS	33.1	3,541

Table 13. Species per acre and total pasture populations in the overgrazed Pasture 24. Harvest mouse, least shrew, and pocket mouse populations are based on catches with the Museum Special traps and all others from rat trap catches.

THE EFFECT OF GRAZING INTENSITY ON RODENT SPECIES AND POPULATIONS AS EVIDENCED BY TRAPPING DATA FROM A LIGHTLY GRAZED, A MODERATELY GRAZED, AND AN OVERGRAZED PASTURE

Data and Discussion

To determine the effect of grazing intensity on rodent species and populations the catches in the lightly grazed, moderately grazed, and overgrazed pastures will be compared. As eleven quadrats were operated in each pasture employing the rat traps, and of the eleven, Museum Special traps were substituted in each of five, numerically the pastures can be compared. The incidences of the species by pastures are presented in Table 14. Of the seven species trapped most frequently (kangaroo rat, grasshopper mouse, cotton rat, spotted ground squirrel, white-footed mouse, harvest mouse, and least shrew) all occurred in each of the pastures. Of the remaining four species caught (ignoring the catch of a single pocket gopher and a mole) the pack rat, silky pocket mouse, and cottontail rabbit were trapped in two of the pastures and a single specimen of plains pocket mouse was taken from the lightly grazed pasture. These data show a uniformity of rodent species over the range as a whole regardless of grazing intensity.

The data of the catches in the pastures (Tables 5, 8, and 11) demonstrate a considerable intrapasture variation, and it was not deemed feasible to directly compare the pasture populations as the sites selected in each of the pastures did not compare. That is the numbers of quadrats located on high, low, moderate dunes, and low flat areas were not the same in each of the pastures. The data have been compared by quadrat sites for the dune heights seemed to be a very influential factor in determining rodent populations. A comparison of the average catch per quadrat for each species for the high dunes in each pasture, the moderate dunes, the low dunes, and the low flat areas are presented in Table 15. Unfortunately under this arrangement the division of the total number

Pasture Number	20	19	24
Grazing Intensity	light	moderate	overgrazed
Dipodomys	X	X	X
Onychomys	X	X	X
Sigmodon	X	X	X
Citellus	X	X	X
Peromyscus	X	X	X
Reithrodontomys	X	X	X
Neotoma	X	X	
Perognathus f.	X		X
Perognathus h.	X		
Sylvilagus	X		X
Cryptotis	X	X	X

Table 14. A comparison of species incidence in each of the pastures based on rat trap and Museum Special trap data. The Xs designate the species caught in the respective pastures. In general the data show a homogeneity of species in the pastures regardless of grazing intensity.

QUADRAT SITES	LOW FLAT AREAS			LOW DUNES			MODERATE DUNES			HIGH DUNES		
Pasture	20	19	24	20	19	24	20	19	24	20	19	24
Grazing Intensity	light	moderate	over grazed	light	moderate	over-grazed	light	moderate	over-grazed	light	moderate	over-grazed
Number of Quadrats	1	3	1	2	2	3	6	5	4	2	1	3
Dipodomys		3.3	1.0	8.0	5.0	4.6	8.5	8.2	8.25	8.5	19.0	15.0
Onychomys	2.0	3.3	1.0	2.5	4.5	4.3	4.6	8.2	4.25	4.5	4.0	3.0
Peromyscus	1.0				0.5	0.3	0.3					
Citellus					0.5	0.6	0.3		0.5			0.6
Sigmodon			1.0	4.0	1.5		2.0	0.6				
Perognathus h.	1.0											
Perognathus f.							0.2					
Reithrodontomys		1.0										0.3
Neotoma		0.3					0.3					
Geomys										0.5		
Sylvilagus									0.25	0.5		
Scalopus									0.25			
X												1.0
TOTALS	4.0	7.9	3.0	14.5	12.0	9.8	16.2	17.4	13.5	14.0	23.0	19.9

Table 15. Average rodent catch per quadrat for pastures compared by dune heights. Only the data from the rat trap catches are included.

of quadrats per pasture (11) results in a very limited number of samples for each quadrat site. For instance in Pasture 19 only one quadrat was on a high dune and a catch of 19 kangaroo rats was obtained from this quadrat. The table does show the relatively low catch of all species on the low flat areas between the dunes, although the thirteen-lined ground squirrels which are supposed to consider these low flat areas as favored habitat (Brown 1946, p. 454; Trowbridge 1941, p. 40) were in hibernation. A large number of species (nine) was taken from the moderate dunes but with low population figures for some of these species their occurrence may merely have been coincidental. The universal distribution of grasshopper mice and the high catch of kangaroo rats on the high dunes is evident.

The data in Table 15 do not indicate very close correlation between rodent populations and grazing intensities and to present these data in better form the average species catches per quadrat for each quadrat site have been added for a pasture summation and are presented in Table 16. For example, for kangaroo rats in Pasture 20 the figures added together were 0.0 from the low flat area, 8.0 from the low dune, 8.5 from the moderate dune, and 8.5 from the high dune making a total of 25. The data in Table 16 show that the highest kangaroo rat catches were from the moderately grazed pasture but these data may be quite strongly influenced by the catch of 19 from the one quadrat on a moderate dune in Pasture 19. The data from both the moderate and overgrazed pastures show a higher catch of kangaroo rats than those of the lightly grazed pasture. For grasshopper mice the moderately grazed pasture gave a definitely higher population than either lightly or overgrazed pastures. White-footed mice and cotton rats both show a higher catch in the lightly grazed pasture and the catch is progressively higher with the lighter grazing intensity. The data for the spotted ground squirrel are the opposite of those for the white-footed mice and cotton rat, and the highest population was in the overgrazed pasture. Catches of other mammals were too few to be significant.

Pasture	Grazing Intensity	Number of Quadrats	Dipodomys	Onychomys	Peromyscus	Citellus	Sigmodon
20	light	11	25.0	13.5	1.3	0.3	6.0
19	moderate	11	35.5	22.0	0.5	0.9	2.1
24	over-grazed	11	28.5	12.5	0.3	1.7	1.0

Table 16. Comparison of average pasture populations of the five rodent species caught most frequently with rat traps. The data were obtained from the average rodent catches per quadrat for each quadrat site as presented in Table 15.

It should be borne in mind that the terms "light," "moderate," and "overgrazed" were merely ocular estimates and do not possess an objective, standardized meaning. The favorable growing seasons of 1948, 1949, and the years preceding up to 1940 have resulted in an excellent growth of forage on the Experimental Range, and the pastures which have been classified as overgrazed have been relatively moderately grazed. These "overgrazed" pastures are not compared to the overgrazed pastures of private holdings where the vegetation is far more profoundly affected. This lack of severe overgrazing may be reflected in the rodent populations and undoubtedly species like the kangaroo rat would have a much higher population on a severely overgrazed range. Costello (1944, p. 324) estimated a population of 300 kangaroo rats per acre on a severely overgrazed abandoned field in northeastern Colorado.

Biomass

To illustrate the relationships of the productivity of the pastures for cattle and rodents, the biomass of each has been determined (Table 17). Biomass as defined by Allee, Emerson, et al. (1949, p. 526) is ". . . a total community weight per unit of area, consisting of many different intracommunity biomasses." The rodent and cattle weights are considered as intracommunity biomasses.

The biomass of the rodents has been computed for each pasture by multiplying the population per acre for each species (Tables 7, 10, and 13) by the average weight of individuals for that species, and then totalling the species per acre biomasses. Average weights for the species were obtained from Trowbridge (1941, 1942) and McMurry (1942, 1943), and have been verified from other literature sources. The average weights, in pounds, used in the computations were: kangaroo rat, 0.15; grasshopper mouse, 0.08; spotted ground squirrel, 0.32; cotton rat, 0.28; pack rat, 0.48; white-footed mouse, 0.04; harvest mouse, 0.03; plains pocket mouse, 0.06; silky pocket mouse, 0.02; least shrew, 0.01; and cottontail rabbit, 1.71

Pasture Number	Grazing Intensity	Biomass in pounds Rodents	Cattle
20	light	4.21	29.6
19	moderate	4.38	37.7
24	over-grazed	5.14	52.9

Table 17. Comparison of biomasses of rodents and cattle from Pastures 20, 19, and 24. Note the progressive increase of the biomass of rodents with the heavier grazing intensity.

The cattle biomass has been obtained from McIlvain, Savage, et al. (1949, p. 14) and represents the average gain per head of stock in continuously grazed pastures for the period 1941 to 1949. The gain per acre was higher in the over-grazed pasture as the rate of stocking was higher. The gain per head was significantly higher in the lighter grazed pasture.

Table 17 shows that the biomass of rodents per acre was from four to five pounds. The figures do not include pocket gophers or hibernating ground squirrels and, from observations on the abundance of these species and from the computed data, the maximum biomass of rodents per acre in each of the pastures was about six pounds. The biomass of cattle varied from about 30 to 50 pounds per acre and under proper grazing would have been approximately 40 pounds per acre. The grazing intensities of the pastures were materially less than the categories "light," "moderate," and "overgrazed" would infer. Using the figures of 6 pounds of rodents per acre and of 40 pounds of cattle, the biomass of rodents was 15 per cent of the biomass of cattle.

The figure of 15 per cent should be examined from the viewpoint of actual competition between the two groups of animals. The kangaroo rats in each of the pastures comprised at least one-half of the rodent biomass. The principal food of kangaroo rats consists of seeds which are not of direct forage value to the cattle. Grasshopper mice, the second most abundant rodent on the range, feed primarily on insects. All the species of rodents have food habits which, to a greater or lesser extent, do not deplete the amount of forage available for cattle. The competitive biomass of rodents and cattle for the forage would be materially reduced from the 15 per cent figure as determined solely on weights.

In summation, from the standpoint of production, the rodents, when compared with the cattle, are actually a small portion of the productive capacity of properly stocked ranges.

Summary

Kangaroo rats have a high population regardless of grazing intensity but will be more abundant on moderately grazed and overgrazed ranges than on lightly grazed ranges. Grasshopper mice will be more abundant on moderately grazed range than overgrazed or lightly grazed. White-footed mice, and cotton rats will decrease in numbers as the grazing intensity increases and will have higher populations on lightly grazed ranges. Populations of spotted ground squirrels will be favored by higher grazing intensities and will be most common on overgrazed ranges. The biomass of rodents was 6 pounds per acre and of cattle 40 pounds per acre. The rodent biomass was 15 per cent that of the cattle.

COMPARISONS OF SMALL MAMMAL POPULATIONS FROM QUADRATS IN CATTLE EXCLOSURES AND QUADRATS IMMEDIATELY OUTSIDE EXCLOSURES IN EACH OF THE PASTURES

To ascertain the influence of grazing in the pastures as compared with ungrazed areas, quadrats were operated in cattle exclosures in the pastures, and immediately outside the exclosures. Each pasture (Pasture 19, 20, and 24) contained an exclosure of 1.5 to 2.0 acres in size (Fig. 3, p. 29). The exclosures were bounded by barbed wire and had been in effect since 1942. All cattle were excluded but rodents and rabbits had free access.

Pasture 20 - Lightly Grazed

The site of the exclosure was on a high dune with relatively steep north and east slopes, and long gradual, moderately steep south and west slopes. The exclosure extended from the crest of the dune at the north end, southward along the long gradual south slope. Inside the exclosure vegetation was abundant and a dense crown canopy of grasses, forbs, and sagebrush predominated. Although there was some loose sand within the exclosure, it was fairly well-bound by vegetation and there was no bare loose sand in patches.

Within the exclosure quadrats were located at the north and south ends and the corresponding quadrats outside the exclosure were located just north of the north end of the exclosure and south of the south end (Fig. 3, p. 29). The quadrats were operated with rat traps the customary five-day and -night period, after which the rat traps in the south pair of quadrats were removed and Museum Special traps substituted.

The data are presented in Table 18 with Quadrats 12 and 13 in the exclosure and Quadrats 10 and 11 outside. In comparing Quadrats 10 and 12, a higher catch (due to a higher catch of kangaroo rats) was obtained outside the exclosure. A low catch of but five individuals was obtained from Quadrat 12, and this was surprising in as much as a catch of 13 was obtained from Quadrat 13 which was also inside the exclosure and a few rods further north. The difference may be attributable to a dense vegetative crown canopy of sand lovegrass in Quadrat 13, and although a dense vegetative crown canopy was present in Quadrat 12 it was of mixed species of grasses and less sand lovegrass. The soil on Quadrat 13 was looser than on Quadrat 12. More exact measurements of variations in soils and vegetation might have produced more substantial evidence of the cause of the catch variation. A comparison between Quadrats 11 and 13 showed a higher catch of kangaroo rats outside the exclosure which was to be expected as Quadrat 11 had loose sand in patches and a light crown density. Quadrat 12 had a high crown density and although loose sand occurred it was not in patches. Conversely a catch of five cotton rats was obtained in Quadrat 13 whereas none were taken in Quadrat 11, indicating that the requirements of this species apparently are the reverse from those of the kangaroo rat. Data for the harvest mice and white-footed mice correspond with that of the cotton rat. The grass-hopper mice seemed to be present equally within and without the exclosure. Seven Museum Special traps were lost in a single night from Quadrat 13, and

	RAT TRAP DATA				MUSEUM SPECIAL DATA	
Quadrat Number	10	12	11	13	11	13
Dune Height	moderately high	moderately high	high	high		
Soil	loose sand	loose sand	loose sand in patches	loose sand		
Crown Density	moderate	high	light	high		
Grazing Intensity	light	ungrazed	light	ungrazed		
Dipodomys	5	1	8	4	1	
Onychomys	2	1	3	2		
Sigmodon	2	1		5		
Peromyscus		2		1		1
Reithrodontomys				1		4
Sylvilagus			1			
X	1				1	7
TOTALS	10	5	12	13	2	12

Table 18. Comparison of rodent catches inside exclosures and outside exclosures in Pasture 20. Quadrats 10 and 11 were outside the exclosure, and Quadrats 12 and 13 inside. After five days and nights of operation with rat traps, Museum Specials were substituted in Quadrats 10 and 12 and operated two days and nights.

these presumably were removed by cotton rats which were caught by a leg or other body part and dragged the traps away.

The data in Table 18 indicate that cotton rats, white-footed mice, and harvest mice prefer ungrazed areas with dense vegetative crown canopy, and soil loose but not exposed in patches between the vegetation; that kangaroo rats prefer the opposite of the above three species, or, a light vegetative crown canopy and abundant exposed loose sand in patches; and that grasshopper mice have no preference. Based on these data it is concluded that grazing produces conditions favorable for kangaroo rats; inimical for cotton rats, harvest mice, and white-footed mice; and indifferent for grasshopper mice.

Pasture 19 - Moderately Grazed

The cattle exclosure in Pasture 19 was situated on a low flat area with tight soil and the four quadrats, two within and two without the exclosure, were on this "flat." Within the exclosure the vegetation had a dense crown canopy and was ungrazed. Outside the exclosure the crown density was moderate and the grazing intensity was light to moderate.

Within the exclosure a quadrat was located at the north end and one at the south end, with the corresponding quadrats located immediately north and south of the exclosure. Museum Special traps were substituted for rat traps in the south pair of quadrats, Quadrats 10 and 12.

The data are presented in Table 19, with Quadrats 10 and 11 outside the exclosure and Quadrats 12 and 13 inside the exclosure. A comparison of Quadrats 10 and 12 showed no difference in catch of kangaroo rats, three being taken in each quadrat. Low populations of kangaroo rats have been associated with the low flat areas and likely the catches in these two quadrats came from adjacent dunes. A definite difference in catch was evidenced with the cotton rats as none were caught outside the exclosure and ten inside. The Museum Special traps showed a higher population of least shrews (1:8) and of white-footed mice (0:6) within the exclosure.

	RAT TRAP DATA				MUSEUM SPECIAL DATA	
Quadrat Number	10	12	11	13	10	12
Dune Height	flat	flat	flat	flat		
Soil	tight	tight	tight	tight		
Crown Density	moderate	high	moderate	high		
Grazing Intensity	light	ungrazed	light	ungrazed		
Dipodomys	3	3	6		3	
Onychomys	3		5			
Reithrodontomys	1		1		5	4
Neotoma			1			
Sigmodon		10		1		
Peromyscus		2		1		4
Cryptotis					1	8
X						3
TOTALS	7	15	13	2	9	19

Table 19. Comparison of rodent catches inside and outside cattle exclosures in Pasture 19. Quadrats 10 and 11 were outside the exclosure, and Quadrats 12 and 13 were inside. After five days and nights of operation with rat traps, Museum Specials were substituted in Quadrats 10 and 12 and operated two days and nights.

A comparison of the catches from Quadrats 12 and 13, both within the exclosure, showed a marked difference in numbers as 15 individuals were caught with the rat traps in Quadrat 12 and only two in Quadrat 13. The only apparent explanation was that the taller grasses were more predominant in Quadrat 12, and blue grama, a short grass, was plentiful in Quadrat 13, although in both places the vegetative crown density was high.

The two catches in Quadrat 13 inside the exclosure were one cotton rat and one white-footed mouse, neither species of which were taken from Quadrat 11. The catch in Quadrat 11 was relatively high for a quadrat on a low flat area and was due to catches of kangaroo rats in the northeast corner of the quadrat where loose sand was present.

The data from these quadrats within and without the cattle exclosure on a low flat area, showed that cotton rats, white-footed mice, and least shrews preferred the ungrazed areas with a high vegetative crown canopy. The grasshopper mice preferred the grazed areas outside the exclosure which were lightly to moderately grazed and had a moderate crown canopy. No grasshopper mice were taken within the exclosure. The kangaroo rats in the south pair of quadrats likely came from adjoining dunes and those from Quadrat 11 were caught in one corner of the quadrat where the soil was loose. Therefore, it is not felt that a comparison should be made for this species which is allied to a loose soil structure whereas the majority of the soils on the flat area were tight.

The preference of the grasshopper mice was different on this set of quadrats than on the set from Pasture 20. The explanation may be that the exclosure and the quadrats outside were situated on a high dune in Pasture 20 and on a low flat area in Pasture 19.

<u>Pasture 24 - Overgrazed</u>

The site of the exclosure in Pasture 24 was located on a large, high dune with the long axis north-south in direction and moderately steep slopes. The long axis of the exclosure was parallel to the long axis of the dune and occupied the east slope.

Quadrat 12 was established in the south end of the exclosure and Quadrat 10 was immediately to the south and outside the exclosure. Quadrat 13 had its long axis parallel to the long axis of the dune and was slightly north of the center of the exclosure. The corresponding quadrat, Quadrat 11, was outside the exclosure and immediately to the west on a gentle westerly slope. Museum Special traps were substituted for the rat traps in Quadrats 10 and 12. For locations of the quadrats see the map in Figure 3 (p. 29).

A comparison of the data (Table 20) for Quadrats 10 and 12 showed a very high catch of kangaroo rats outside the exclosure where loose sand was common and in patches, and the vegetative crown canopy had a density of moderate to light. The combined data of rat trap and Museum Special trap catches showed that only three kangaroo rats were taken within the exclosure in Quadrat 12 and 23 were taken from Quadrat 10, outside the exclosure. Cotton rats were caught only from the quadrat inside the exclosure. Harvest mice were taken from both quadrats but in greater numbers from Quadrat 12 (2:12). One spotted ground squirrel was taken from Quadrat 10 and one silky pocket mouse from Quadrat 12 but these numbers are too small to be significant.

