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An Ecological Study of The Pocket Gopher In An Sandy Loam Area of Ellis County, Kansas.

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AN ECOLOGICAL STUDY OF THE POCKET GOPHER IN A SANDY LOAM AREA OF ELLIS COUNTY, KANSAS

being

A thesis presented to the Graduate Faculty of the Fort Hays Kansas State College in partial fulfillment of the requirements for the Degree of Master of Science

by

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INTRODUCTION

Taxonomic Distinctions and General Distribution of Pocket Gophers in the United States

The family Geomyidae, which consists of nine genera, is representative of the southern half of North America. Five genera are found in Mexico, one in Costa Rica, and three in the United States. The three United States genera (Thomomys, Geomys, and Cratogeomys) consists of over a hundred recognized and named species and subspecies. The chief taxonomic distinction among these three genera lies in the type and number of grooves on the upper incisor teeth.

Thomomys

The genus Thomomys is found in the great plateau region which extends from Central Mexico and Lower California northward into Canada. This group has no median groove on the upper incisor, but occasionally there is a fine marginal groove.

Geomys

The genus Geomys is restricted to two large distinct areas. One area includes parts of Alabama, Georgia and Florida. The other includes most of the Mississippi Valley Plain and extends from the Rio Grande north to Minnesota

and Wisconsin, and west from Central Illinois to Colorado and Wyoming. Geomys is characterized by two grooves on the upper incisors. There is a fine marginal groove along the inner margin of the teeth and a larger median groove.

Cratogeomys

The genus Cratogeomys ranges from Mexico north and west through New Mexico, Texas, Western Oklahoma and Eastern Colorado. This group is characterized by a single median groove on the upper incisor teeth.

Related Studies

During the past several years considerable research has been carried on concerning the relation of burrowing rodents to land usage. Grinnell (1923) carried out excellent work concerning the action of pocket gophers in relation to soil formation. He also worked out a series of reports dealing with the geography and evolution of gophers.

Dixon (1929) performed many experiments dealing with control measures of the various rodent groups.

Scheffer (1910) studied the ecological relationships of pocket gophers over all the western half of the United States.

Mohr (1936) and Ellison (1946) carried out work concerned with the digging rate and the relation of gophers

to soil erosion.

Davis, Ramsey, and Arendale, Jr. (1938) studied the relation and distribution of pocket gophers to different kinds of soils. Their experiments showed that the distribution of the gophers is in no way correlated with the pH value of the soil. Gophers are just as likely to be found in acid soils as they are in neutral or basic soils.

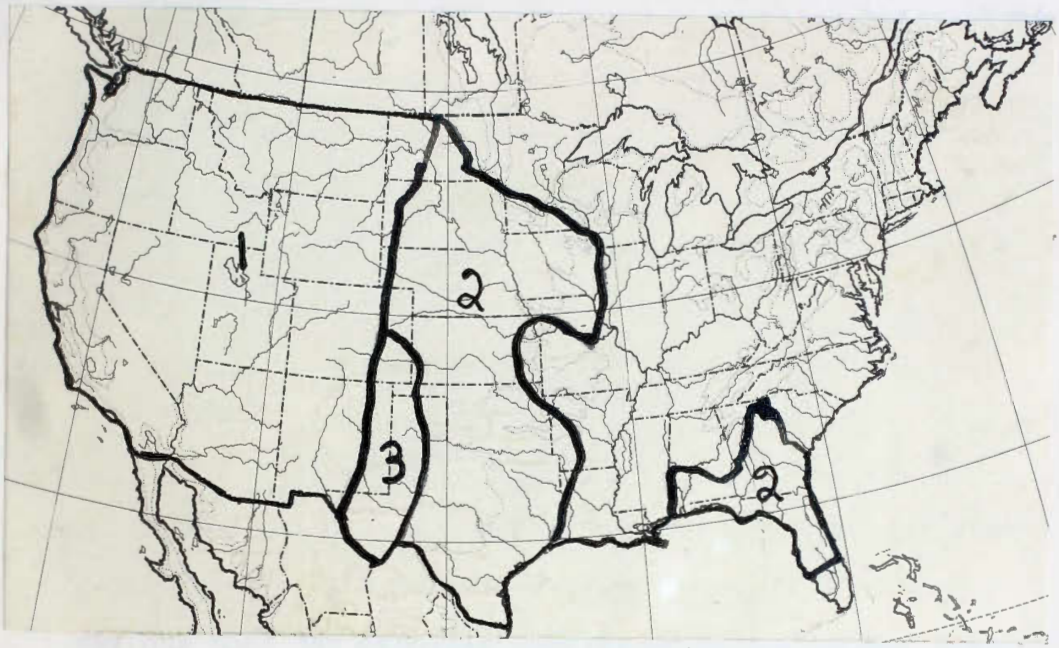
Goldman (1938) has described many new species and sub-species of gophers. He was one of the foremost taxonomists of rodent groups at the time of his death. These men and many others have been important in carrying out studies of ecological importance of burrowing animals.