A comparison of the catches from Quadrats 12 and 13 did not show a material difference and from the standpoint of soil, vegetation, and slope they were very similar.

The data from Quadrats 11 and 13 compare similarly with those of Quadrats 10 and 12, with kangaroo rats in greater numbers outside the exclosure and cotton rats, harvest mice, and white-footed mice in greater numbers inside the exclosure. No particular correlation was noted for grasshopper mice other than they were caught on all quadrats.

	RAT TRAP DATA				MUSEUM SPECIAL DATA	
Quadrat Number	10	12	11	13	10	12
Dune Height	high	high	high	high		
Soil	loose sand in patches	loose sand	loose sand	loose sand		
Crown Density	moderate	high	moderate	high		
Grazing Intensity	over-grazed	ungrazed	over-grazed	ungrazed		
Dipodomys	20	3	10	1	3	
Onychomys	4	1	1	1	1	
Citellus	1					
Reithrodontomys		1			2	6
Sigmodon		6		13		
Peromyscus				3		
Perognathus f.						1
X	2		1		3	1
TOTALS	27	11	12	18	9	8

Table 20. Comparison of rodent catches inside and outside cattle exclosures in Pasture 24. Quadrats 10 and 11 are outside the exclosure and Quadrats 12 and 13 are inside. After five days and nights of operation with rat traps, Museum Specials were substituted in Quadrats 10 and 12 and operated two days and nights.

Apparently the kangaroo rats prefer a grazed condition to ungrazed as was found from the data from quadrats in, and adjoining, the exclosure in Pasture 20. Cotton rats, harvest mice, and white-footed mice prefer ungrazed areas.

<u>Summary</u>

Trapping quadrats placed in exclosures and immediately outside exclosures in pastures having different grazing intensities were used to determine the effects of grazing on rodent species and numbers. On the vegetated sand dunes with loose sand present, kangaroo rats were favored by grazing and numbers showed a definite preference for grazed rather than ungrazed areas. On low flat areas between the dunes where the soil was tight kangaroo rat populations were low regardless of grazing. Cotton rats, harvest mice, white-footed mice, and least shrews favored a habitat that was ungrazed and with a high vegetative crown density, preferably of tall grasses. The least shrew was taken only from a low flat area that was ungrazed. Grasshopper mice exhibited a wide-spread distribution apparently unaffected by grazing intensity, although on a low flat area they were present in greater numbers in a moderately grazed pasture than in an ungrazed exclosure.

RODENT SPECIES AND POPULATIONS IN LIGHTLY GRAZED, MODERATELY GRAZED, AND OVERGRAZED PASTURES

INTRODUCTION

A comparative study of rodent species and populations in pastures with different grazing intensities was undertaken to determine the effects of the various grazing intensities on the rodent species and numbers. The pastures studied were Pasture 18 (lightly grazed), Pasture 17 (moderately grazed), and Pasture 21 (overgrazed). Trowbridge (1941, 1942) did most of his investigations in these pastures and the procedures used in the present study were, as much as possible, identical with those of Trowbridge. The sameness of the methods has permitted a comparison of populations prior to the initiation of the grazing programs on the range (Trowbridge's data) with present populations after eight years of grazing. The comparison has been made in a subsequent section. The rodent species and populations in each pasture and a comparison between the pastures is presented in this section.

METHODS

The procedures followed were the same as those in pastures previously reported except a grain bait mixture of equal parts wheat, milo maize, kaffir corn, and whole oats was used as bait. The quadrat sites were selected from a map of Trowbridge's quadrat sites and an effort was made to use the same locations. No information relative to Trowbridge's sites was available other than the map, but in most instances terrain features were sufficiently pronounced that the locations of the sites were quite obvious.

Eleven quadrats, ten on dune formations and one on a low flat area, were established in each of the pastures.

The quadrats were operated five consecutive days and nights in all pastures except Pasture 21 where, due to illness of the operator, the traps were not inspected on December 14. A relatively large catch was present the following day, December 15, which indicated that the previous day and night catch and the current day and night catch were both represented. The traps in Pasture 21 were left in the field for only the customary five-day and -night trap period. No correction has been made for the failure to inspect and rebait the traps on December 14 and the data have been used per se.

The study was conducted from November 28 to December 17 which was the same relative period of time when Trowbridge did his investigations. Quadrats were operated in Pasture 18 from November 28 to December 3; in Pasture 17 from December 5 to December 10; and in Pasture 21 from December 12 to December 17.

Rat traps were the only kind of traps used in the quadrats.

PASTURE 18 (LIGHTLY GRAZED)

Description

Pasture 18 was managed as a lightly grazed, continuous, yearlong pasture by the Southern Great Plains Field Station. It was 213 acres in area and for location see Figure 3 (p. 29). Reconnaissances of the pasture were made on September 26 and October 6.

An excellent stand of grass was present in the fall of 1949 and grass fruiting stalks and forbs were very abundant with sand lovegrass fruiting stalks particularly abundant on the dunes. Very little cropping of the herbage was noted and, except on the high dunes, the vegetative crown canopy of grasses and forbs was very dense. When walking over the area a high crown density was particularly noticeable in the western half of the pasture and the herbage was as high, or higher, than the sagebrush, making walking difficult. This was in marked contrast to the overgrazed pastures (Pastures 21 and 24) where one could easily walk between the clumps of sagebrush and the herbage was grazed to about the height of a lawn. According to the Grazing Service classification of range use the grazing intensity would have been "slight."

The aspect in late September and early October was predominately the gray-green of the sagebrush and purplish-tan fruiting stalks of sand lovegrass. Brown and tan fruiting stalks of other grasses and the light gray coloration of individual stalks of annual eriogonum were scattered throughout. The low areas between the dunes, where tighter soils prevailed, were readily distinguishable by the yellow-green of the horseweed. Clumps of sand plum and ill-scented sumac were scattered and were minor constitutents. No tree growth was present. As the fall season advanced the sand lovegrass became tan in color and the horseweed a dark brown.

The plant species with indications of relative abundance were as follows: Sand lovegrass and sand sagebrush were very common. Little bluestem, sand bluestem, blue grama, sand dropseed, and annual eriogonum were common with sandbur, horseweed, ill-scented sumac, sand plum, broomweed, and ragweed common locally. Indiangrass, showy gaillardia, dew flower and Aplopappus divaricatus were frequently noted. Sand paspalum, wild ryegrass, Riddell's senecio, western daisy fleabane, prickly pear cactus, partridge pea, yucca, loasa, and lespedeza were also observed in the pasture.

The southeast corner, near Well 4, and the north corner, near Corral 1, had low dunes and flat areas. Elsewhere in the pasture the dunes were moderate to high (15 to 50 feet above the general base level of the dunes) and were numerous, frequently adjoining each other without intervening low flat areas. The physiography of the pasture can be obtained from the topographic map in Figure 9.

The soils were principally Tivoli loamy fine sand, Tivoli sand, and Pratt fine sandy loam, with most of the dunes consisting of the Tivoli sand. On the dunes the sands were loose underfoot with bare loose sand exposed in patches between the vegetation on the higher dunes. On the low dunes the sands felt solid underfoot and were bound.

Data and Discussion

Six species of rodents and one of rabbits were caught in Pasture 18. The species were as follows: kangaroo rat, grasshopper mouse, white-footed mouse, cotton rat, pack rat, harvest mouse, and cottontail rabbit. Species of small mammals not taken, but present on the range, were pocket mouse, thirteen-lined ground squirrel, spotted ground squirrel, pocket gopher, jack rabbit, and least shrew. Pocket mice were seldom caught and, like the least shrew, usually only with Museum Special traps. The ground squirrels were in hibernation; jack rabbits were never taken in the traps; and the traps were not suitable for catching pocket gophers.

The quadrats sites were as follows: one on a low flat area, one on a low dune, six on moderate dunes, and three on high dunes. The distribution seemed to form a representative sample of the pasture.

The data for the catches on the various quadrats are presented in Table 21. From the eleven quadrats the total catch of rodents (including the cottontails) was 167 individuals for an average of 15.2 per quadrat. Comparatively good catches were obtained from all quadrats except the one on a low flat area (Quadrat 11) and one on a moderate dune (Quadrat 6). The low catch in the former substantiated data from other pastures which show a low rodent population on the low flat areas with tight soil. Quadrat 6 was different than any of the other quadrats as it was on a moderate dune with rather tight soil; had a moderate crown density; was moderately grazed; and contained very little sand lovegrass. Which of these variations, if any, was responsible for the low

Quadrat No.	1	2	3	4	5	6	7	8	9	10	11	TOTALS
Dune Height	low	moderate	moderate	moderate	moderate	moderate	high	high	high	moderate	flat	
Soil	loose sand	loose sand	loose sand	loose sand	loose sand	moderate tight	loose sand in patches	loose sand in patches	loose sand in patches	loose sand	tight	
Crown Density	moderate	high	moderate	high	moderate	moderate	low	low	moderate	moderate	high	
Grazing Intensity	light	light	light	light	moderate	moderate	light	light	light	light	light	
Dipodomys	8	8	13	7	9	1	20	13	6	12		97
Onychomys	5	6	3	2	3	1	3		4	3	2	32
Peromyscus						1	4	3	1	3		12
Sigmodon		4		5	1				1			11
Reithrodontomys	1	2			1							4
Neotoma										1		1
Sylvilagus						1						1
X	1			1			1	3	3			9
TOTALS	15	20	16	15	14	4	28	19	15	19	2	167

Table 21. Quadrat catches from the lightly grazed pasture (Pasture 18) using rat traps and a grain bait mixture. The traps were operated five consecutive days and nights.

rodent population is a matter of conjecture, but it has been noted that areas with abundant loose sand and the accompanying sand lovegrass gave good catches of rodents, particularly kangaroo rats. The catches for the other five quadrats on moderate dunes averaged 16.8 individuals, and the average catch from the three high dunes was 20.6 per quadrat. These figures indicate a higher population on the dunes where there was abundant loose sand and a moderate to low vegetative crown canopy.

Kangaroo rats were taken in all quadrats except Quadrat 11, which was on a low flat area, and only one individual was caught in Quadrat 6 which had the characteristics as previously described. The animals seemed to favor areas with exposed loose sand in patches and a moderate to light vegetative crown cover. The average catch for the three high dunes on which these conditions were present was 12.6 and for the five moderate dunes with loose sand it was 9.8. The kangaroo rats were the most common rodent and comprised 58.1 per cent of the total catch.

Grasshopper mice were taken on all quadrats save one and no apparent reason, other than chance, can be advanced for its absence from the one quadrat. The average catch per quadrat for the eleven quadrats was 2.9 individuals and the catch of grasshopper mice represented 19.2 per cent of the total catch of rodents from the pasture. No correlation was noted in the distribution of the species within Pasture 18 and it seemed to have a uniform distribution pattern.

White-footed mice were taken in five of the quadrats and three of these were on high dunes. A correlation seemed to be indicated between the higher dunes and the catch of this species. Other trapping has demonstrated that the rat traps are not very efficient in catching white-footed mice but this does not invalidate the higher catch on the higher dunes in Pasture 18. Most of the data from the other pastures showed the reverse of this correlation, or, that the white-footed mice were more common on the moderate and low dunes where a dense vegetative crown canopy was present. The species comprised 7.2 per cent of the total catch in the pasture.

The incidence of cotton rats was 36 per cent, as they were present on 4 of the 11 quadrats. They comprised 6.6 per cent of the total catch of 167 individuals. Despite the low catch, the correlation of a dense vegetative crown cover and cotton rat populations was evident. On the three quadrats with a high vegetative crown canopy, 2 were on loose sand and 82 per cent (9 individuals) of the cotton rat catch was taken from these two quadrats. The third was on a low flat area with tight soil and cotton rats have been consistently absent from these areas despite a dense crown canopy.

The catches of harvest mice and cottontail rabbits were too low to be significant. The rat traps are too large and insensitive to catch a representative population of harvest mice. The single catches of a cottontail rabbit and of a pack rat substantiate field observations which indicate a low population of both species.

Each of the quadrats enclosed 0.5 acres and the average species catches per quadrat have been considered an absolute population. The average populations per acre per species have been obtained by multiplying the average catch per species per quadrat by two; and the result was multiplied by the acreage of the pasture (213) for pasture populations. Data are presented for all the species taken to enable later comparisons of populations. It is not believed that these figures represent true populations except for the kangaroo rats and possibly the cottontail rabbits and pack rats. The type of bait and kind of trap were not conducive to taking all individuals of all species present in the pasture. Table 22 presents the per acre and pasture populations.

<u>Summary</u>

Eleven quadrats were operated five consecutive days and nights in a lightly grazed pasture. Rat traps and a grain bait were used. The quadrat sites

Species	Average number per acre	Pasture population
Dipodomys	17.6	3,749
Onychomys	5.8	1,235
Peromyscus	2.2	469
Sigmodon	2.0	426
Reithrodontomys	.7	149
Neotoma	.2	43
Sylvilagus	.2	43
X	1.6	341
TOTALS	30.3	6,455

Table 22. Rodent populations per acre and pasture populations for Pasture 18. Data are based on 11 quadrats operated with rat traps.

consisted of a low flat area, a low dune, six moderate dunes, and three high dunes. Six species of rodents and one of lagomorph were taken and the catch averaged 15.2 per quadrat. Kangaroo rats comprised 58.1 per cent of the total catch and grasshopper mice, 19.2 per cent. High populations of kangaroo rats and white-footed mice were correlated with the high dunes. Grasshopper mice had a wide-spread distribution and cotton rats were allied to a high vegetative crown density.

PASTURE 17 (MODERATELY GRAZED)

Description

Pasture 17 was under a range management program of moderately grazed, continuous, yearlong range use. Excluding the reseeded pastures, it was the most northwesterly pasture on the range, and its location and bounds are shown in Figure 3 (p. 29). In size it was 160 acres. Reconnaissances were made on September 30 and October 6, 1949.

As a whole the pasture was moderately grazed with a good stand of grass and abundant grass fruiting stalks and dried forbs present. In the northeast corner near Corral 1 rather heavy grazing had occurred. The pasture was more heavily grazed than Pasture 18 although there were dunes in the west half that had been very lightly grazed. The Grazing Service range use classification would have been "light."

The fall aspect consisted of the gray-green of the sagebrush, clumps of purplish-tan fruiting stalks of sand lovegrass, the browns and tans of fruiting stalks of other grasses, and the light gray of scattered stalks of annual eriogonum. In the low areas with tighter soils the yellow-green of horseweed predominated.

Sand sagebrush and sand lovegrass were very abundant as was blue grama locally. Sand bluestem, little bluestem, sand dropseed, and annual eriogonum were common with horseweed and ragweed common locally. Switchgrass, wild ryegrass, indiangrass, sideoats grama, prickly pear cactus, partridge pea, ill-scented sumac, showy gaillardia, dew flower, western daisy fleabane, loasa, sand plum, broomweed, lespedeza, and Aplopappus divaricatus were also present. There was no tree growth.

The terrain was essentially the dune formations with low areas of tight soil between the dunes. The highest dunes (25 to 40 feet) were in the west half, with moderate dunes in the south and central portion, and low dunes in the northeast.

Soils were sandy with Pratt loamy fine sands in the northeast and Tivoli loamy fine sand and Tivoli sand elsewhere. The Pratt loamy fine sands were tighter than the other types and had more blue grama and less sand lovegrass.

Data and Discussion

Eleven quadrats were operated in Pasture 17 and the following species of mammals were caught: kangaroo rat, grasshopper mouse, white-footed mouse, cotton rat, harvest mouse, and cottontail rabbit. Other species which may have been present in the pasture and not taken in the traps were ground squirrels, pocket mice, least shrew, pocket gopher, and jack rabbit. The traps, bait, method, or other factors, prevented the taking of these species.

Table 23 presents the data for Pasture 17 relative to the catches in the quadrats. The quadrat sites were one low dune, six moderate dunes, three high dunes, and one low flat area between dunes. The highest catches were obtained from the high dunes and averaged 24.3 individuals. An average catch of 12.9 individuals was taken from the moderate dunes. The low flat area had the lowest catch of any of the quadrats. The average catch for all quadrats was 15.1 individuals and the total was 167 which is identical with the total catch from Pasture 18.

Kangaroo rats had an incidence of 100 per cent and comprised 62 per cent of the total catch of 167 individuals. The highest catches were made on the high

Quadrat No.	1	2	3	4	5	6	7	8	9	10	11	TOTALS
Dune Height	low	moderate	moderate	high	moderate	high	high	moderate	moderate	moderate	flat	
Soil	moderate tight	loose sand	loose sand	loose sand in patches	loose sand	loose sand in patches	loose sand in patches	moderate tight	loose sand	loose sand	tight	
Crown Density	moderate	moderate	moderate	light	moderate	light	light	moderate	light	moderate	moderate	
Grazing Intensity	moderate	moderate	light	light	light	light	moderate	light	light	light	moderate	
Dipodomys	4	14	6	19	8	14	19	5	11	3	1	104
Onychomys	3	3	3	2	3	5	5	3	2	5	5	39
Peromyscus	3		1			1				2		7
Sigmodon			1									1
Reithrodontomys					1							1
Sylvilagus										1		1
X		1			2	5	3		1	1	1	14
TOTALS	10	18	11	21	14	25	27	8	14	12	7	167

Table 23. Quadrat catches from the moderately grazed pasture (Pasture 17) using rat traps and a grain bait mixture. The traps were operated five consecutive days and nights.

dunes and the lowest catch from the one quadrat on the low flat area. Catches varied within the moderate dunes but generally a higher catch of kangaroo rats was taken from quadrats with abundant loose sand and sand lovegrass, and lower catches in quadrats with tighter soils and more species of mixed grasses.

The incidence of grasshopper mice was 100 per cent and it was 23.4 per cent of the total catch. Its distribution was rather wide-spread and did not seem to be correlated with any particular habitat.

The numbers of other species caught were too small to be significant.

Average per acre populations and pasture populations have been computed and are presented in Table 24.

<u>Summary</u>

Eleven quadrats were operated in a moderately grazed pasture with one on a low dune, six on moderate dunes, three on high dunes, and one on a flat area. The highest rodent catches were from the high dunes and the lowest from the low flat area. Kangaroo rats and grasshopper mice together formed 85.4 per cent of the catches. The pasture populations and per acre population for each species were computed.

PASTURE 21 (OVERGRAZED)

<u>Description</u>

Pasture 21 was managed as an overgrazed continuous yearlong pasture. It was 107 acres in area and for location see Figure 3 (p. 29). Reconnaissances were made on September 28 and October 7, 1949.

Although managed as an overgrazed pasture the forage in the pasture was not severely grazed, and the Grazing Service range use category of "close" would aptly apply. The forage had been cropped and the cropping was particularly noticeable on the dunes where sand lovegrass was eaten back to the tops of the sagebrush. Grass fruiting stalks were much less abundant than in the moderately grazed and lightly grazed pastures (Pastures 17 and 18) and fewer

Species	Average number per acre	Pasture population
Dipodomys	19.0	3,040
Onychomys	7.0	1,120
Perognathus	1.2	192
Sigmodon	.2	32
Reithrodontomys	.2	32
Sylvilagus	.2	32
X	2.6	416
TOTALS	30.4	4,864

Table 24. Rodent populations per acre and pasture populations for Pasture 18. Data are based on 11 quadrats operated with rat traps.

forbs were noted. Due to the close cropping of the vegetation between the sage-brush one could readily walk between the clumps of sagebrush as contrasted with the lightly grazed and moderately grazed pastures where the grasses on the dunes were as high or higher than the clumps of sage. Vegetative crown density was light to moderate.

The aspect was the gray-green of the sagebrush with the light gray of annual eriogonum, browns and tans of grasses, and on some dunes the purplish-tan of sand lovegrass was evident. The low areas between the dunes were characterized by the gray-green color of blue grama grass and clumps of sagebrush. Very little horseweed was present on the low areas as contrasted with the moderately and lightly grazed pastures.

Sagebrush and blue grama were very common with the latter confined to the low areas between the dunes and the low dunes. Sand bluestem, little bluestem, sand lovegrass, and annual eriogonum were common. Sand paspalum, sand dropseed, switchgrass, indiangrass, horseweed, broomweed, dew flower, yucca, showy gaillardia, western daisy fleabane, partridge pea, prickly pear cactus, and Aplopappus divaricatus were present.

Moderate dunes prevailed in the north portion of the pasture with low dunes and extensive low flat areas in the south portion. The topographic map, Figure 9, indicates the terrain. No dunes were as high as the highest dunes in the other pastures and the maximum dune height in Pasture 21 was about 30 feet.

Soils were sandy and loose on the dunes but tight on the low flat areas and some of the low dunes. These tighter soils were most likely Pratt loamy fine sands. Blue grama grass predominated on such areas. The other soil types were Tivoli loamy fine sand, and Tivoli sand.

Data and Discussion

The traps were baited and set on December 12 and where checked and rebaited on December 13. Due to illness no work was performed on December 14 and the traps were not checked and rebaited until the 15th. Regardless of the variation in procedure the period of operation was the same as in the other pastures, that is a five-day and -night trapping period. The data obtained will be used as if the lapse in operations had not occurred for despite the fact some of the traps were not available to rodents on the night of December 14 (they contained dead individuals from the night of December 13) and no rebaiting was done on December 14, the data for the trapping period were higher than from any other pasture. It can be considered a minimum for pasture 21 under the procedure of trapping used in this study. In addition Quadrat 5 was not checked on December 15 but as the catch would be a minimum for the five-day and -night trapping period, the data have been used as if all the traps had been in continuous operation.

Eleven quadrats were operated in Pasture 21 and were distributed as follows: one on a low flat area, four on low dunes, four on moderate dunes, and two on high dunes. These quadrat sites appeared to be representative of the pasture and may be considered a fair sample of the terrain. The highest rodent catch was taken from the high dunes with no particular difference between the average catches from the low dunes and moderate dunes. The low flat area had a catch of 11 which was unusually high for such an area.

The trapping data by quadrats are presented in Table 25. A catch of 186 individuals for an average quadrat catch of 16.9 was obtained. More individuals were taken from Pasture 21 than any of the other five pastures previously reported. The species catch consisted of kangaroo rat, grasshopper mouse, harvest mouse, cotton rat, and pack rat. As Museum Special traps were not operated in the pasture the smaller rodents were not taken in representative numbers.

The commonest rodent taken was the kangaroo rat which had an incidence of 100 per cent, an average per quadrat catch of 14.4, and comprised 84.9 per cent of all individuals taken. The highest catches were from the two high dunes with light vegetative crown canopy and loose sand in patches.

Quadrat No.	1	2	3	4	5	6	7	8	9	10	11	TOTALS
Dune Height	low	high	high	low	moderate	moderate	low	moderate	low	moderate	flat	
Soil	loose sand	loose sand in patches	loose sand in patches	loose sand	loose sand	loose sand	loose sand	loose sand	loose soil	loose sand	tight	
Crown Density	moderate	light	light	moderate	light	moderate	moderate	moderate	moderate	moderate	moderate	
Grazing Intensity	over-grazed	over-grazed	over-grazed	light	moderate	moderate	light	moderate	moderate	moderate	over-grazed	
Dipodomys	16	24	20	7	15	10	14	14	15	14	9	158
Onychomys	2		2	1	3	3	1		1	4	2	19
Reithrodontomys							1					1
Sigmodon									1			1
Neotoma									1			1
X		3	1					1	1			6
TOTALS	18	27	23	8	18	13	16	15	19	18	11	186

Table 25. Rodent catches with rat traps from eleven quadrats operated five days and nights in Pasture 21.

Grasshopper mice were taken in nine quadrats, making an incidence of 82 per cent. The average per quadrat catch was 1.7 per cent and the species was 10 per cent of the total catch. No correlation was noted in the distribution of the catches and occurrence seemed to be wide-spread.

The catches of the other species were too small to be of significance. No white-footed mice were taken with the rat traps in Pasture 21 and this may have been correlated with a lower vegetative crown density due to grazing.

The per acre and pasture populations for each species have been computed as in the other pastures and are presented in Table 26.

Summary

Eleven quadrats were operated in an overgrazed pasture and five species of rodents were caught. The total catch was 186 individuals which was higher than from any other pasture on the range in which quadrats were operated. The average catch per quadrat was 16.9 rodents. Kangaroo rats formed 84.9 per cent of the total catch and grasshopper mice 10 per cent. Per acre and pasture populations were computed.

COMPARISON OF RODENT POPULATIONS IN LIGHTLY GRAZED, MODERATELY GRAZED, AND OVERGRAZED PASTURES

The effects of the grazing intensities (light, moderate, and overgrazed) on the rodent species and populations will be explained from the results of trapping data. The methods of procedure used in each pasture were similar, except as noted for Pasture 21. As the pastures were of different sizes it has not been considered desirable to directly compare pasture populations. The most important influence on rodent numbers was the height of the dunes and their attendant variations in soil and vegetation. Therefore the most feasible method of comparison was to compare the rodent populations on similar quadrat sites in the different pastures; that is to compare the data from the moderate dunes in each of

Species	Average number per acre	Pasture population
Dipodomys	28.8	3,082
Onychomys	3.4	364
Reithrodontomys	.2	21
Sigmodon	.2	21
Neotoma	.2	21
X	1.0	107
TOTALS	33.8	3,616

Table 26. Species per acre and total pasture populations in an overgrazed pasture, Pasture 21. Data are based on catches from 11 quadrats operated five days and nights.

the pastures, the high dunes, the low dunes, and the low flat areas. Under this method there appeared to be only one variable—the grazing intensity which varied with the pastures.

Victor Rat traps were the only traps used in Pastures 17, 18, and 21, and a grain mixture the only bait. The smaller rodents were not readily caught in the rat traps and under the methods used only two species, the kangaroo rat and grasshopper mouse, were taken in quantity. The data actually present the effects of grazing intensity on kangaroo rats and grasshopper mice which were numerically the most important rodents on the range as evidenced from their percentages of catches in the pastures.

Table 27 presents the comparison data for the quadrat sites in Pastures 18, 17, and 21. The pasture grazing intensity category is for the entire pasture as managed by the Southern Great Plains Field Station, regardless of individual quadrat variations. It should be remembered that the grazing intensities in all pastures were actually lighter than the classifications light, moderate, and overgrazed, and conformed closer to the Grazing Service range use classifications of slight, light, and close. The figures in Table 27 represent the average quadrat catches for the particular sites and pastures.

Although only Victor Rat traps were used in the study, thus eliminating the possibility of catches of small rodents which could be used for computing actual populations, some of the smaller forms were taken. These catches of the smaller rodents do not distort the data for comparison values as the chances of catching the small rodents were equal in all quadrats, at least in respect to traps, bait, and procedure.

Examination of Table 27 shows an excellent correlation between rodent catches and dune heights. Regardless of the grazing intensity, the higher dunes produced the highest catches of rodents. The data are particularly significant when the low dunes and moderate dunes are considered collectively and this is

QUADRAT SITES	LOW FLAT AREAS			LOW DUNES			MODERATE DUNES			HIGH DUNES		
Pasture	18	17	21	18	17	21	18	17	21	18	17	21
Grazing Intensity	light	moderate	over-grazed	light	moderate	over-grazed	light	moderate	over-grazed	light	moderate	over grazed
Number of Quadrats	1	1	1	1	1	4	6	6	4	3	3	2
Dipodomys		1.0	9.0	8.0	4.0	15.0	8.33	7.83	13.25	13.00	17.33	22.0
Onychomys	2.0	5.0	2.0	5.0	3.0	1.25	3.0	3.33	2.5	2.33	4.0	1.0
Peromyscus					3.0		.66	.5		2.67	.33	
Sigmodon						.25	1.66	.17		.33		
Reithrodontomys				1.0		.25	.5	.17				
Neotoma						.25	.17					
Sylvilagus							.17	.17				
X		1.0		1.0		.25	.17	.83	.25	2.33	2.67	2.0
TOTALS	2.0	7.0	11.0	15.0	10.0	15.25	14.66	13.00	16.00	20.66	24.33	25.0

Table 27. Average rodent catch per quadrat for pastures compared by dune heights.

permissible as their ecological conditions were essentially the same. The correlation holds for each pasture regardless of the grazing intensity within the pasture, and is also applicable between pastures. For instance the average catch of all species on high dunes in Pasture 18 (lightly grazed) was 20.66 which is higher than any average catches of all species on moderate dunes, low dunes, or low flat areas. The superiority of the high dunes is due to the higher catches of kangaroo rats on these sites. The exposed loose sand in patches and open condition of the vegetative crown canopy evidently provide favorable habitat for this species. The grasshopper mouse did not show any affinity for a particular quadrat site but seemed to have a wide-spread distribution. The carnivorous habits of the species allied with relatively high mobility and lack of definite home range, may explain the universal distribution. Considering the remaining species (white-footed mouse, cotton rat, pack rat, and cottontail rabbit) collectively, they were more abundant on the moderate and low dunes than on the high dunes or low flat areas.

Table 28 has been compiled for each pasture by adding the average per quadrat species populations for each quadrat site. For example for Dipodomys in Pasture 18 the figures 0.0, 8.0, 8.33, and 13.00 were added to give the sum of 29.33 which has been used in Table 28. The data in the table show that the highest rodent populations, taken as a whole, were on the overgrazed pasture (Pasture 21). The correlation is also applicable for kangaroo rats as a species. In fact it is the high kangaroo rat populations in the overgrazed pasture that makes the first statement possible, and therefore the true correlation is that the highest population of kangaroo rats occurred in the overgrazed pasture. Grasshopper mice were more abundant in the moderately grazed pasture than in the lightly grazed and overgrazed pastures. The meager data for harvest mice, and cotton rats indicate higher populations on lightly grazed pastures.

Pasture Number	18	17	21
Grazing Intensity	light	moderate	overgrazed
No. of Quadrats	11	11	11
Dipodomys	29.33	30.16	57.25
Onychomys	12.33	15.33	6.75
Reithrodontomys	1.5	.17	
Peromyscus	3.33	3.83	
Sigmodon	1.99	.17	.25
Neotoma	.17		.25
Sylvilagus	.17	.17	
X	3.5	4.5	2.5
TOTALS	52.32	54.33	67.00

Table 28. Comparison of average pasture populations for each species. The data were obtained from the average rodent catches per quadrat for each quadrat site as presented in Table 27. Note the high catch of kangaroo rats in the overgrazed pasture and the low catches of harvest mice and cotton rats.

The very important conclusion that the influence of grazing intensity on rodent populations varies with the individual rodent species is clearly evident from the data in Table 28. The statement that higher populations of rodents occur in overgrazed pastures should not be employed unless particular species are indicated. In this study it has been shown that overgrazing at least up to a certain point does produce high populations of kangaroo rats but not necessarily of all rodent species. Cotton rats are found in greatest numbers in lightly grazed or ungrazed pastures and are practically non-existent in overgrazed pastures. High populations of grasshopper mice seemed to be correlated with moderate grazing but the species was obtained in all pastures and on almost all quadrats. The statement that overgrazing increases rodents is fallacious for overgrazing favors some species of rodents and is detrimental to others.

Summary

A comparison of population data from quadrat trapping in lightly grazed, moderately grazed, and overgrazed pastures is presented. The highest rodent populations occurred on the high dunes with exposed loose sand in patches and the lowest populations on low flat areas between the dunes where the soil was tight. The high populations on the high dunes are due to the high populations of kangaroo rats on these dunes. Kangaroo rats were most abundant in the overgrazed pastures. The few data obtained on harvest mice and cotton rats showed they were most common in lightly grazed pasture. Grasshopper mice and white-footed mice had their highest populations in moderately grazed pasture. These statements clearly indicate that the effect of grazing intensity on rodent populations varies with the individual species.

COMPARISON OF 1949 DATA WITH THAT COLLECTED IN 1940 AND 1941 BY A. H. TROWBRIDGE

One of the objectives of the present study has been to compare the existing species composition and populations of rodents and lagomorphs on the Southern Great Plains Experimental Range after eight years of grazing programs, with those obtained by Trowbridge in 1940 and 1941, before the start of the grazing programs when the range was grazed as a single unit. Prior to, and at, the time Trowbridge did his studies in 1940 the range was uniformly grazed with blue grama and sand dropseed the predominate grasses.[1] During 1941 the range was entirely protected from grazing and was divided into pastures from 50 to 200 acres in extent. Except for replicate pastures each pasture has been under a different grazing intensity since that time. In 1940 Trowbridge tested various quadrats and line trap methods in Pastures 17, 18, 19, 20, 21, and 37, finally concluding that the one-half acre quadrat of 27 rat traps was the most satisfactory. The work in 1941 was principally confined to Pastures 17, 18, 20, and 21, and a control area adjoining the Experimental Range and west of United States Interstate Highway 283 on lands owned by the Irish Syndicate Ranch. The first year's work (1940) followed the poorest growing season on record at the Southern Great Plains Field Station. However, at the time the work was performed a "wet" spell began which eventually proved to be the wettest year on record and the best growing season. In 1949 the growing season was excellent with ample rainfall.

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[1] C. C. Smith, formerly of the Soil Conservation Service, in a personal interview stated that sand lovegrass was the predominate grass at this time, although Trowbridge has failed to mention it. Certainly the species was present.

The investigations in 1949 were conducted mainly in Pastures 17, 18, 19, 20, 21, and 24 but, as a bait different from that used by Trowbridge was employed in Pastures 19, 20, and 24, only the data from Pastures 17, 18, and 21 will be used for comparison. The bait in the latter three pastures was a grain mixture, the same as used by Trowbridge.

Essentially the rodent species taken on the range by Trowbridge and those taken in 1949 were the same, namely: kangaroo rat, grasshopper mouse, white-footed mouse, harvest mouse, pack rat, cotton rat, silky pocket mouse, plains pocket mouse, and cottontail rabbit. No spotted ground squirrels were taken by Trowbridge and none was taken in 1949 in Pastures 17, 18, and 21 during the period of operation comparable with Trowbridge's (late November and December). However spotted ground squirrels were taken by the writer in some of the other pastures in October and early November of 1949 and McMurry (1942, 1943) also trapped this species in June. The lack of spotted ground squirrels in the catches by Trowbridge and in late November and December of 1949 was due to its hibernation. Likewise the thirteen-lined ground squirrel was present on the range but not trapped by Trowbridge nor the present writer. McMurry caught this species in June of 1941 and 1942, and other collectors have taken specimens from the range. The thirteen-lined ground squirrel also hibernates. Trowbridge trapped no cotton rats in 1940 but did take the species in 1941 and it was taken in abundance in 1949. Pocket gophers were present during all periods of trapping as were jack rabbits, although but one of the former, and none of the latter, were caught in the traps. The least shrew was taken with Museum Special traps in 1949, but was not taken by either Trowbridge or McMurry, although the latter found one dead in a post hole (McMurry 1942).

To compare the species populations on the range for the trapping periods of 1940, 1941, and 1949, Table 29 has been compiled. All data are for sand dunes only and do not include the areas of tight soil. Traps which were missing from

Year	1949	1941	1940	1941 control
Grazing Intensity	varied with pasture	ungrazed	grazed uniformly	grazed
Dipodomys	12.6	21.3	16.0	22.8
Onychomys	2.7	2.7	1.8	1.8
Peromyscus	0.6	trace	trace	0.4
Sigmodon	0.4	2.4		
Reithrodontomys	0.2	0.3		0.2
Neotoma	0.1-	0.2	1.5	0.6
Sylvilagus	0.1-	0.1	0.7	0.5
Perognathus		0.6		0.1

Table 29. Average quadrat catches of small mammals for 1940, 1941, and 1949 from the Southern Great Plains Experimental Range.

quadrats and not found were considered as kangaroo rat catches as Trowbridge had computed his 1940 and 1941 data in this manner. The 1949 data are based on thirty quadrats on sand dunes, ten each from Pastures 17, 18, and 21; those for 1941 on 34 quadrats; and those for 1940 on 29. The 1941 control consisted of ten one-half acre quadrats located on an adjoining range. The figures represent the average catches per quadrat.

Kangaroo rats and grasshopper mice ranked first and second in numerical importance with the kangaroo rats much more numerous than any other rodent species. Due to trapping selectivity the catches of all the rodent species cannot be ranked numerically for mouse traps or Museum Special traps, which are particularly suitable for catching the smaller rodents, were not operated. Nevertheless all data show that kangaroo rats were the most common rodent on the range and were followed in numbers by grasshopper mice.

Kangaroo rats increased from 1940 to 1941 on both the grazed control and ungrazed range, and had decreased significantly by 1949. The increase from 1940 to 1941 was probably due to an increase in food supply as a very favorable growing season was experienced in 1941 and the species increased on both grazed and ungrazed ranges. The range as a unit was likely heavier grazed prior to, and during, 1940, presenting a more uniform condition and more exposed loose sand. High populations of kangaroo rats have been correlated with exposed loose sand in patches as evidenced by the trapping data for 1949. No apparent difference in population density on high and low dunes was discerned in 1940 which would tend to indicate the overall grazing intensity was quite uniform. From these correlations it has been concluded that the successional trend of the vegetation, augmented by lighter grazing, has produced a higher vegetative crown canopy; decreased the amount of exposed loose sand; and consequently decreased the amount of suitable habitat for the kangaroo rat.

Grasshopper mice increased in abundance on the range from 1940 to 1941 but remained the same on the grazed control. The range populations in 1941 and 1949 were the same. The universality of occurrence of this species, its mobility, and carnivorous food habits make it independent of vegetation. Obviously its habitat requirements depend on different factors than those of the other rodents. Trowbridge believed grasshopper mice to be more common on sandy soils than the tighter soils but this was not corroborated in 1949. In general, there has been little change in the population of the species.

White-footed mice showed an increase in 1949 over the 1940 and 1941 data. Trowbridge does not explain what the category "trace" (Table 29) means but presumably it was somewhat less than 0.1 catch per quadrat. This species prefers a moderately or lightly grazed pasture to overgrazed as the average per quadrat catches on sand dunes in Pastures 18, 17, and 21 were 1.2, 0.7, and 0.0 respectively. Therefore it is probable that the increase of vegetative crown canopy has been responsible for the increase of the species from 1940 to 1949. As only ten quadrats were operated in the 1941 control, a catch of but two individuals would represent an average per quadrat catch of 0.4, as given in Table 28. This number is too small to be significant.