General Description of a Pocket Gopher

Pocket gophers are locally called salamanders, camas rats, pouched rats or gophers. The term "gopher" is also applied to various species of ground squirrels and is used in reference to a burrowing land tortoise of Southeastern United States. In many instances gophers are mistakenly called moles. The true pocket gopher (Fig. 1) is easily recognized. It derives its name from its most outstanding characteristic; it is a burrowing animal and it has large external cheek pockets.

Pocket gophers have extremely stocky bodies, which are heavy anteriorly and are well built to support the muscles necessary for extensive burrowing activities. The

Figure 1. Picture of an Ellis County pocket gopher (Geomys bursarius).



1 - Thomomys
2 - Geomys
3 - Cratogeomys

Figure 2. Map of the United States showing the general distribution of the three genera of pocket gophers in the United States.

shoulders and forelegs are exceptionally well developed, with the forefeet having long strong claws. The hind legs and posterior parts of the body are less developed. Scheffer (1910) aptly described the gopher as being built short and broad "like a typical Hungarian coal miner." The body hair is soft and glossy. The tail is short and scantily haired. The ears and eyes are small and inconspicuous. The upper incisor teeth are large and cannot be concealed within the lips.

Economic Importance

Agricultural Districts

The economic importance of the pocket gopher varies with the type of land and with its use. It is rather obvious that the economic importance of the gopher changed with the widespread advent of the settlers into Western United States. From the viewpoint of extensive agricultural practices, the pocket gopher must be considered a menace to cultivated lands.

On irrigated areas it is condemned for its destructive effects on ditches, levees and dams, and for the vegetation it destroys in the quest for food. On hay fields the chief destructiveness lies in the throwing out of mounds which cover the vegetation. These mounds cause the vegetation to die and they also are nuisances in mowing operations. Fruit growers and truck farmers also have a

just complaint against this incessant burrower. Even the grower of small grains may have reason to complain in heavily infested areas. Ranchers are likely to be affected only on overgrazed lands. On certain overgrazed areas, burrowing rodents may appear as direct competitors with livestock. Since most overgrazed areas are characterized by an increase in forbs and weedy species of plants, the population of burrowing animals tends to increase. Such an increase will probably place a greater pressure on the already overtaxed range. However, in some cases the harmful effects may be somewhat retarded, since the burrowing tends to counteract the packing effects of livestock on the soil.

Non-Agricultural Districts

On non-agricultural districts the condition is in general reversed. Most ecologists recognize a definite benefit from burrowing animals on wild land. Grinnell (1923) recognized several general effects that pocket gophers have on the terrain of the Sierra Nevada Range. These effects are as follows:

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

(2) The subsoil is broken up and carried to the surface where it is exposed to a 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 slopes to fill up glacial depressions and to make meadows of them. When the depressions 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 runoff is retarded and the supply to the streams below is distributed over a longer period of time. Spring floods are less likely to occur since the porous soil retains the water longer than packed ground, and gives it up with corresponding slowness. This insures a more regular water supply to the lowlands.