The cotton rats increased from 1940 to 1941 on the range, although none was taken in the control. These data show the preference of this species for a dense vegetative crown cover. A drop in populations was experienced from 1941 to 1949 but the species has an irruptive population, possibly even cyclic, and in 1949 there was no evidence of a peak or a low—rather a normal population. It is not to be inferred that a peak was evidenced in 1941 but the population may have reacted vigorously to the increase in vegetative crown density of 1941, which was uniform over the range. The difference in grazing pressures in Pastures 17, 18, and 21 would tend to show a lower population due to lack of uniformity of range conditions.

Harvest mice are another species which prefer a dense vegetative crown cover so there was an expected increase from 1940 to 1941 on the range. An increase also occurred on the control area but, as with the white-footed mouse, only two individuals were trapped. The populations for 1941 and 1949 were about the same, averaging 0.2 individuals per quadrat for the 30 quadrats in Pastures 17, 18, and 21, and 0.3 for the quadrats for 1941. However in 1949 the ten quadrats in the lightly grazed pasture, Pasture 18, had an average catch of 0.4 harvest mice. Again the uniformity of the range in 1941 was likely responsible for a relatively good over-all catch. The actual abundance of this species is greater than the data in Table 29 would indicate, as has been shown by catches with Museum Special traps in other pastures.

Pack rat populations experienced a decided decline from 1940 to 1941, and from 1941 to 1949. In all six pastures in which concentrated trapping was conducted in 1949, only 5 individuals were taken in 8,910 trap nights. Pack rat dens were very scarce on the range in 1949 being mainly confined to the buildings about the wells and corrals. Grass ranges are not particularly favorable habitat for the pack rat and likely a higher population existed in the forest and shrub growth along the North Canadian River at the south end of the Experimental Range (Fig. 9). Why there has been a decrease of pack rats since 1940 is not readily explainable unless there has been a decrease in desirable shrub growth or other plants which were abundant during the drouth years of the late 1930's and 1940. It is very possible that with an increase in grass the brushy species, excluding the sagebrush, have decreased. There has been a tendency on the range as a whole to have a dense vegetative crown canopy but that does not apply to the overgrazed pastures which too had a low pack rat population in 1949.

In like manner there has been a decrease in cottontail rabbits since 1940 when Trowbridge considered them very numerous. Usually cottontail rabbits increase in population with a decrease in grazing intensity but this correlation has not held for the Experimental Range. In 1949 cottontail rabbits were common in the evening around the corrals and wells but at all times were relatively scarce on the range proper. The only explanation apparent for the marked decrease in cottontail rabbits is that they were at a high in an irruptive population in 1940 and a decline was experienced some time later. Jack rabbits also experienced a like decline and were the least common of any rodent or lagomorph on the range in 1949. Only two or three individuals were seen during the entire period of study.

Pocket mice showed a relatively good catch in 1941 but were very scarce in 1949, none being taken in Pastures 17, 18, and 21, although a few were taken in some of the other pastures. A single plains pocket mouse was trapped in 1949 plus a few silky pocket mice. Trowbridge had an average catch of 0.6 individuals per quadrat in 1941 and as these animals are closely allied ecologically and taxonomically to the kangaroo rats it would be expected that their requirements and reactions would be similar.

FACTORS INFLUENCING TRAPPING OPERATIONS

A total of 80 quadrats were operated in Pastures 17, 18, 19, 20, 21, 24, 26, and 28 using Victor rat traps, and Museum Special traps were substituted in 22 of these quadrats after the customary five-day and -night trapping period. Rat traps were operated 10,800 trap nights and Museum Specials for 1,188, making a total of 11,988 trap nights. The total catch consisted of 1,192 individuals.

UNDESIRABLE ANIMALS AND ANIMAL ACTIVITY

No particular difficulty was experienced in the trapping operations and within the limits of the ability of the traps to take certain species the catches were satisfactory. Trapping in the late fall and early winter had the advantages of little interference by weather, and a minimum bait loss due to ants, grasshoppers, and small birds, which can be an important factor during the summer months (McMurry 1941, p. 8). During the trapping period three western meadow larks, Sturnella neglecta; one western lark sparrow, Chondestes grammacus strigatus; one lesser prairie chicken, Tympanuchus pallidicinctus; and one unidentified species of bird were taken in the traps. The prairie chicken, two of the meadow larks, and the unidentified bird were eaten by hawks, presumably the marsh hawk, Circus hudsonicus. One salamander, Ambystoma tigrinum mavortium, was taken in one of the traps.

Millipedes (Diplopoda) were frequently noted beneath and on traps in the quadrats in Pastures 26 and 28 and apparently were attracted to the traps. The attraction could have been the dark moist areas beneath the traps or the bait. An individual was observed feeding on a piece of rolled oats at one of the traps and easily manipulated a morsel nine by six millimeters in size. Its mouth parts were used to move the food item and its geniculate antennae moved over the piece as if appraising the situation. Upon moving a trap and placing it a few inches from exposed individuals, the animals immediately crawled under the trap evidencing a negative phototropism. When grasped with forceps they would coil themselves into a spiral and assume an inactive or dead appearance. On some occasions millipedes were present on dead animals in the traps which had been partially eaten, presumably by grasshopper mice. One spotted ground squirrel was found which had a freshly-made circular hole, about five millimeters in diameter, in the abdominal region and did not show indications of having been chewed by a rodent. It is possible that this hole was made by millipedes as they were present on the dead animal, and Storer (1943, p. 523) has stated that although their food is of dead plant material they also will eat animal matter. On the morning of October 18 eleven individuals were present under the traps in Quadrat 4, Pasture 28; two in Quadrat 4, Pasture 26; and nine in Quadrat 3, Pasture 26. The principle of making a moist habitat by placing pieces of wood on the ground surface, and using the paste bait mixture could be employed to collect millipedes. A modification thereof could also be used to obtain comparative populations. The position of these arthropods in the biotic community would warrant investigation from the standpoint of their effects on the soils.

Marsh hawks were a problem and interfered with the trapping. These avian predators frequently made persistent raids on the quadrats and often took both the traps and rodents. In most instances the traps were ultimately found as the birds seldom removed them over 200 to 300 feet from the trap sites and invariably the movement was downhill to the base of the dune. Trowbridge (1941, p. 13) believed the distance a trap was removed from a trap site was a trait of the individual birds. It was sometimes possible to stand at a trap site from which a trap was missing and by looking downhill decide the most likely places to search for the missing trap. This was practicable as most traps were found in small openings, 10 to 20 square yards in area, devoid of sagebrush and tall grasses, and where the birds could alight with ease. Hawk pellets were noted more frequently in such openings than on other areas of the range. Sometimes the rodents were devoured at the trap sites. The typical remains of a rodent eaten by a hawk consisted of scattered wisps of hair, and frequently portions of the hind legs and tail in the case of the kangaroo rat. The rodent species could be identified by the hair. Marsh hawks were observed feeding, or leaving a rodent catch on which it had been feeding, on seven occasions. Fifty-nine kangaroo rats, seven grasshopper mice, five cotton rats, one harvest mouse, and one white-footed mouse were taken from the traps and eaten by marsh hawks. In addition 30 traps were not found which undoubtedly had contained rodents, probably kangaroo rats, and were taken from the trap sites and devoured elsewhere. Each of the missing traps has been considered a rodent catch in the data, and likely could be considered a kangaroo rat catch as Trowbridge (1941, p. 14) has done. An interesting note on prey selectivity was shown with the marsh hawks as regards grasshopper mice. On November 23 a grasshopper mouse and trap were found about 30 yards downhill from its trap site, near two other traps which had been brought there by a marsh hawk. The latter two traps contained remains of kangaroo rats, but the grasshopper mouse was intact. Seemingly this was the work of a single bird as all three traps were in the same small opening in the sagebrush crown canopy. From the beginning of the trapping period until December 9 only one instance of a marsh hawk feeding on a grasshopper mouse was found. The night of December 8-9 an ice storm occurred and the following morning four grasshopper mice and one white-footed mouse had been eaten by marsh hawks. Frequently grasshopper mice were untouched in quadrats from which three or more kangaroo rats were eaten. These observations would indicate that the grasshopper mouse, which is itself essentially a carnivorous feeder, was not a desirable prey of the marsh hawk. Trowbridge (1941, p. 14) noted that grasshopper mice were seldom taken. In June of 1941, McMurry (1942, p. 9) did not experience any trouble from raptores. Probably the high concentration of wintering raptores in the Southern Great Plains Region, together with the limited food supply during the winter season, were responsible for the marsh hawks taking a considerable number of the rodent catches. Under natural conditions it is doubtful if the marsh hawk would be a factor in governing populations of kangaroo rats as the former is a diurnal species and the latter nocturnal. Other species of hawks and owls were present on the range but no indications of their feeding on trapped rodents was found. All the hawks and owls were active in searching for rodents and at almost any time during the day one of these species could be seen hunting.

Rodents taken in the traps were frequently found to have been partially devoured by other animals and it is believed that the grasshopper mouse was responsible for many or most of the depredations. Usually the abdominal cavity was exposed and the viscera partially eaten although on some occasions other parts of the body such as the head region had been attacked. One grasshopper mouse had flesh eaten from between its ribs and the feeding appeared to have been done by the least shrew. Others of the rodent group are most likely not adverse to flesh as a food but the grasshopper mouse was the only species whose food has been found to be predominately carnivorous (Bailey and Sperry 1929, p. 19). The species were common on the range. Rodents found partially devoured in the traps were: 32 kangaroo rats, 8 grasshopper mice, 6 white-footed mice, 6 harvest mice, and 3 spotted ground squirrels.

WEATHER

Weather data on the range have consisted merely of observations on gross variations as weather instruments were unavailable. The evaluation of the effects of weather on rodent catches is extremely complicated for weather is composed of numerous elements (temperature, humidity, winds, precipitation, cloudiness, and other meteorological phenomena) which collectively or individually may affect each rodent species differently, and most likely affect the various age classes of rodents differently. The elements of weather vary almost constantly throughout a 24-hour period and data on the reactions of rodents to these elements is almost nil. To further confuse the situation there exists the problem of microclimates due to slope, elevation, exposure, soils, and other features of the terrain. A study of weather and its effects on rodents would be a major undertaking.

Rodents were taken every night the traps were in operation and no weather encountered during the trapping period from October 10 to December 17 was sufficiently extreme to stop all surface activities of the animals. The most severe weather was an ice storm which began the afternoon of December 8 and continued during the night of December 8-9, culminating in coating all vegetation and ground surface with a layer of ice. Despite the ice a catch of 23 individuals was taken which was eight more than the catch of the preceding night. The following night, December 9-10, was cloudy with moderate temperatures and a catch of 56 was obtained which would indicate a curtailment of activity during the night of the storm. These data were for the same number of traps operated at the same trap sites. Kangaroo rats comprised 22 per cent of the catches taken the night of December 8-9 and 62 per cent the night of December 9-10, showing this species was probably affected most. Trapping operations initiated on December 19 on an adjoining range had to be abandoned on December 21 due to an ice and snow storm which began the afternoon of December 20 and continued during the night of December 20-21. It is not to be inferred that the trapping was terminated due to lack of rodent activity but the traps could not be located under the ice and snow. Trowbridge (1941, p. 19) also experienced such an ice and snow storm on December 18, 1940, and rain on December 25 and 26, 1940, caused a cessation of trapping operations. No prolonged period of rainfall occurred during the trapping operations of 1949. Trowbridge observed that light rain, snow, or cold had little effect on the rodent catch and the data for 1949 corroborate his observation.

On some nights a high catch of rodents was taken (indicative of high rodent activity) and these nights were not necessarily the first nights of trapping. No explanation can be given for these peak activity periods as no correlations could be found with the weather data as recorded. Possibly detailed weather records made at various places on the range with accurate instruments would show the factor or group of factors responsible for the reactions of rodents to weather, and would explain the reason for highs and lows in rodent activity. Instruments as devised by Spencer (1939), which electrically record activities of rodents as they enter or leave dens, or pass along runways, will materially assist in determining activity periods. Also the use of instruments to obtain microclimates as have been employed by Schmidt-Nielsen and Schmidt-Nielsen (1950) indicate possible methods.

BAIT SELECTIVITY

To obtain a representation of rodent species and numbers on the range, two types of baits were used in the 1949 trapping operations. The traps in the quadrats in Pastures 19, 20, and 24 were baited with a paste mixture of rolled oats, peanut butter, and bacon grease; those in Pastures 17, 18, and 21 with a grain mixture of milo maize, kaffir corn, whole wheat, and whole oats. To compare the efficiency of each bait a comparison has been made of the rat trap catches from the eleven quadrats operated in each of Pastures 19, 20, and 24 with the paste bait (this does not include quadrats in exclosures) and the eleven quadrats operated in Pastures 17, 18, and 21 with the grain bait. The trapping in each group represented 4,455 trap nights. The data, as presented in Table 30, show that the grain bait was superior to the paste bait for kangaroo

Species	Paste bait	Grain bait
Dipodomys	257	359
Onychomys	144	90
Sigmodon	27	13
Peromyscus	5	19
Citellus	9	
Reithrodontomys	4	6
Neotoma	3	2
Perognathus	2	
Sylvilagus	2	2
X	7	29
TOTALS	460	520

Table 30. Comparison of rodent catches from Pastures 19, 20, and 24 using a paste bait, and from Pastures 17, 18, and 21 using a grain bait. The number of trap nights in each group of pastures was 4,455.

rats as a larger number were taken with the grain bait. A higher catch of grasshopper mice was taken with the paste bait. As kangaroo rats are primarily seed eaters and grasshopper mice are carnivorous in food habits the reactions of the species to the baits is in conformity with their food habits. Catches of other rodents are too small to be significant. The data show the difficulty or rather impossibility in obtaining an accurate population of all rodents on an area using a single bait.

RODENT CATCHES BY NIGHTS OF TRAP OPERATION

The night by night catches of kangaroo rats, grasshopper mice, all other rodents taken in 1949, and of kangaroo rats for 1940 and 1941 as given by Trowbridge (1941, p. 21; 1942, p. 12) are presented in Table 31. Logically the rodent catch should be greatest the first night of trapping and then gradually decline as animals are removed from a quadrat. This sequence of catches occurred for kangaroo rats in 1940 and 1941 as shown by Trowbridge's data in Table 30. However, the trapping data for 1949 did not follow this pattern. Considering all species, a high catch was taken the first night; the second night the catch dropped; the third night an increase occurred over the second but it was considerably lower than the first night; the fourth night the lowest catch was taken; and on the fifth night a marked increase followed which was exceeded only by the first night's catch. Kangaroo rats and the combined data for all species exclusive of kangaroo rats and grasshopper mice exhibited a like pattern—a high catch (maximum), a drop, an increase, a drop (minimum), and an increase. Grasshopper mice varied from this order in that a gradual decline occurred until the fifth night when catches increased over the third and fourth nights. Considerable variations occurred in the night to night catches in the individual quadrats (Appendix C).

The variation of catches from a high first night's catch and a decline during the subsequent nights may be attributed to rodent activity periods. On

Nights	1	2	3	4	5	Totals
Trowbridge's 1940 data for kangaroo rats	225	148	112	71	72	628
Trowbridge's 1941 data for kangaroo rats	319	190	168	141	135	953
1949 data for kangaroo rats	141	82	104	76	104	507
1949 data for grasshopper mice	87	53	41	36	47	264
1949 data for all other small mammals	50	29	38	25	42	184
Total data for 1949	278	164	183	137	193	955

Table 31. Night by night rodent catches from 69 quadrats operated in 1949, and for kangaroo rat catches made by Trowbridge in 1940 and 1941. The 1940 data were from 13 trap lines and 29 one-half acre quadrats. The 1941 data were presumably from 10 one-acre and 52 one-half acre quadrats. The 13 trap lines of 1940 were continued in operation nights 6, 7, and 8 and catches were 12, 1, and 2 respectively.

some of the nights weather conditions or other factors apparently were favorable for rodent activity and high catches were obtained. The nature of the factors or conditions conducive to high rodent activity were not determined. The increase in catches on the fifth night of trapping operations was noted by Trowbridge (1942, p. 11) in ten one-acre quadrats. He analyzed the night by night catches and concluded there was no direct constant relationship between the numbers of traps set and the numbers of animals taken. Rather the evidence indicated, at least for kangaroo rats, a more or less rhythmic activity; and periods of high activity were followed by those of low activity. The increase of catch on the fifth night might be due to a high in activity or movement (drift) of animals into the quadrat area subsequent to the removal of resident animals. With a movement into the quadrat area the outer lines of traps, A and C, would be encountered first by the animals and therefore these two lines should have a higher catch than the center line, line B. Trowbridge (1941, p. 11) in examination of data from 75 one-half acre quadrats did not find that the outer lines of traps had a higher catch than the center line. The 1949 data for 72 quadrats showed that 355 individuals were taken in line A, 347 in line B, and 343 in line C. These figures substantiate Trowbridge's data and indicate that the drift factor was not responsible for the increase of catches on the fifth night of trap operations. An analysis of the fifth night catches from 72 quadrats gave 81 catches from traps in line A, 70 from line B, and 77 from line C. These data indicate some drift but not of the magnitude to produce an increase in catch as was taken on the fifth night of trapping. The spacing of the traps (27 feet apart in each line) may have been large enough to have permitted rodents to pass through the trap lines A and C without encountering the traps and consequently the catches in the trap lines would be approximately equal. Also drift might have occurred from the ends of the quadrats and would not show in the trap line catches. Closer spacing of the traps might have shown a higher drift population.

It is difficult to explain the increase in catch on the fifth night on the basis of rodent activity. In Pastures 19, 20, and 24, Quadrats 1, 2, and 3; 4, 5, and 6; 7, 8, and 9; and 10, 11, 12, and 13 were operated at different periods so that the fifth night of trapping occurred on four different nights, and yet an increase catch on the fifth night over that of the fourth night was present in the data from Pastures 19 and 20 (Table 32). The data from Pasture 24 showed that the catch on the fifth night was lower than that of the fourth. Pastures 17 and 18 were each trapped as units and an increase was noted on the fifth night. It scarcely seems plausible that a peak in rodent activity could have occurred on all of these "fifth" nights.

A paste bait was used in Pastures 19, 20, 24, 26, and 28, and as Trowbridge used only a grain mixture it was thought that this factor might account for the night by night catch variations. A grain bait mixture, the same as used by Trowbridge, was used in Pastures 17 and 18. The separation of the data by types of bait showed an increase in catch on the fifth night for both the paste bait and the grain bait. The increase was actually larger with the grain bait (33 on the fourth night and 82 on the fifth) than with the paste bait (104 and 111).

Stickel (1946) in studies of wood mice, Peromyscus leucopus (Rafinesque) ran 200 snap traps for 35 consecutive nights on a one-acre quadrat. The one-acre quadrat was in the center of a circular 17-acre plot on which live trapping, marking, and releasing had been conducted for seven nights previous to the snap trapping. A total of 76 mice were taken with the snap traps and 42 of them were caught the first five nights. The data showed a gradual decline after the first night catch and after six nights of trapping the individual night catches were low (maximum of three). Drift was responsible for the continuation of catches and in general the more time that elapsed before a mouse was taken, the farther from the central acre was its original home range. In the first night of snap

Pasture Number	Number of Quadrats	Nights 1	2	3	4	5	Totals
26	4	17	5	3	8	7	40
28	4	16	10	7	9	9	51
17	11	43	15	29	23	57	167
18	11	72	31	29	10	25	167
19	13	35	39	43	25	33	175
20	13	46	33	39	26	35	179
24	13	49	31	33	36	27	176
TOTALS	69	278	164	183	137	193	955

Table 32. Night by night rodent catches for the various pastures. Quadrats in Pastures 19, 20, and 24 were trapped during four different trapping periods. Quadrats in Pastures 17 and 18 were each operated as a unit.

trapping 16 individuals were taken on the central acre, although from live trapping, Stickel had calculated a population of 6 to 7 mice per acre.

Spencer (1936) working near Tucson, Arizona, operated 150 snap traps on a five-acre quadrat for 20 consecutive days and nights. The catches of Merriam kangaroo rats went from a low of 0 on the first night to a high of 11 on the third, and from that point varied from 0 to six per night. Wood rats which were the commonest species on the area exhibited an increase in catches on the fifth night over that of the third and fourth. After the initial trapping period, traps were operated at the trap sites twice a month for a period of 48 hours each time. The study continued for ten months (Spencer 1941). The amount of drift was determined for seven rodent species and the Merriam kangaroo rat had the highest sustained annual drift.

Townsend (1935, p. 19) in his studies of small mammals in central New York ran trap lines for 14 consecutive nights. At the end of the fourteenth night animals were still being caught showing a drift factor. No particular increase in catch was taken on the fifth night. He considered the catch of the first three nights as "home animals" and the catches made after that as "wandering individuals."

The increase of rodent catches on the fifth night of trap operations, as shown for the 1949 data in Tables 31 and 32, was probably due to a combination of drift and rodent activity.

AN EVALUATION OF SMALL MAMMALS ON SAND SAGEBRUSH GRASSLANDS IN THE SOUTHERN GREAT PLAINS REGION

The material that has been presented has shown repeatedly that small mammals, particularly rodents, are an integral part of the biotic community termed range. These animals are acted upon by the environment, react on the environment, and coact with other animals and plants.

The exact position of small mammals in a biotic community cannot be readily ascertained as has been evidenced by Fautin's work on the biotic communities of the northern desert shrub biome in Utah (Fautin 1946). Certainly no detailed investigation of the ecology of the ten or more species of small mammals, which have been included in this work, could be completed in the time allocated for the study. However it would be amiss if the fragments of ecological knowledge gathered were not presented in an attempt to evaluate the position of the rodents and small mammals on the range. Although no specific studies were made on other areas, the position of the mammals on the Southern Great Plains Experimental Range will most probably be applicable to all the sand sagebrush grasslands in the Southern Great Plains Region.

KANGAROO RAT, *Dipodomys ordii richardsoni* (Allen)

The kangaroo rat is the commonest small mammal in the sand sagebrush grasslands. Its distribution is correlated with loose sand and the highest populations occur where loose sand is exposed in patches presenting a clump-like appearance to the vegetation. Fautin (1946, p. 280) has also found higher populations of kangaroo rats on loose sands where the vegetative crown density was light.

A few individuals were caught on small flat areas with tight soil and it is believed they drifted from adjacent dunes of loose sand as no burrows were ever noted on tight soils. These observations show the species is completely absent from tight soils except as they proximate loose sand. The tight soils of the Permian Red Beds prevail throughout western Oklahoma and probably are the factor delimiting the distribution of the kangaroo rats.

The highest populations of kangaroo rats in a localized area will be found on the higher sand dunes where the sand is loose and in patches. Overgrazing on the sand sagebrush grasslands, accompanied by drought, will result in a decrease in vegetation, particularly grasses and forbs, and an increase in the amount of loose sand as the binding effect of the vegetation is diminished. Even without drought, overgrazing tends to produce conditions conducive to high kangaroo rat populations, although the result may be less severe. Conversely, light grazing will cause a decline in kangaroo rat populations.

As kangaroo rats are burrowing rodents they tunnel into soil and with their powerful hind legs kick the spoil out of the burrow entrances to form small mounds (Fig. 15). These mounds cover vegetation and provide sand for blowing. The magnitude of their activities is dependent upon the population and probably upon the texture of the soil. How much vegetation is covered; how much soil exposed; how is the natural vegetative succession affected--are all interesting problems awaiting factual information. Here it is merely recorded that these activities of kangaroo rats do occur.

The foods of kangaroo rats primarily consist of seeds, although some foliage is consumed and stored (Trowbridge 1941, pp. 31-33). Nests of kangaroo rats are usually of grass leaves. In most years kangaroo rats store quantities of seeds. Surface runways are made by kangaroo rats and a runway is a more or less winding transect devoid of vegetation. All of these statements show that kangaroo rats decrease forage and seed supply. Under proper range use the amount of

Fig. 15. Spoil thrown out of a burrow by a kangaroo rat, Dipodomys ordii richardsoni (Allen).

vegetation or seed eliminated by kangaroo rats would not materially affect forage production. Vorhies and Taylor (1922, p. 29) concluded that the banner-tailed kangaroo rat was not of great economic significance in ordinary seasons, except locally or during periods of drought. On the Southern Great Plains Experimental Range sand lovegrass, the predominate grass, fruits prolifically, and the amount of seeds consumed by kangaroo rats would be small in comparison to the seed production on a properly grazed range. Possibly one of the most important effects of kangaroo rats on forage would be selectivity of seeds which might affect vegetative composition. Costello (1944, p. 324) has mentioned the lack of western wheatgrass, Agropyron smithii Rydb., in abandoned fields in northeastern Colorado due to activities of kangaroo rats and white-footed mice. On one field which was denuded of all grasses and had the forb population considerably reduced, the kangaroo rat population was estimated at 300 per acre. With excessively high populations of kangaroo rats a resultant loss in forage will occur. However populations will not be excessive if the range is properly stocked.

Kangaroo rats, the commonest rodent on the sand sagebrush grasslands in the Southern Great Plains Region, can be effectively controlled by proper range use and under normal weather conditions and proper use will be interesting, but not economically important, members of the community.

GRASSHOPPER MOUSE, Onychomys leucogaster breviauritus Hollister

Grasshopper mice are the second most abundant rodent on sand sagebrush grasslands although in localized areas may be exceeded by cotton rats or some of the smaller rodents such as harvest mice or white-footed mice. They have a wide-spread distribution and are found under all variations of soils and grazing intensities. The only correlation found between this species and its environment was higher populations in moderately grazed pastures than in lightly or overgrazed pastures. The reason for this correlation is not known.

The foods of the grasshopper mouse consist of arthropods, particularly insects, small mammals and vegetation (Bailey and Sperry, 1929; Fautin 1946, p. 283). Vegetation is of minor importance and there is nothing to indicate the species is inimical to forage production.

The status of a species which appears to be transient as regards home range; eats a variety of foods, particularly insects; is vicious in association with other rodents; and has a wide-spread distribution is unique. The only apparent conclusion that can be reached as regards grasshopper mice is that they are of no particular importance to the range. Unfortunately this conclusion is probably based on ignorance of fact.

POCKET GOPHER, *Geomys breviceps llanensis* Bailey

No studies were conducted on populations or habits of the pocket gopher. The species was a common rodent on the range as evidenced from mounds, although no indications of excessively high populations were observed.

Pocket gophers have numerous effects on soil and vegetation which probably are as profound as for any range rodent excluding the prairie dog. In construction of their tunnels quantities of earth are moved. Smith (1948) excavated a burrow system of a gopher and found 70 cubic feet of earth had been moved in its construction. Gophers by construction of mounds cover vegetation and reduce the amount of available forage. Ellison (1946, p. 113) in studies on the Wasatch Plateau in Utah computed that 3.5 per cent of the ground surface was covered by gopher mounds and that the animals displaced at least 5 tons of earth per acre annually. The vegetative composition of a range can be altered by feeding of gophers, and Doran (1948) has shown weed density decreased where gophers were present and increased in their absence. In addition there are the effects of direct forage loss through feeding and plant vigor, as well as the influences on erosion, soil fertility, percolation, and structure.

Numerous studies of the effects of pocket gophers on range lands have been conducted by the Fish and Wildlife Service and various state agencies, but no studies have been made in sand sagebrush grasslands. The previous investigations have shown the effects of gophers on soil and forage varied with habitat, and the application of results found in one locality cannot be readily applied to other areas. Phillips (1936, p. 677) in studies in central Oklahoma found gophers more abundant in mowed hayfields and moderately overgrazed pastures than in undisturbed areas and were entirely absent in heavily overgrazed pastures. They definitely are not absent in heavily overgrazed pastures in sand sagebrush grasslands.

On the sand sagebrush grasslands the gopher is one of the major rodent components of the biotic community and future rodent studies on the Southern Great Plains Experimental Range should give this species primary consideration.

COTTON RAT, Sigmodon hispidus texianus (Audubon and Bachman) (Fig. 16)

Cotton rats will have high populations on lightly grazed or ungrazed ranges, and in localized areas on properly grazed ranges where due to topography, plant species, or other factors, the forage is little utilized and a dense vegetative crown canopy occurs. The species will be scarce or absent on overgrazed ranges. The trapping data have consistently proven the preference of these animals for dense crown cover. Phillips (1936, p. 676), Smith (1940, p. 394), Blair (1938, p. 514), Stickel and Stickel (1949, pp. 147-148), and Cahalane (1947, p. 485) have also recorded this preference.

Apparently the need of dense vegetative cover as a protection from avian predators is a prerequisite for the existence of this diurnal species.

The foods of cotton rats are varied but mainly consist of stems, leaves, and seeds of grasses and sedges (Cahalane 1947, p. 486). Insects, roots, and bird eggs are also included in their diet. The loss of forage from utilization of grasses is normally slight. However cotton rat populations are irruptive and at

Fig. 16. A cotton rat, <u>Sigmodon hispidus</u>. Courtesy of the United States Fish and Wildlife Service, by A. M. Pearson.

such times the amount of forage destroyed can be important (Schendel 1940, p. 33). The cause or causes of these population peaks is not known, but at apparently irregular intervals cotton rats increase in numbers to plague proportions (Smith 1940, p. 394).

Under normal conditions, proper range use will be adequate to control cotton rats. A high population may occur which will seriously deplete range forage. No known method of predicting population peaks is available and little to be done when one occurs—let the natural agencies of population control prevail and a decrease will ensue.

PACK RAT, Neotoma micropus micropus Baird

Although Trowbridge in 1940 found pack rats numerous on the Experimental Range, they were very scarce in 1949 and, except for a nuisance value in constructing dens in the small out-buildings on the range, they had very little importance. The only explanation that can be offered for the decline is that drought conditions occurred in 1940 and prior thereto, and the range was relatively depleted. With an increase in forage due to favorable growing seasons and proper grazing the pack rat numbers declined. Vorhies and Taylor (1940, p. 526) considered increases in the white-throated wood rat an effect of overgrazing. Regardless of its distribution in grasslands the pack rat is essentially a species that prefers brushy habitat and will likely not occur in excessive numbers on grass ranges.

On properly managed sand sagebrush grasslands the pack rat is of little importance although on overgrazed ranges their numbers and importance may be magnified. High populations of pack rats may occur along the stream courses and no trapping was done in these localities.

WHITE-FOOTED MOUSE, Peromyscus maniculatus nebrascensis (Coues)

The white-footed mouse was never taken in very high numbers on the Experimental Range, even when using Museum Special traps. The data from trapping in exclosures showed the species preferred a dense vegetative crown cover and comparisons of catches in lightly, moderately, and overgrazed pastures gave the highest populations in the lightly grazed pastures. Smith (1940, p. 395) in comparing populations on areas under different grazing intensities in central Oklahoma found no particular correlation between grazing intensities and numbers of white-footed mice. Phillips (1936, p. 678) in similar studies found the highest populations in moderately overgrazed pastures and about equal numbers in undisturbed grasslands, mowed hayfields, and heavily overgrazed areas. Considerable more investigations are needed to definitely determine the position of this species in grassland communities.

The white-footed mouse is omnivorous in food habits as has been determined by Brown (1946, p. 451-452) who found insects, particularly grasshoppers, and seeds heavily utilized.

The low populations of white-footed mice, their omnivorous food habits, and small size reduce the species to a relatively insignificant role in the sand sagebrush grassland community. Proper grazing will most likely offer a means of retaining the species in its proper position.

SPOTTED GROUND SQUIRREL, Citellus spilosoma major (Merriam) (Fig. 17)

The status of the spotted ground squirrel was difficult to determine as the animals were in hibernation during much of the trapping period. It did occur in all pastures trapped prior to its hibernation and can be expected to be present under all grazing intensities. A comparison of catches in various pastures showed that the species preferred overgrazed ranges to moderate or lightly grazed ranges. From casual observation the animals seemed to be more abundant

Fig. 17. A spotted ground squirrel, Citellus spilosoma. Courtesy of the United States Fish and Wildlife Service, by V. Bailey.

on the tighter soils where blue grama was present, although the catches of the species did not necessarily confirm this observation. In June, 1942, McMurry (1943, Table 1) caught spotted ground squirrels in the seven pastures in which he trapped, indicating a wide-spread distribution. A total of 57 individuals were taken by McMurry from May 22 to June 6 and 25 were pregnant females.

Bailey (1905, p. 87) found grasshoppers and beetles in stomachs of these animals and seeds of sandburs in their cheek pouches. They probably are omnivorous like most of the other species of ground squirrels.

There is surprisingly little known of the spotted ground squirrel and purely from an academic viewpoint future rodent investigations on the Southern Great Plains Experimental Range should be directed, as much as feasible, toward obtaining data on its life history and habits. In the 20-year index for the Journal of Mammalogy there are but two references to Citellus spilosoma major and one is a record of distribution and the other of a breeding female.

Assuming a negative attitude, the species cannot be of very great importance to the range for few studies have been made of these animals. Despite the backward approach it is most likely correct and the spotted ground squirrel will have to be considered one of the minor constituents of the sand sagebrush grasslands until further studies reveal otherwise. Severe overgrazing may alter this premise.

THIRTEEN-LINED GROUND SQUIRREL, Citellus tridecemlineatus arenicola Howell

No thirteen-lined ground squirrels were trapped in 1949 during the time of the present studies or by Trowbridge in 1940 and 1941. At the time of these studies, November and December, the species was in hibernation. McMurry (1943, p. 8) caught a few specimens in June of 1942. Apparently a low population exists on the Experimental Range. Phillips (1936, p. 676) working in central Oklahoma found their dens more numerous in mowed hayfields than in moderately overgrazed range, and very few dens were present in undisturbed grasslands or heavily overgrazed pastures. Smith (1940, p. 395) determined that the species was ". . .

especially favored when the taller grasses are eliminated from the vegetation, leaving a dense mat of short grasses and clumps of forbs." The thirteen-lined ground squirrel was found to be most common in natural revegetation of short grass than other forage types in mixed prairie in Kansas (Brown 1946, p. 454). The few observations of the Experimental Range also show the species prefers the short grass areas. Overgrazing, accompanied by drought, may increase populations of this species by increasing the amount of short grasses.

The food habits of the animals are omnivorous and there are numerous references to its insect consuming propensities; even to the point of considering the species definitely beneficial.

The thirteen-lined ground squirrels are a minor component of the sand sagebrush grasslands and occur on the areas of tight soil between the dunes. Overgrazing and drought probably favor the increase of those animals as the short grasses become more abundant under such conditions. Proper range use will materially assist in maintaining normal populations.

HARVEST MOUSE, Reithrodontomys montanus griseus Bailey

The diminutive rodent, the harvest mouse, was present in all pastures and had a wide-spread distribution. Trapping in exclosures and immediately adjacent thereto showed the animals preferred a dense crown cover of tall grasses. Catches of harvest mice usually occurred from trap sites in dense vegetative crown cover, although the quadrat as a whole may have had a moderate or light crown density. The latter explains its wide-spread distribution. Smith (1940, p. 394) in studies on overgrazed and eroded areas in central Oklahoma caught harvest mice only in areas having a fairly dense cover of vegetation. The proclivity of harvest mice for grassy prairie has been noted by Bailey (1931, p. 166). On the Experimental Range the species was taken from soils of loose sand and the tighter soils between the dunes. The catches indicated local abundance and ten animals were removed from a single quadrat.

The foods of harvest mice, according to Cahalane (1947, p. 469) and Brown (1946, p. 453) consist of seeds of grasses and forbs, sprouting grasses, and insects.

Unless these animals were to become extremely abundant it is doubtful if they would exert a very great influence on the biotic community. In sand sagebrush grasslands they can be expected to occur in areas of dense vegetative crown cover and will be most numerous in lightly grazed pastures.

POCKET MICE, Perognathus flavus flavus Baird and
Perognathus hispidus paradoxus Merriam

The pocket mice were infrequently taken during the trapping period of 1949 and all indications were that a low population existed. Trowbridge and McMurry both found low populations in 1940 and 1941. Their small size and low populations preclude any possibility of their being of major importance to the community.

Their habits and effects on the range are similar in nature to those of the kangaroo rats as regards foods and burrows, although the magnitude thereof is much less. Smith (1940, p. 395) found that the pocket mouse in central Oklahoma preferred eroded areas with sparse weedy vegetation. Blair (1937) has studied the burrows and foods of the pocket mouse in Rogers county, Oklahoma.

The pocket mice will occur as interesting, innocuous species in the sand sagebrush grasslands.

COTTONTAIL RABBIT, Sylvilagus floridanus llanensis Blair

Trowbridge in 1940 and 1941 considered the cottontail rabbit one of the important members of the range community and it was commonly observed. In 1949 the cottontail was commonly noted about the wells and corrals in the evenings but was uncommon on the range proper. The habitat requirements of the cottontail are not clearly defined in the tall grass, or mixed grass, prairie. Brown (1947, p. 40) in a comparison of pellet counts from grazed, ungrazed, and reseeded pastures in a mixed prairie in Kansas found the highest numbers in lowlands and ungrazed little bluestem. A pellet count study in central Oklahoma on variously grazed pastures gave the highest count in undisturbed grassland and the lowest in heavily overgrazed pastures (Phillips 1936, p. 677). Smith (1940, p. 394) in studies on the effects of overgrazing and erosion on the biota in central Oklahoma noted that cottontails preferred overgrazed pastures for feeding. Taylor (1944, p. 121) has found cottontails more numerous where grazing was light or absent. From these studies it would seem that cottontail rabbits should have increased markedly in the change from a uniformly overgrazed area to a lightly or moderately grazed range as has been experienced on the Experimental Range. However the cottontail rabbit population actually declined with the lighter grazing intensity. Possibly the excellent growing seasons with the resultant luxuriant grass cover materially reduced forbs which are a desirable food of cottontails. A combination of suitable cover plus overgrazing to produce weed species would likely give high populations of cottontails in grassland areas.

The high numbers of rabbits in 1940 and prior thereto may have been due to a population property, which functioned independently of environment, and the subsequent drop a normal decline. Duck and Fletcher (1944, p. 111) have stated that a peak population was present in western Oklahoma in 1939 and a decline occurred in 1940.

The foods of cottontails on grassland areas have not been studied very thoroughly but presumably they consist of leafy portions of grasses and forbs. From the standpoint of food, cottontails would compete directly with cattle on range lands.