(5) A porous moist soil produces a fuller vegetational cover--forest, brush 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 burrows. In this way both air and water are admitted 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 soil.

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

From these facts it is easy to see that the pocket gopher plays an important part in the enriching of the soil on wild land. Such enriching is accomplished by the deposition of raw soil on the surface to be weathered, by the burying of vegetation beneath the soil and by the carrying of vegetation into the burrows to form future humus.

Since the modern pocket gopher is identical in all

respects with the gopher of Miocene times, it has as its existence period some 200,000 years. (Grinnell, 1923). Estimating the rate of soil turnover at one-tenth inch per year would make a total of 1,700 feet or the equivalent of 3,400 plowings to a depth of six inches. It has been estimated that pocket gophers do as much soil mixing in five months as earthworms do in five years.

Means of Control

The most common methods by which gophers may be controlled are poisoning, trapping, flooding, fumigating and encouragement of their natural enemies. Shooting has been suggested but it is a very ineffective control. Often a combination of two or more of these methods is necessary to obtain the desired results. Trapping and poisoning are the most practical and efficient controls. The determination of the method to apply will depend on the species of gopher, the locality, the season and the local agricultural practices. In general, control operations can best be conducted during the season when the gophers are most active. In most localities autumn is the best time to carry on an effective control program.

Poisoning

Poisoning is one of the cheapest and easiest applied controls. In many cases it is the most effective. The

danger of destroying useful birds and animals is slight, since the bait is placed in the runway through an opening which is then closed. (Dixon, 1929).

Baits are usually vegetable roots, leafy plants, or grain. The favorite root baits are sweet potatoes, carrots, parsnips, potatoes, turnips and beets in the order listed.

Gophers vary in their tastes and not all the individuals in the same area may accept the same bait. In such cases it may be necessary to re-treat an infested area using another type of bait. A good plan is to use sweet potatoes for the first treatment and carrots for the second. If these baits do not prove successful a third bait of grain could be used. Regardless of the bait used, it is necessary to bait only the runways leading to comparatively fresh mounds.

In preparing the vegetable root bait the following steps should be taken. The vegetables should be thoroughly cleaned and cut into pieces about an inch and half long and half an inch square. This is to defeat the gopher's frequent practice of storing foods before eating them. Pieces of this size would either be eaten or cut into smaller, more easily handled pieces, thus attaining immediate results. Crouch (1942) recommended the following poison bait formulae for gopher control.

Formula No. I--Vegetable root bait: Cut into pieces 1 1/2 inches long and 1/2 inch square--2

quarts sweet potatoes or carrots. Dust over these from a sifter (pepper box) while stirring--1/8 ounce strychnine (alkaloid powdered).

Formula No. II--Leaf bait: Gather fresh alfalfa or clover leaves, free of moisture, dew or dust--1 1/4 pounds. Dust over the leaves, covering each leaf surface from a sifter--1/8 ounce strychnine (alkaloid powdered). Prepare only one day's supply.

Formula No. III--Grain bait: Mix 3/4 pint water with 2/5 ounce laundry starch. Bring the mixture to a boil, stirring constantly. Boil until a lump free paste is obtained. Stir into the paste 1/4 pint corn syrup and 1/2 ounce glycerine. Mix 1 ounce strychnine and 1 ounce baking soda in a gallon container. Add the hot paste and stir thoroughly. Pour the mixture over 16 quarts wheat (plump kernels) or steam rolled oats. Stir until the kernels are well coated, then spread out to dry.

A probe is useful for locating runways and a little practice makes a person adept at this job. Probes may be of many types, steel rods, broom sticks, shovel handles, or anything which is pointed and can be easily handled. In probing, the opening to the runway should be at least eighteen inches from the mound to insure that the opening leads to the main runway and not to a lateral. A hole just large enough for the placing of the poisoned bait should be made. After the bait is placed the hole should be covered.

Trapping

Trapping is recommended for control of small areas or for lightly infested large areas. This method is slower

than poisoning but the results are sure. Several types of commercial gopher traps are manufactured and they are all satisfactory if they are set properly. Care should be taken, however, that the type of trap which is to be used has sufficient jawspread for the species of gopher to be trapped.