The low populations of cottontails on sand sagebrush grasslands relegate them to a minor role in the range community despite their direct competition with cattle for forage. Duck and Fletcher (1944, p. 110) computed the cottontail rabbit population in the fall of 1940 on sand sagebrush grasslands as 9.3 acres per rabbit. This was a lower population than for any other habitat type. What the effect of overgrazing will have on the populations is problematic but under present conditions, consisting of good forage and excellent growing seasons, the population is low.

JACK RABBIT, *Lepus californicus melanotis* Mearns

The jack rabbit has reduced in population to the status of an uncommon mammal on the Experimental Range. In 1940 Trowbridge also found the species to be relatively uncommon on the Experimental Range although in November and December it was possible to count 10 to 12 freshly killed jack rabbits along the 20-mile stretch of highway between Woodward and the Experimental Range (Trowbridge 1941, p. 38). A single dead jack rabbit was noted on this same stretch of highway from October 1 to December 21, 1949. Apparently a decrease in numbers has occurred over the entire range country in western Oklahoma and the explanation seems to be correlated with the irruptive characteristics of jack rabbit populations. Jack rabbit numbers on occasion increase until they virtually amount to a plague and then suddenly, for some unaccountable reason, the population drops sharply to a very low level. Taylor (1948) has reported a "high" in a jack rabbit population in Texas, and the phenomenon has been observed by other investigators. Probably one factor in the decline in jack rabbit numbers on the Experimental Range was the excellent growing season of 1941 and subsequent years after the drought years of the 1930's and 1940. The good growing season resulted in an increase in tall grasses and a decrease in short grasses (Carpenter 1940, p. 647). The jack rabbit is typically a short-grass plains animal. Wooster (1935, p. 351) in studying the effect of drought on animal populations in western Kansas noted that jack rabbits increased during periods of drought and decreased during wet years.

The present low population on the Experimental Range will be maintained as long as moderate to light grazing practices persist and no drought occurs which would kill the tall grasses and reduce the vegetative crown density. Taylor and

Vorhies (1933, p. 563) have shown jack rabbits prefer moderately overgrazed range and this was confirmed by further studies by Taylor, Vorhies, and Lister (1935, p. 493). Phillips (1936, p. 676) in studies of rodent distribution on overgrazed and normal grasslands in central Oklahoma found jack rabbits more abundant on moderately overgrazed ranges. All studies have shown that jack rabbits do not thrive on lightly grazed ranges with a dense vegetative crown canopy.

Potentially jack rabbits are a threat to forage production for they utilize forage as food. Taylor and Vorhies (1933, p. 580) determined that 15 antelope jack rabbits consumed as much forage as one sheep and 74 as much as one cow. Also 30 Arizona jack rabbits consumed as much as one sheep and 148 as one cow. Arnold (1942, p. 83) from forage plots and feeding experiments in Arizona determined that, when competition was considered to be direct, 62 $\pm$ 7 Arizona jack rabbits or 48 $\pm$ 2 antelope rabbits consumed the equivalent of a 1,000-pound range cow. When the two classes of animals were considered to compete only for perennial grasses, the equivalents were 260 $\pm$ 20 for the Arizona jacks and 164 $\pm$ 7 for the antelope jacks.

The jack rabbit will be of little importance in the sand sagebrush grasslands if the range is properly grazed and an adequate vegetative cover maintained. Overgrazing will result in an increase in numbers of this species. The forage consumption of jack rabbits is relatively high compared with rodents and the result of the increase in numbers on overgrazed ranges will be more seriously overgrazed ranges. With proper range management the jack rabbit will fit nicely into its own niche in the biotic community as well as the economy of range management.

COMMON MOLE, Scalopus aquaticus intermedius (Elliot)

The tunnels of the common mole were frequently noted on the range and one specimen was caught in a rat trap. At no place was there any evidence of the species being particularly common and likely it will always occupy a minor position in the community as regards numbers. Arlton (1936, p. 351) has stated the species does not favor loose and sandy soil unless there is moisture and abundance of food. With the comparatively low amount of precipitation in the Southern Great Plains Region it is extremely doubtful if high populations of moles will occur.

The foods of moles consist mainly of earth worms, insects, and insect larvae (Arlton 1936, p. 363). Cahalane (1947, p. 117) has stated that the eastern moles do not eat tulip bulbs but this is open to serious doubt and likely bulbs, succulent roots, and rhizomes will be consumed by moles when these foods are encountered in their tunneling.

The mole may be of some importance as a mixer of soils and by tunneling increase soil porosity and aeration. In the sandy soils of the sand sagebrush grasslands this cannot have much importance. Their tunneling might be of significance in some sections of Oklahoma for breaking "plow sole." The latter, according to Mr. Edd Roberts, Extension Soil Conservationist, Oklahoma Agriculture and Mechanical College, Stillwater, Oklahoma, is a layer of hardpan 1 to 1½ inches thick, which forms at the bottom of the plowed depth of soil on lands devoted to cultivation. The "plow sole" is formed by the impact of the plow and the infiltration of finer soil particles through the plowed soil and redeposition at the bottom thereof. As the fine soil fills the interstices a layer developes which is impervious to water and thereby causes erosion and excessive run-off. "Plow sole" occurs world-wide wherever agriculture is practiced and is particularly prevalent in the wheat-growing section of Oklahoma where the soils are derived from the clays of the Permian Red Beds. The numbers of moles and the effects of their tunneling on the "plow sole" would warrant investigation.

LEAST SHREW, Cryptotis parva (Say) (Fig. 18)

The least shrew was taken in almost all pastures in which Museum Special traps were operated. Catches were usually made from quadrats with a high

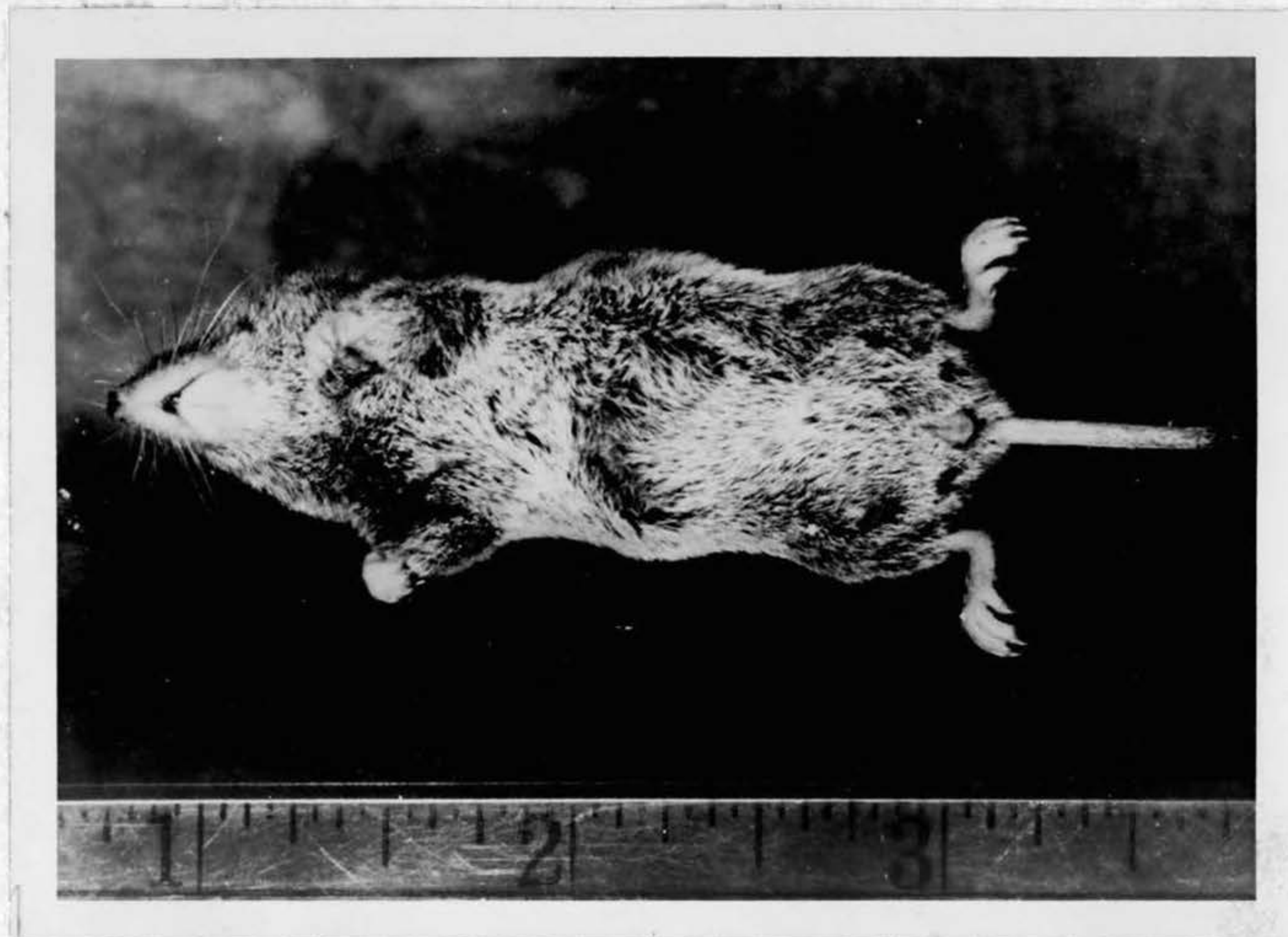


Fig. 18. A least shrew, Cryptotis parva (Say). Courtesy of the United States Fish and Wildlife Service, by W. P. Taylor.

vegetative crown density and eight individuals were taken from a quadrat inside a cattle exclosure and a catch of but one in a quadrat immediately outside the exclosure. Vegetative crown density was high in the exclosure and moderate outside. Although this species was taken on loose sand the higher catches were from the areas of tight soil between the dunes where there was good vegetative cover of mixed grasses. Blair (1938, p. 495) has stated that the least shrew is essentially a grassland animal. It occurs throughout the eastern half of the United States and sometimes in forested habitats. The species has never been found to be abundant.

The foods of the shrew consist mainly of arthropods and earthworms and Welter and Sollberger (1939, p. 78) have recorded the feeding of the young on ants, ant pupae, and crickets. It is probable that this species, like the mole, may sometimes consume bulbs or fleshy roots.

The small size of the least shrew and its relatively low population make the species a minor constituent of the sand sagebrush grassland community. Very little factual data relative to the life history and habits of the species is known. It is the shortest mammal in the United States.

S O M E C H A R A C T E R I S T I C S O F R O D E N T P O P U L A T I O N S

FREQUENCY — LENGTH DATA

Kangaroo rat

The total lengths of kangaroo rats caught in 1949 have been separated into five-millimeter length groups and frequency-length graphs for the total population and the segregated sexes are presented in Figure 19. These data were collected from October 1, 1949, to January 12, 1950, and in addition to individuals taken on the Experimental Range include 107 specimens taken about 1.5 miles north of Woodward, Oklahoma—a distance of about 17 miles from the Experimental Range. The graphs are based on 606 specimens consisting of 393 males and 313 females. The curves of the total populations and for the males and females are all bimodal with peaks at the 246-250 and 256-260 groupings, and lows at the 251-255 group. As the curves of the males and females are bimodal, it indicates that the bimodality is a characteristic of the populations as a unit and not a sex differentiation. The graphs of the male and female populations showed no size differentiation between males and females.

Information obtained on kangaroo rats during the course of these studies and by Trowbridge (1942, p. 10) show that breeding activity is rhythmic in nature. Females were not commonly found pregnant until mid-December by the writer or by Trowbridge and the latter did not find pregnant females in September, 1940, nor did McMurry (1942, p. 15; 1943, p. 10) find much evidence of breeding in June, 1941, and June, 1942. From December 15 to December 20, 1949, at least half of the females showed signs of sexual activity and about one-fourth were

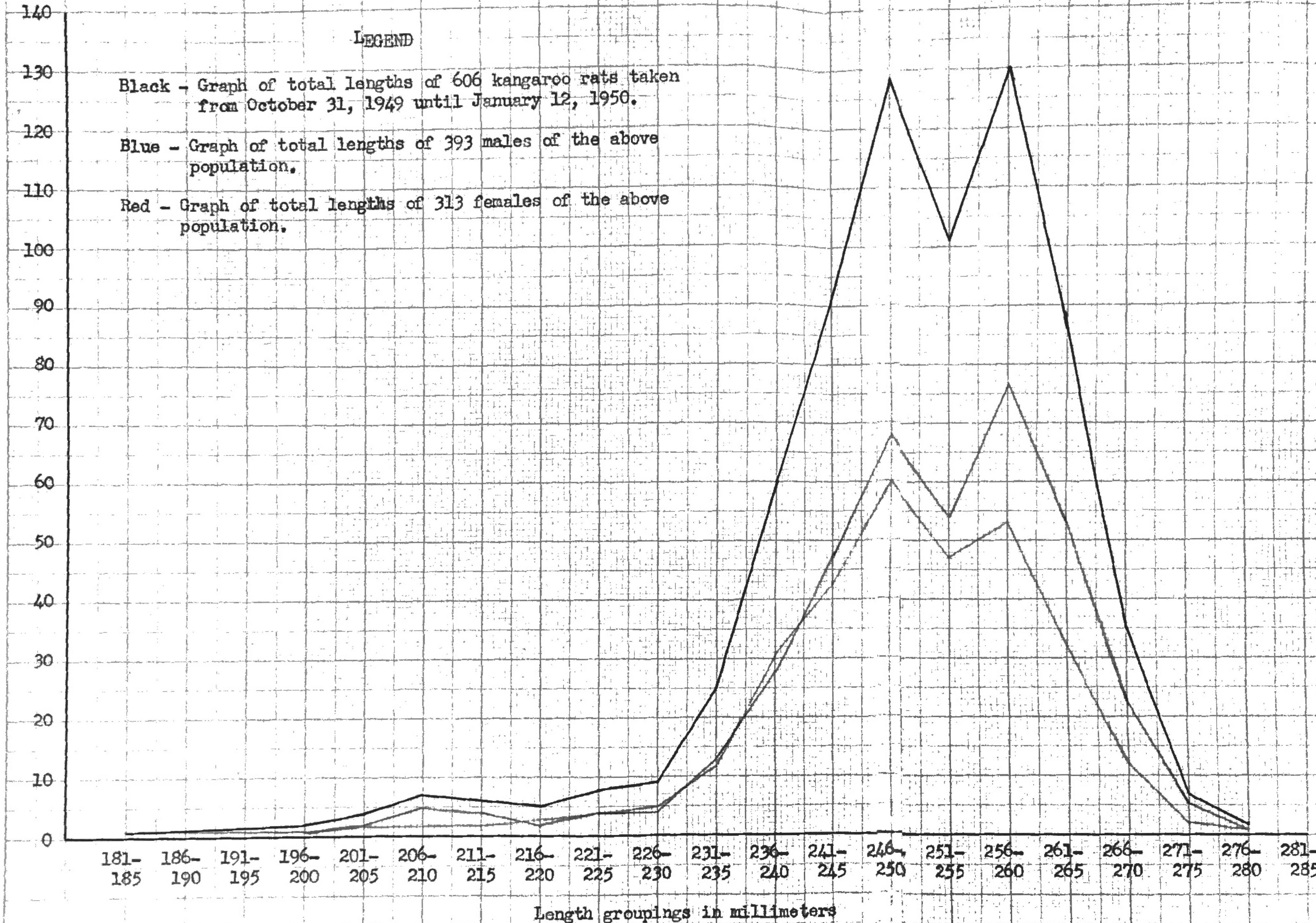


Fig. 19. Frequency-length graphs of kangaroo rats and for the separate sexes.

pregnant. This would indicate a sudden mass population increment occurred periodically. Therefore, the first, or left mode of the bimodal curve can be considered an immature population which was approaching maturity as exemplified by the second mode. A further substantiation of the second mode as the zenith of mature populations is shown in Figure 21, where the graphs based on data for 1940, 1941, and 1949 all show the largest number of animals in the 256-260 length group—the length group of the second mode.

In Figure 20 the 1949 material has been seperated by trapping periods and graphed. The data for the blue pencil and black ink graphs were obtained on the Experimental Range, and that of the red pencil graph from 1.5 miles north of Woodward. The first trapping period (blue pencil graph) was from October 31 to November 24, 1949, and includes data for 246 individuals taken from quadrats in Pastures 19, 20, and 24. The data for the second trapping period (black ink graph) was collected from November 29 to December 20, 1949, and consist of 213 kangaroo rats taken from Pastures 17, 18, and 21. The figures for the third period, December 30, 1949, to January 12, 1950, (red pencil graph) were obtained from 107 specimens. The graph for the first trapping period shows the bimodal effect as was noted with the total population in Figure 19. However the graph of the second trapping period which was about the first three weeks in December is a fairly normal curve with a peak at the 256-260 length group and a slight indication of one at the 246-250 group. These two groups are the peaks of the bimodal curve of the total population. The change from the bimodal curve based on data from the first three weeks in November to a unimodal, almost normal, curve based on data taken the first three weeks in December may be explained by the biological phenomenon of growth. A sufficient number of individuals of the 246-250 length group increased in size from November to December to alter the population composition and give the unimodal curve of December. As shown previously the first mode was undoubtedly an immature population. Actually to change the

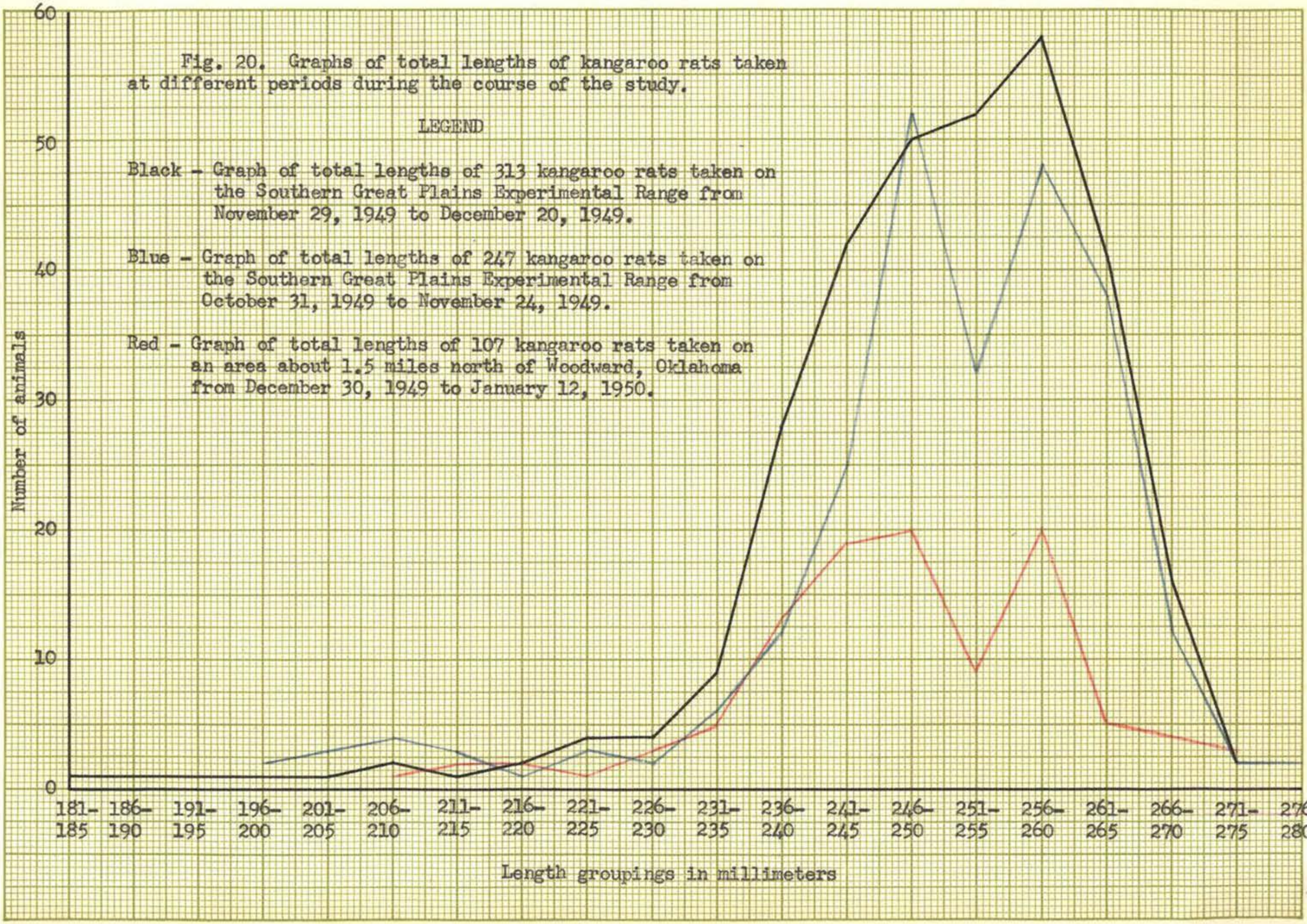


Fig. 20. Graphs of total lengths of kangaroo rats taken at different periods during the course of the study.

curve from bimodal to unimodal required the addition of only 1 millimeter of length growth to about ten kangaroo rats, each 250 mm. long. There were at least ten of that length in the October 31 to November 24 data. The only apparent explanation for the bimodal curve in the red pencil graph based on data taken near Woodward, is that the populations functioned independently of each other. Sexually the population north of Woodward was about 15 days later than the population on the Experimental Range. Sexual activity was noted in animals in the 246-250 length group and likely all individuals greater than 236 mm. in length can be considered sexually mature.