In setting the trap a comparatively fresh mound should be selected. The lateral, by means of which the dirt is brought out to the mound, should be opened and the trap set in the lateral. Care should be taken that the trap does not extend beyond the lateral into the main runway. The lateral should be left open in order to draw the gopher into the trap. Once a gopher is caught the trap should be moved to another setting. It is seldom that more than one gopher will be caught in the same burrow system.

In order to trap a given area systematically, it is advisable to mark each setting by attaching a bit of cloth to a stake. Such markings show when an area has been covered and serves also as a convenient means for locating and tending the traps. In cases where certain wary individual gophers are nearly impossible to trap, the trapping should be followed by poisoning.

Fumigation, Flooding, and Shooting

Fumigation has been used for gopher control but has not proved wholly successful. Carbon bisulphide vapor and

burning sulphur fumes have been the chief methods of fumigation. One reason that fumigation is not successful is because of the types of burrow systems of gophers. The burrows are long and near the surface of the ground and often have numerous weakened places from which the fumes can escape. Also the burrows form such an intricate network of branches that it is difficult to force the fumes equally throughout the entire burrow system.

Flooding is an effective means of ridding an area of gophers if the entire area can be flooded. In districts of extensive irrigation there are very few gophers due to the fact that the area is frequently under water.

Shooting gophers may provide the hunter with a certain amount of sport since it takes a sure aim and quick trigger to bag these rodents. Only in the evening or early morning can these small animals be seen and then it is just a flash of nose and a spurt of earth. As a means of control shooting is not effective.

Natural Enemies

Natural enemies are one of the most important means of rodent control. Such animals as snakes, hawks, owls, coyotes, badgers and weasels are important natural enemies of pocket gophers.

The bullsnakes and weasels are said to be the chief natural enemies of gophers. Bull snakes are common in

areas of heavy gopher infestation and a weasel's favorite habitat is the center of a gopher infested alfalfa field. Natural enemies of rodents should be encouraged so long as they do not cause serious damage otherwise.

STUDY OF GEOMYS ON SANDY LOAM AREA IN ELLIS COUNTY, KANSAS

Selection of Area for Study

Size and Location

An area of about nine acres was selected for study. This is a triangular shaped plot of land lying just west of the Fort Hays campus. It is bounded on the southwest by Big Creek, on the north by the Union Pacific railroad, and on the east by the Fort Hays campus.

This area was selected because of the relative abundance of pocket gophers and because it could readily be divided into a number of vegetation types. The soil is primarily sandy loam.

Division Into Vegetal Types

This area was divided into five vegetal types for purposes of study and convenience. Figure 3 is a rough sketch of the area showing the approximate size and location of each of the various types. Following is a list of the

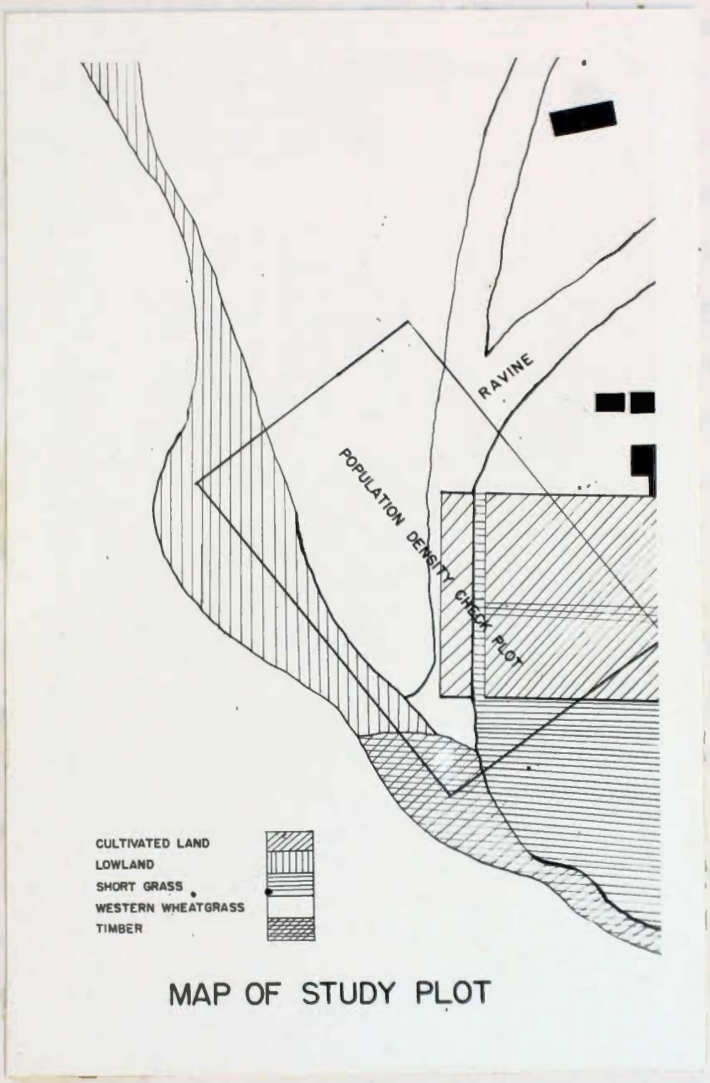


Figure 3. Map of the study area showing the division into the vegetal types.

types with the major plants and other distinguishing characteristics listed.

Type I - Lowland. This type constituted the lowland area along the stream. It was made up of such plants as Virginia wild rye (Elymus virginicus), Canadian wild rye (Elymus canadensis), Indian grass (Sorghastrum nutans), switch grass (Panicum virgatum) and big bluestem (Andropogon furcatus) as the primary grasses. Some weedy forbs such as sunflowers, marsh elders, and wild lettuce were also quite prevalent. This area is susceptible to flooding.

Type II - Wheatgrass. This type comprised the swales and hillsides and covered most of the upper flat area. The dominant form of vegetation was almost entirely western wheatgrass (Agropyron smithii).

Type III - Shortgrass. This type was found on the flat upland area but did not cover such an extensive area as type II. Buffalo grass (Buchloe dactyloides) and blue grama (Bouteloua gracilis) were the dominant plant species.

Type IV - Timber. The timber was chiefly in the southeast corner of the study plot. Elm trees, hackberry trees and a few evergreens were the main trees. June grass (Hordeum pusillum) and wild lettuce were abundant along the outer fringe of the timber.

Type V - Cultivated land. This type comprised all

the cultivated land. A pop-corn field, tree nursery, and flower and vegetable gardens were included in this type.

Methods of Estimating Density of Population

There were two general methods used in estimating the population density of the gophers in a given area. One method was to estimate the number of gophers by a pattern grouping of the mounds. The other method was to thoroughly trap the area. An area was selected and the density of population was checked by the pattern method. This area was then systematically trapped in order to check the results obtained through both methods.

Pattern Method

The pattern method of estimating the density of population of gophers over an area is probably as accurate as the trapping method. It has certain limitations in that it must be employed during periods of rather intense gopher activity.

A person familiar with the habits of gophers can usually distinguish individual territories within an area. Gophers (except during the breeding season) respect their neighbor's territory, so in most cases a fairly accurate estimate of the number can be made. In all cases where the pattern method is used only the fresh mounds should be considered. This is because occasionally a territory is

abandoned and a new territory is taken over. The old territory may or may not be taken over by another individual.

The following study was performed in order to test the population density methods.

A representative area which contained parts of all five vegetation types was measured. This plot was 300 by 500 feet. The total acreage in the population check plot was about 3 1/4 acres. On November 4, 1946 the total number of gophers on this small plot was estimated to be nine. This area was then systematically trapped to check the results by each method.

Trapping Method

By systematically trapping this plot, with the idea of catching about one gopher per week in order to maintain a sufficient number for future study, eight gophers were caught. The trapping period extended over a period of about six weeks. The number caught by the trapping was one less than the number estimated by the pattern method. Three possible explanations can be offered for this difference in numbers.