Figure 21 presents the frequency-length graphs for 1940 and 1941 from Trowbridge (1942, p. 7b) and for the December data for 1949. The data for 1940 were collected from November 22 to December 25; for 1941 from November 25 to December 19; and for 1949 from November 29 to December 20. The 1940 and 1949 data give unimodal graphs and indicate a stable population of adult animals. In 1949 the stability of the population was corroborated by lack of lactating females and the majority of the females were attaining pregnance in mid-December. The 1941 data showed a slight trimodality and was present in both males and females (Trowbridge 1942, p. 8a). Trowbridge believed these modes were due to (1) the normal adult population, (2) a group of advanced juveniles, and (3) a group of very young animals probably born in October. These data show that populations may function independently from year to year.

Grasshopper mice

A frequency-length graph for the 1949 grasshopper mouse population is presented in Figure 22. The data include 328 individuals caught during the trapping operations from October 31, 1949, to January 12, 1950. The sex ratio of the population was 167 males to 161 females. Sexually mature individuals probably include all animals over 135 mm. in length. The curve approximates a normal curve showing that the population during the period of study was relatively

Fig. 21. Frequency-length graphs of total lengths of kangaroo rats taken in late November and in December of 1940, 1941, and 1949.

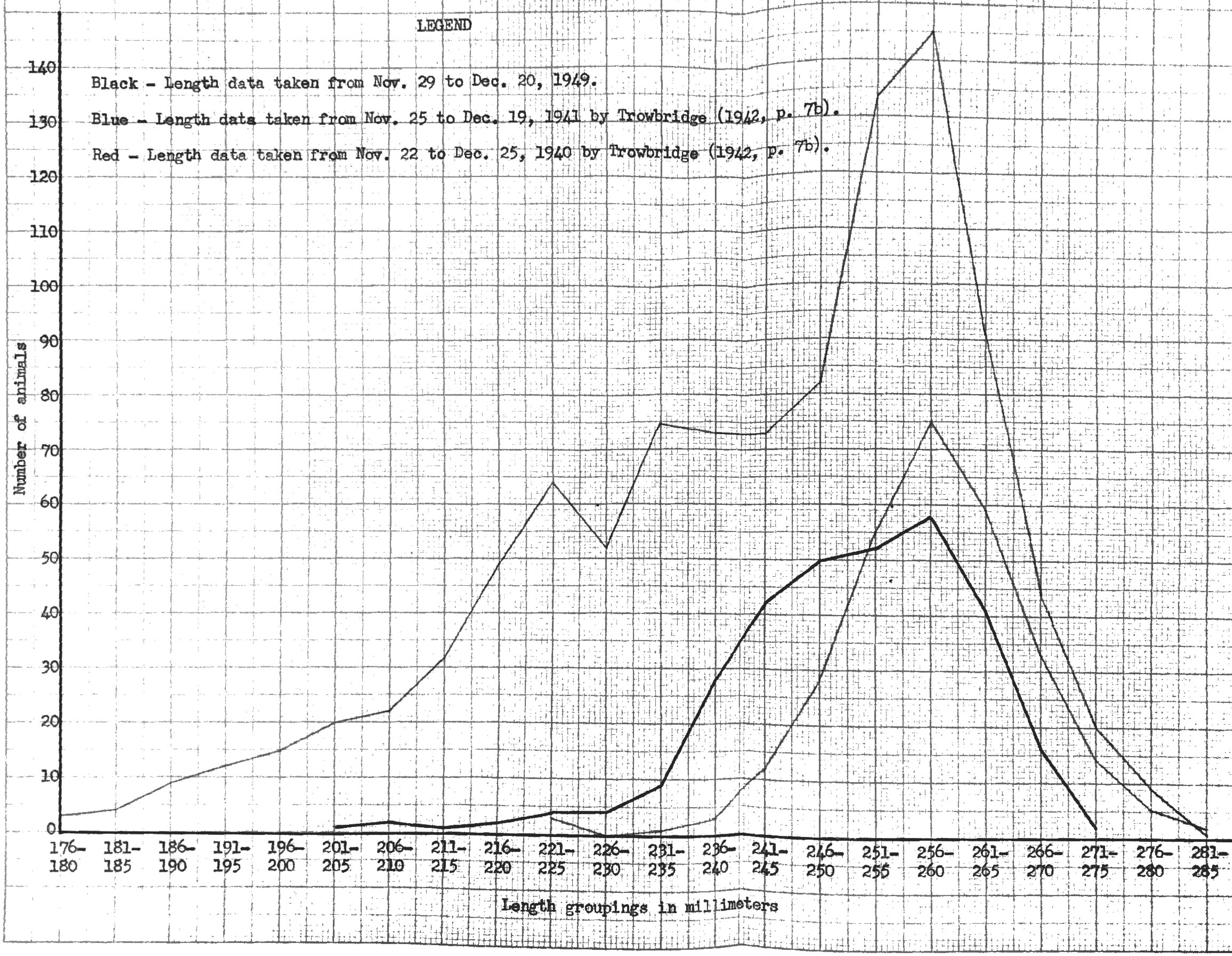
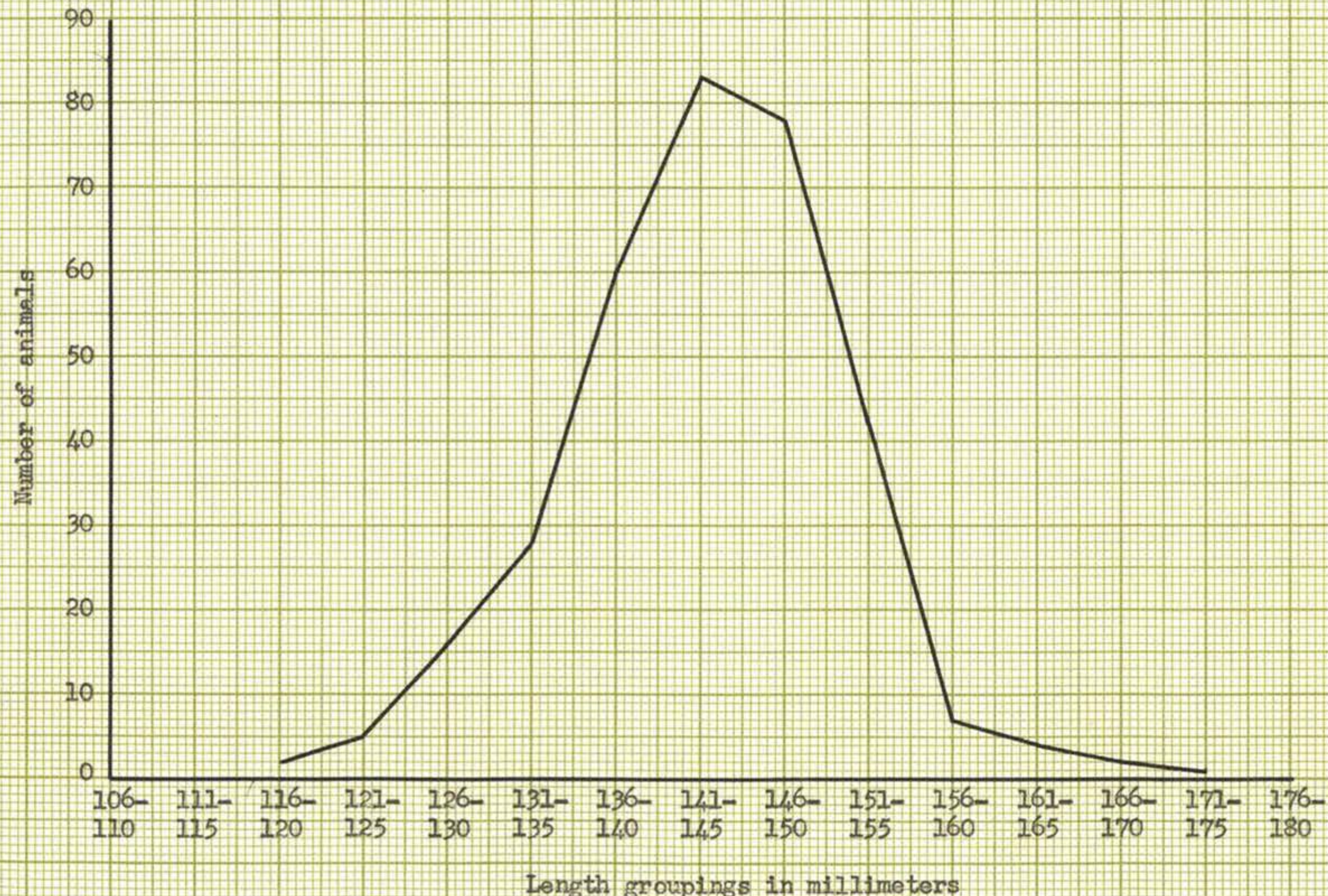


Fig. 22. Frequency-length graph of grasshopper mice based on 328 individuals.



stable and mainly of mature individuals. No sexual activity of grasshopper mice and no indications of a large group of immatures was noted.

Frequency-length graphs for the separate sexes of grasshopper mice showed that males were larger than females and had their peak at the 146-150 grouping. The peak of the graph for the females was at the 141-145 grouping.

SEX RATIOS

The sex ratios of the specimens trapped are presented in Table 33. Considering all species as a unit the males exceeded the number of females and this ratio prevailed for most of the species. The male catch was particularly dominant in the kangaroo rat and white-footed mouse populations. Grasshopper mice, cotton rats and other species did not show a very great difference between the sex ratios. The predominance of males is likely due to a larger home range and a greater "wandering tendency" as was found by Townsend (1935, p. 103).

Species	Males	Females	Totals
Dipodomys	442	341	783
Onychomys	167	158	325
Sigmodon	45	36	81
Peromyscus	44	22	66
Citellus	10	6	16
Neotoma	9	5	14
Reithrodontomys	20	21	41
Perognathus f.	1	1	2
Perognathus h.		1	1
Cryptotis	7	7	14
Sylvilagus	1	2	3
TOTALS	746	600	1,346

Table 33. Sex ratios of small mammals taken from October 5, 1949, to January 12, 1950, on the Southern Great Plains Experimental Range and from an area about 1.5 miles north of Woodward, Oklahoma.

S U M M A R Y   A N D   C O N C L U S I O N S

A study of the effects of various grazing intensities on species and populations of small mammals, particularly rodents, was conducted on the Southern Great Plains Experimental Range near Supply, Oklahoma. The range is located in the sand sagebrush grasslands of the mixed-prairie climax. Trapping quadrats were operated in pastures under different grazing programs and the results were compared to determine the effects of the grazing intensities on the rodent species and numbers. The majority of the work was confined to two groups of pastures, each containing a lightly grazed, a moderately grazed, and an overgrazed pasture. Quadrats were also operated inside and outside exclosures in the pastures to determine the species and populations on ungrazed range as compared to species and populations on ranges under the different grazing intensities. The data were examined to determine the habitat requirements of the various species. The methods employed in one group of pastures (Pastures 17, 18, and 21) were identical with those used by Trowbridge (1941, 1942) who conducted rodent investigations in these pastures in 1940 and 1941 when the range was grazed as a unit and before the pasture programs were put into effect. The present species composition and populations have been compared with the 1940 and 1941 data. The position of each of the species of small mammals in the sand sagebrush biotic community has been evaluated. Frequency-length data for kangaroo rats and grasshopper mice have been compiled and the sex ratios of the catches ascertained.

The following conclusions have been determined.

(1) The quadrat method of trapping with snap traps is satisfactory for obtaining comparative populations. Rat traps will give satisfactory numbers of the larger rodents but Museum Special traps, or mouse traps, are necessary to obtain quantitative data on the smaller species.

(2) Little difficulty was experienced in trapping in the late fall and early winter except from marsh hawks which frequently removed the traps and catches.

(3) The night by night catches of rodents varied considerably and did not conform to a high catch the first night and a diminishing catch on the succeeding nights. The reasons for the variations were probably due to activity peaks of rodents and drift factor.

(4) Two baits were used and a higher catch of kangaroo rats was taken with a grain bait mixture than with a paste bait mixture of peanut butter, rolled oats, and bacon grease. A higher catch of grasshopper mice was taken with the paste bait. These preferences are in accordance with the food habits of the species. The results show the difficulty of utilizing a single bait to obtain absolute numbers of rodents.

(5) The following species of small mammals were taken in the traps: Richardson kangaroo rat, short-eared grasshopper mouse, Texas cotton rat, gray harvest mouse, white-footed mouse, plains pack rat, spotted ground squirrel, pocket gopher, plains pocket mouse, silky pocket mouse, eastern mole, least shrew, and eastern cottontail rabbit. Thirteen-lined ground squirrels were present on the range but were in hibernation.

(6) The catches in the pastures showed a homogeneity of species over the range as a whole regardless of grazing intensity.

(7) Kangaroo rats were the most abundant small mammal on the range and reached their maximum populations on high dunes with exposed loose sand in patches. Minimum populations occurred on the areas of tight soil between the dunes. Higher populations of kangaroo rats were associated with overgrazing.

(8) Grasshopper mice were the second most abundant species and together with the kangaroo rats formed about 90 per cent of the total catches. Higher populations of grasshopper mice occurred in moderately grazed pastures than in lightly grazed or overgrazed. Excepting for this correlation the species had a

wide-spread distribution and seemed to be independent of soils and vegetation.

(9) White-footed mice, harvest mice, and cotton rats had their highest populations in the lightly grazed pastures and the cattle exclosures where there was a high vegetative crown cover. The cotton rat was more closely associated with the high vegetative crown cover than the other two species.

(10) Spotted ground squirrels were in hibernation during much of the study period but data obtained showed they preferred overgrazed pastures.

(11) Pack rats were uncommon in 1949 and a decline had occurred in their population since 1940. The decline was probably due to an increase in vegetative crown density—the result of favorable growing seasons and proper range use.

(12) The pocket gopher was a common animal on the range and is one of the most important rodent members of the biotic community. Future investigations should attempt to evaluate the position of this species in the community.

(13) The two species of pocket mice were poorly represented in the population and are a minor constituent of the community. More representative numbers of these species might be obtained with different trapping techniques.

(14) The least shrew was found to be most common in areas of dense vegetative crown cover and was particularly prevalent on areas of tight soil with a dense cover of mixed species of grasses.

(15) Cottontail rabbits were uncommon on the range proper although they were frequently noted about the wells and corrals. The species has declined in numbers since 1940. Prior to 1941 drought and overgrazing had prevailed on this range. Since 1941 favorable growing seasons have prevailed and as each of the pastures has been grazed differently the range as a whole is less overgrazed and has a denser crown cover.

(16) Jack rabbits are very scarce on the Experimental Range and have experienced a decline since 1940 similar to that of the cottontail rabbit.

(17) The effects of grazing on rodents varies with the individual species. Overgrazing favors high populations of kangaroo rats, spotted ground squirrels,

and probably pocket mice. Light or no grazing favors high populations of cotton rats, harvest mice, least shrews, and probably white-footed mice. Grasshopper mice are favored by moderate grazing.

(18) The rodent and rabbit biomass (6 pounds) on the Experimental Range was 15 per cent of the cattle biomass (40 pounds). Most of the rodent biomass consisted of species which do not compete directly with cattle for forage.

(19) A frequency-length graph of the total lengths of kangaroo rats taken in 1949 showed a bimodal curve which was due to a group of individuals slightly below maturity. The bimodality prevailed in the population obtained in November but was changed in December to almost a normal curve as the population obtained full maturity.

(20) The frequency-length curve of the grasshopper mice was approximately a normal curve indicating a stable relatively homogeneous population during the time of trapping. The males of the grasshopper mice were larger than the females.

(21) Sex ratios of the species showed a significantly higher catch of male kangaroo rats and white-footed mice. No important variations were noted with the other species.

APPENDIX A

Soil types on the Southern Great Plains Experimental Range[1]

Number	Soil types
2	Riverwash
3	Yahola very fine sandy loam
8	Lincoln fine sand
9	Lincoln silty clay loam
10	Lincoln fine sandy loam
18	Canadian loamy fine sand
19	Canadian fine sandy loam
31	Vernon silty clay loam
32	Vernon very fine sandy loam
33	Vernon fine sandy loam
52	Potter fine sandy loam
60	PRATT FINE SANDY LOAM[2]
61	PRATT LOAMY FINE SAND
64	TIVOLI LOAMY FINE SAND
65	TIVOLI SAND
70	ALBION SANDY LOAM
71	Albion fine gravelly loam
72	Carwile fine sandy loam
79	Springer loamy fine sand
81	Rough broken land. Vernon soil material
91	Garfield silty clay loam

[1] Material obtained from the Southern Great Plains Field Station, Woodward, Oklahoma.

[2] Soil types in bold letters are those that predominate on the Experimental Range.

Fig. 23. Soils map of the Southern Great Plains Experimental Range. Numbers above the lines refer to soil types.