(1) The pattern method may have been the point of error.

(2) A natural enemy or death may have caused the difference.

(3) The gopher may have moved to a new territory.

This experiment showed that the difference in numbers between the two methods is relatively slight. A number of limiting factors must be considered in all ecological studies and any one of these factors may cause a lack of agreement in results.

Obtaining Specimens

In addition to the eight gophers already mentioned five other gophers were caught elsewhere on the nine acre area. Figure 3 shows the location of the population density check area, while Table I shows the number of specimens and the vegetation types in which they were caught.

Regulation Gopher Traps

Twelve of the thirteen gophers were caught in regular commercial traps. The type of trap used killed the specimens by a combination of constriction and penetration of the body with pointed jaws.

Improvised Box Trap

It was deemed advisable to secure at least one live specimen for study purposes. After a series of unsuccessful attempts a box trap was devised that would catch gophers alive. The finished trap was in the shape of a box 18 inches long with three inch sides. A trap door hinged

Table I Number of pocket gopher specimens, sex, date caught and habitat in which they were caught.

Specimen Number	Date Caught	Sex	Habitat Type
1	Nov. 5	F	Wheatgrass
2	Nov. 9	F	Wheatgrass
3	Nov. 17	F	Wheatgrass
4	Nov. 23	F	Timber
5	Dec. 4	F	Wheatgrass
6	Dec. 5	F	Shortgrass
7	Dec. 15	F	Cultivated Land
8	March 21	F	Wheatgrass
9	March 26	F	Wheatgrass
10	April 2	F	Wheatgrass
11	April 9	F	Wheatgrass
12	June 24	M	Shortgrass
13	June 25	M	Shortgrass

from the top and attached to a mouse trap spring prevented escape from the trap. A screen was placed at the rear end of the trap to admit light and to prevent escape in that direction. An overhead trip and trigger mechanism was placed in the trap. The trigger was suspended at a distance of eleven inches from the front of the trap. This distance was calculated by adding 1 1/2 inches (for the wall of soil the gopher pushed before itself) to the length of the gopher, which is 9 to 9 1/2 inches.

To set the box trap a mound was opened and the trap set in the lateral. The lateral was left open and light shining through the screened end of the trap drew the gopher into it. The trip mechanism would be tripped by the entrance of the gopher and the trap door would fall, preventing the gopher's escape.

Number of Specimens

Only one live specimen was procured since this was sufficient for this study. The measurements obtained from the total of the number caught were deemed a sufficient number to secure a fairly accurate approximation as to the average measurements of the Ellis County gophers. Table II shows the measurements of the trapped gophers.

The measurements included overall length or total length from the tip of the tail to the tip of the nose, the

Table II Measurements of the trapped specimens, and the average measurements of each sex.

Date	Specimen No.	Sex	Total Length (cm.)	Tail Vertebrae	Hind Foot
Nov. 5	1	F	23.50	6.35	2.86
Nov. 9	2	F	22.86	6.68	2.86
Nov. 17	3	F	24.13	6.68	3.18
Nov. 23	4	F	23.50	6.05	2.86
Dec. 4	5	F	23.50	5.73	3.50
Dec. 5	6	F	23.16	5.73	3.18
Dec. 15	7	F	23.50	6.05	2.86
March 21	8	F	23.80	6.35	3.18
March 26	9	F	22.86	6.35	2.86
April 2	10	F	23.50	6.05	3.50
April 9	11	F	23.16	5.73	2.86
June 24	12	M	24.77	6.35	3.50
June 25	13	M	24.13	6.35	3.18
Average Female			23.40	6.17	3.06
Average Male			24.45	6.35	3.34

tail vertebrae length, and the hind foot length. These measurements were originally made to the nearest one-eighth inch and later changed to centimeters.

Study of the Burrows

Mounds

The size and number of mounds thrown out by pocket gophers vary with a number of factors. Such factors as temperature, moisture content of the soil, type of soil, amount of available food and the season all exert a decided influence on the number of gopher mounds.