Vernon Series

No. 31 Vernon Silty Clay Loam
No. 32 Vernon Very Fine Sandy Loam
No. 33 Vernon Fine Sandy Loam
No. 81 Vernon Rough Broken Land

Vernon Series:

The Vernon series includes immature, shallow soils developing *in situ* on the finer textured strata—red clays and fine arenaceous shales of the Red Beds. These soils are chiefly in eroded situations but also occur on nearly level areas and gentle slopes wherever relatively fine textured red beds are at or near the surface. Gypsum and dolomite outcrop in places.

The soil material, where present, is red, usually bright red, although locally its surface may be darkened somewhat by organic matter. Below the surface layer, which does not exceed six inches in thickness except locally, the red material has been little altered either by weathering or soil development. It varies considerably in texture and consistence but everywhere has enough silt and clay to afford good body or coherence. In places it consists largely of clay.

These soils are highly calcareous from at or near the surface downward but have no zone in which carbonates have accumulated through soil-forming processes. They represent the first stages in soil development on the finer textured Red Beds.

Pratt Series

No. 60 Pratt Fine Sandy Loam
No. 61 Pratt Loamy Fine Sand

Pratt Series:

These are dark brown soils developed from Quaternary or late Tertiary deposits consisting of brown, pale reddish-brown or gray sand containing enough silt and clay to give it slight to moderate coherence or "body." They occur nearly level, gently rolling and hummocky areas throughout the uplands, commonly in association with Tivoli soils. Surface drainage channels are poorly established or absent as the soil material absorbs the precipitation rapidly. Internal drainage is thorough. The soils hold moisture well.

The topsoils are from 5 to 12 inches thick, are dark grayish-brown, have a fine crumb to single grain structure, and are friable except in the more sandy types where they are rather incoherent. Fine sandy loam and loamy fine sand textures predominate although loam occurs in places.

The upper part of the subsoil is a trifle lighter colored and except in the loam type, is slightly heavier than the topsoil. It consists of dark grayish-brown or dark brown fine sandy loam or light sandy clay loam. This layer is moderately hard and brittle when dry, but a small lump can be easily crushed between the fingers and thumb into semi-coherent mass of sand, silt and clay, the sand predominating. It is from 8 to 15 inches thick. Below it the material becomes increasingly sandy and lighter colored, being pale reddish brown, brown or gray below about 30 inches.

The subsoil is massive to cloddy throughout. The soils are calcareous at depths ranging from 20 to 50 inches and commonly have a well developed zone of lime accumulation within a four foot depth.

The subsoils in the Pratt series are definitely of the semi-hard land type. They have some coherence or body but are not notably silty or clayey. Neither are they incoherent as in Tivoli soils.

Tivoli Soils

No. 64 Tivoli Loamy Fine Sand
No. 65 Tivoli Sand

Tivoli Series:

The soils of this series are light colored and immature. They are developing, for the most part, on wind-blown material consisting largely of sand in areas of undulating, or hummocky relief. The surface layers to a depth of from 4 to 8 inches may vary in consistence and somewhat in color, the degree depending upon the amount of silt, clay and organic matter which they contain. They are usually darker than the material below but do not become darker than grayish-brown. The remainder of the section consists of incoherent gray to pale reddish-brown sand of from medium to very fine grade. It extends to depths below 30 inches. The soils are not usually calcareous within a 3-foot section and may give no visible lime reaction to depths exceeding 10 feet.

Tivoli soils differ from dunesand mainly in having slightly darker surface layers and in occupying areas of less hilly and dunelike relief. They are very similar to the Valentine soils which occur in more northern states but are developing on brown to pale reddish-brown and in places slightly limey sands, whereas, the Valentine soils are on gray to light gray, non-calcareous sands.

Potter Series

No. 52 Potter Fine Sandy Loam

Potter Series:

The Potter series includes shallow, immature and light colored soils on marly clays and on caliche having various amounts of sand. These soils occupy narrow ridges, shoulders of hills and scarps, and rolling to hilly areas where erosion has prevented normal soil development.

The topsoils do not usually exceed six inches in thickness. They have no well defined structure. Where best developed they are brown or grayish-brown, the lighter color predominating. Clay loam, gravelly loam and sandy loam types predominate.

The subsoil, where present, consists of light gray or very light grayish-brown friable clay, silty clay or sandy clay. It is ordinarily less than 12 inches thick. At numerous places the topsoil rests directly on the parent material which is everywhere coherent.

In most areas of these soils, numerous fragments of hard caliche are scattered through the soil section and over the surface of the ground. In some areas waterworn granitic gravel makes up most of the upper part of the soil section. The parent material consisting of Tertiary clay or sandy clay, usually more or less cemented with caliche, outcrops at numerous places in many of the areas.

The soils are limey, generally throughout the section, but have no zone in which the carbonates have accumulated through soil-forming processes.

Springer Series

No. 79 Springer Loamy Fine Sand

Springer Series:

Soils of this series are mapped in localities where the solum, although otherwise resembling that of Pratt soils, has a light brown topsoil. The Springer differ from the Pratt soils only in having a lighter colored surface and commonly, higher lying lime. The carbonates are usually within a 20 inch depth. The soils may be limey to or near the surface of the ground locally.

Most of these soils will occur on ridges and hills where wind erosion has prevented the accumulation of much organic matter in the topsoil or has thinned or removed the topsoil since development.

Albion Series

No. 70 Albion Sandy Loam
No. 71 Albion Fine Gravelly Loam

Albion Series:

The Albion series includes semi-mature soils developing from coarse Quaternary or late Tertiary sand and fine gravel on well drained undulating to rolling uplands in this district.

The topsoils are brown to grayish brown, are from 8 to 10 inches thick, and have a massive to single-grain structure. The sandy loam and fine gravelly loam textures predominate.

The upper part of this subsoil, which continues to depths ranging from 20 to 30 inches, is composed of a semi-coherent mass of sand, silt, clay, and fine gravel, the latter constituent predominating. It is brown to grayish brown.

The remainder of the section commonly consists of incoherent fine gravel and coarse sand but may contain enough silt and clay to afford moderate coherence.

The soils are not limey, as a rule, though calcareous spots and splotches occur below a 30 inch depth at places.

The Albion soils differ from Pratt soils chiefly in having slightly lighter colored surface layers and much coarser—more gravelly subsoils.

Carwile Series

No. 72 Carwile Fine Sandy Loam

Carwile Series:

This series includes dark moderately heavy soils developing on flats and in swales and slight sags within or adjacent areas of higher-lying more sandy soils. Drainage, although rather slow, is adequate for cultivated crops.

The topsoils, which are massive to crumb-structured, are dark grayish-brown, are friable under average moisture conditions and are from 8 to 12 inches thick. The fine sandy loam texture predominates.

The remainder of the section consists of massive and moderately heavy sandy clay loam or clay loam. It is dark grayish brown in the upper part where it merges with the topsoil, and becomes lighter colored downward, being brown, yellowish-brown or mottled brown and rusty brown below a depth of about two feet. The subsoil contains enough sand to give it a more or less gritty feel almost invariably and is commonly quite sandy. The clay content, however, is sufficient to make the material moderately heavy.

These soils are limey at depths ranging from about 17 to 30 inches. An ill-defined zone of carbonate accumulation having lime both in finely divided form and in scattered hard concretions may occur between the 2 and 3 foot depths but is not persistent.

The parent material is of Quaternary or late Tertiary age. Much of it is colluvium washed or blown from higher levels though a part may have weathered in situ from underlying formations.

These soils differ from those of the Stonington series, tentatively established in the Soil Conservation survey of northeastern Baca county, Colorado, chiefly in having darker colored topsoils. They are associated with Pratt and Tivoli soils in most places.

Garfield Series (Tentative)

No. 91 Garfield Silty Clay Loam

Garfield Series:

This series is tentative and was set by field men during the progress of the Harper County Survey.

The following is a brief summary and description of areas observed:

The Garfield series was found on divides on nearly flat to gently undulating topography. It occurred in areas of Pratt, Springer, and Potter soils and therefore probably developed from some silts but mostly clays of Tertiary age.

It is a dark, very heavy soil with good external drainage but a tight clay subsoil makes internal drainage very slow. During dry periods the surface of the ground has numerous large cracks.

A brief description of the profile observed is as follows:

0 to 6 in.	Dark grayish-brown silt loam, crumb structure and calcareous.
6 to 24 in.	Mixed brown and yellowish brown, reddish-brown and yellow clay or a clay loam in places. Some cubical structure. Calcareous.
24 inches plus	Yellow, yellow-brown, red and reddish-brown mixed silts and clays and lime concretions in places.

APPENDIX B

LIST OF COMMON AND SCIENTIFIC NAMES OF MAMMALS MENTIONED IN SECTION, "INFLUENCES OF RODENTS AND RABBITS ON RANGE LANDS"

Antelope jack rabbit, Lepus alleni alleni Mearns
Arizona jack rabbit, Lepus californicus eremicus (Allen)
Banner-tailed kangaroo rat, Dipodomys spectabilis spectabilis Merriam
Black-tailed jack rabbit, Lepus californicus melanotis Mearns
Bottae pocket gopher, Thomomys bottae centralis Hall
Brazos pocket gopher, Geomys breviceps brazensis Davis
California ground squirrel, Citellus beecheyi beecheyi (Richardson)
California ground squirrel, Citellus beecheyi fischeri Merriam
Chisel-toothed kangaroo rat, Dipodomys microps bonnevillei Goldman
Columbian ground squirrel, Citellus columbianus columbianus (Ord)
Desert harvest mouse, Reithrodontomys megalotis deserti Allen
Giant kangaroo rat, Dipodomys ingens (Merriam)
Gray harvest mouse, Reithrodontomys montanus griseus Baird
Harvest mouse, Reithrodontomys sp.
Long-toothed ground squirrel, Spermophilus leptodactylus
Moore pocket gopher, Thomomys talpoides moorei Goldman
Nebraska deer mouse, Peromyscus maniculatus nebrascensis (Coues)
Nelson antelope ground squirrel, Ammospermophilus nelsoni (Merriam)
Ord kangaroo rat, Dipodomys ordii celeripes Durant and Hall
Pacific pocket mouse, Perognathus pacificus Mearns
Plains wood rat, Neotoma micropus micropus Baird
Prairie harvest mouse, Reithrodontomys megolantis duchei Allen
Richardson kangaroo rat, Dipodomys ordii richardsoni (Allen)
Santa Cruz kangaroo rat, Dipodomys venustus venustus Merriam
Streater wood rat, Neotoma fuscipes streatori Merriam
Thirteen-lined ground squirrel, Citellus tridecemlineatus arenicola Howell
Tulare kangaroo rat, Dipodomys heermanni tularensis (Merriam)
Western pocket gopher, Thomomys sp.
Western pocket gopher, Thomomys bottae (Eydoux and Gervais)
Western pocket gopher, Thomomys talpoides (Richardson)
Western upland meadow mouse, Microtus ochrogaster haydenii Baird
White-throated wood rat, Neotoma albigula albigula Hartley
Zuni prairie dog, Cynomys gunnisoni zuniensis Hollister

APPENDIX C

DATA SHEETS FOR INDIVIDUAL QUADRATS

The following sheets are samples of 80 quadrat data sheets filed at the Oklahoma Cooperative Wildlife Research Unit, Oklahoma A. and M. College, Stillwater, Oklahoma. A sheet has been prepared for each of the quadrats. The fractions after the whole numbers represent the sex ratio of males to females. The underlined data in the "Diagram of Catches" show the individuals caught with the Museum Special traps. For convenience the following abbreviations have been used in the "Diagram of Catches."

M - male

F - female

? - sex unknown

Do - kangaroo rat

O - grasshopper mouse

C - spotted ground squirrel

R - harvest mouse

P - white-footed mouse

Pf - silky pocket mouse

Ph - plains pocket mouse

Sh - cotton rat

G - pocket gopher

Saq - eastern mole

Cr - least shrew

Sy - cottontail rabbit

X - unknown animal

10/1 - month/day

PASTURE 19 : QUADRAT 1

<u>Location</u>: Northwest of trail through Pasture 19, in southwest section. First moderate dune southwest of high dune along west fence line.
<u>Dune</u>: A typical moderate dune (-15 feet). Long axis N-S in direction and at south end joined a NE-SW dune. The dune was flat-topped and sloped moderately on sides.
<u>Soil</u>: Sandy and loose with small patches of loose sand between vegetation.
<u>Vegetation</u>: Sagebrush and sand lovegrass predominate. Vegetation dense in east half and moderate elsewhere. Lightly grazed.
<u>Quadrat</u>: Extended N-S along main axis of dune. Line B on top of dune, line A at top of west slope, line C on last slope.
<u>Bait</u>: A mixture of peanut butter, rolled oats, and bacon grease.

<u>Table of Catches</u>:

Date	Time	Dipodomys	Onychomys	Totals
Oct. 30	3:30 P	All traps baited and set. Rat traps.		
Oct. 31	10:15 A	$2\frac{1}{1}$	$1\frac{0}{1}$	$3\frac{1}{2}$
Nov. 1	10:45 A	$1\frac{1}{0}$	$3\frac{3}{0}$	$4\frac{4}{0}$
Nov. 2	10:00 A	$1\frac{1}{0}$	$2\frac{1}{1}$	$3\frac{2}{1}$
Nov. 3	9:05 A	$1\frac{0}{1}$		$1\frac{0}{1}$
Nov. 4	11:06 A	$1\frac{1}{0}$	$1\frac{0}{0}$' All traps removed	$2\frac{1}{0}$'
	TOTALS	$6\frac{4}{2}$	$7\frac{4}{2}$'	$13\frac{8}{4}$'

Diagram of Catches:

	X	X	X	X	X	X	X	X	X
(A)		10/31 F Do		11/1 M O 11/2 M O					
(B)	11/1 M Do				11/2 F O	10/31 F O		10/31 M Do 11/4 M Do	
(C)				11/1 M O	11/2 M Do			11/4 ? O	11/1 M O 11/3 F Do

<u>Remarks</u>: Nothing particularly impressive in this quadrat. Was surprised that more kangaroo rats were not taken.

PASTURE 19 : QUADRAT 2

Location: A low dune in the south end of Pasture 19. First low dune southwest of Quadrat 3.
Dune: A low dune area (-10 feet) made of three or four small connected dunes. The main axis is NE-SW in direction.
Soil: Sandy and loose particularly in west portion of quadrat.
Vegetation: Sagebrush and sand lovegrass. Density high in east half of quadrat and moderate in west half.
Quadrat: Long axis is NE-SW. Line B to east of center of dune, line A on flat top of dune, line C at foot of east slope. South end of quadrat at base of south slope and about 75 yards from east fence line.
Bait: A mixture of peanut butter, rolled oats, and bacon grease.

Table of Catches:

Date	Time	Dipodomys	Onychomys	Sigmodon	Citellus	Cryptotis	Totals
Oct. 30	3:38 P	All traps baited and set. Rat traps					
Oct. 31	9:30 A	$1\frac{1}{0}$	$2\frac{0}{2}$	$1\frac{1}{0}$			$4\frac{2}{2}$
Nov. 1	10:03 A	$1\frac{0}{1}$		$1\frac{0}{1}$			$2\frac{0}{2}$
Nov. 2	8:55 A	$3\frac{0}{3}$	$1\frac{0}{1}$				$4\frac{0}{4}$
Nov. 3	8:30 A	$2\frac{1}{1}$			$1\frac{1}{0}$		$3\frac{2}{1}$
Nov. 4	10:15 A	No catch.					
	TOTALS	$7\frac{2}{5}$	$3\frac{0}{3}$	$2\frac{1}{1}$	$1\frac{1}{0}$		$13\frac{4}{9}$
Nov. 4	10:15 A	Substituted Museum Special traps for rat traps.					
Nov. 5	8:00 A		$2\frac{2}{0}$			$1\frac{1}{0}$	$3\frac{2}{1}$
Nov. 6	3:50 A	All traps removed.				$2\frac{0}{1}{}^{1}$	$2\frac{0}{1}{}^{1}$
	TOTALS		$2\frac{2}{0}$			$3\frac{1}{1}{}^{1}$	$5\frac{2}{2}{}^{1}$

Diagram of Catches:

(A) X X X X X X X X X
11/5 F O
10/31 M Do
11/2 F O
11/3 M Do
11/5 M O
11/2 F Do
10/31 F O
11/1 F Do
11/2 F Do
11/3 M O
11/2 F Do
11/3 F Do

(B) X X X X X X X X X

(C) X X X X X X X X X
11/6 ? Cr
10/31 F O
10/31 M Sh
11/1 M Sh
11/5 M Cr
11/6 F Cr

Remarks: Note high catch of kangaroo rats and grasshopper mice from line A which had a moderate crown density and considerable exposed loose sand between vegetation. Conversely the cotton rats and least shrews were taken only in line C which had a high crown density and tighter soil.

PASTURE 19 : QUADRAT 3

<u>Location</u>: In southeast portion of Pasture 19, southeast of trail. First dune southeast along east fence line from fence gate.
<u>Dune</u>: A typical moderate dune (415 feet). Long axis NW-SE. Moderately steep slopes.
<u>Soil</u>: Sandy and loose with moderate amount of exposed sand between vegetation.
<u>Vegetation</u>: Sagebrush and sand lovegrass with clumps of little bluestem and some stalks of indiangrass. Vegetation dense on east slope and moderate elsewhere. Lightly to moderately grazed.
<u>Quadrat</u>: Along main axis NW-SE of dune. Lines A and C on sides, line B on top.
<u>Bait</u>: A mixture of peanut butter, rolled oats, and bacon grease.

<u>Table of Catches</u>:

Date	Time	Dipodomys	Onychomys	Reithrodontomys	Cryptotis	Totals
Oct. 30	3:50 P	All traps baited and set. Rat traps.				
Oct. 31	9:50 A	$1\frac{1}{0}$	$1\frac{0}{1}$			$2\frac{1}{1}$
Nov. 1	10:18 A		$1\frac{1}{0}$			$1\frac{1}{0}$
Nov. 2	9:15 A	$4\frac{1}{3}$				$4\frac{1}{3}$
Nov. 3	8:45 A		$1\frac{1}{0}$			$1\frac{1}{0}$
Nov. 4	10:45 A	$2\frac{2}{0}$				$2\frac{2}{0}$
	TOTALS	$7\frac{4}{3}$	$3\frac{2}{1}$			$10\frac{6}{4}$
Nov. 4	10:45 A	Substituted Museum Special traps for rat traps.				
Nov. 5	8:15 A	$1\frac{0}{1}$		$3\frac{1}{2}$		$4\frac{1}{3}$
Nov. 6	3:55 P				$2\frac{1}{0}$'	$2\frac{1}{0}$'
	TOTALS	$1\frac{0}{1}$		$3\frac{1}{2}$	$2\frac{1}{0}$'	$6\frac{2}{3}$'

<u>Diagram of Catches</u>:

(A) X X X X X X X X X
11/4 M Do
11/4 M Do
<u>11/5 F Do</u>
11/1 M O
11/3 M O
<u>11/5 M R</u>

(B) X X X X X X X X X
<u>11/6 M Cr</u>
11/2 M Do
<u>11/5 F R</u>
<u>11/6 ? Cr</u>

(C) X X X X X X X X X
11/2 F Do
11/2 F Do
<u>11/5 F R</u>
10/31 M Do
10/31 F O
11/2 F Do

<u>Remarks</u>: More evidence that the least shrew and harvest mouse are not caught with the rat traps.

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