A mound may be from 2 to 3 inches in diameter or it may be as many as 30 inches. It may be a few inches in height or it may be a foot or more in height.

Most of the mounds thrown out are fairly similiar in size and shape. Exceptionally large mounds are usually an indication of food stores or a nesting site for young gophers.

Personal observations and other sources indicate that important limiting factors in the number of mounds thrown out. In exceedingly cold weather the gophers cease to throw out mounds. If the weather is hot and dry the number of mounds thrown out is decreased to an extent. On the other hand a warm moist temperature seems to stimulate the digging rate and large numbers of mounds may be thrown out.

The season or time of year plays a fairly important role in the number of mounds thrown out (Mohr, 1936). In the autumn when activity is at its peak, many mounds are built. During the winter the number of mounds is limited by the temperature. In the spring activity is again increased and consequently the number of mounds is increased. It may be said that the number of mounds thrown out is directly proportional to the degree of activity.

As many as five mounds daily may be thrown out by an individual gopher during periods of intense activity. On the other hand, there may be days on which no mounds will be thrown out. In this particular study a period of 65 days, extending from January 15 to March 21, elapsed without a single mound being thrown out. There was likely a limited amount of activity going on and the loose dirt and soil materials were probably packed into portions of the burrow systems.

Runways and Laterals

As far as could be discovered there is no definite pattern in the establishment of the runways and laterals by the gophers. Gophers are unpredictable creatures that dig in the direction in which their fancy leads them. They may veer from a straight line course for a choice root or for a loose textured, easy digging soil.

The runway is nearly always parallel or nearly

parallel with the ground surface. A short extension known as a lateral connects the runway to the ground surface. The lateral is seldom more than 18 inches in length and is usually plugged at the surface end by a plug of moist earth. Every mound is connected by a lateral to the runway. In some cases the lateral is so tightly plugged that it is hard to find.

It is possible to follow the general outline of the burrow system by drawing or visualizing an imaginary line between successive mounds which appear on the ground surface. This method is subject to some error, however, as burrow systems which have been dug out showed some deviation from the above plan.

Anyone who contemplates digging out the burrow system of a gopher may find it quite a job. In some instances the total length of the burrows may exceed three hundred feet before the system is blocked off and a new one is started.

Special Chambers

Three types of special chambers may be recognized in the burrow systems of pocket gophers, (1) the excreta chamber, (2) the food store, and (3) the nesting chamber.

The excreta chamber is usually no more than a blind pocket dug into the side of the runway. It is seldom more than three inches in depth. The excreta of the gophers are placed in these special chambers, after which the chamber

is plugged up. These chambers are dug only as they are needed and are usually plugged after they have been used. They are seldom noticed unless accidently discovered during the excavation of a burrow system. These chambers are doubtless of some value in contributing fertilizer to the soil.

The food storage chambers are usually found only during the autumn and winter seasons. In many burrow systems no evidences of food stores may be found. Generally these stores are located at greater depths than are the runways. They may appear as pockets in the floor or side of a runway and may extend to depths of twenty inches or more. Usually they are found at depths of ten to fifteen inches. The type of food stored may be roots, grass, stems of forbs, and ears of corn have been found. Occasionally a very shallow pocket is dug in the runway and filled with food. There are two types of food stores, the permanent and the temporary. It is seldom that the permanent type is found, although the temporary stores are quite common. In cases of especially succulent food, the gopher may store a quantity of it for future use. Many food stores appear never to be touched. This untouched material may be added to the soil in the form of humus. In this respect the food storing habits of the gophers may serve as a beneficial factor toward the formation of a well formed soil.

The nesting chambers are usually dug immediately before or soon after the breeding season. Only one nesting site was discovered and this was at a depth of twenty-seven inches. The site of this chamber was characterized by the presence of a very large mound. This mound was about thirty inches in diameter and a foot in height. Near the bottom of the chamber was a handful of dried grass. This nest was dug out on January 15, 1947, and it had not been used.

Depths

It has been observed that the average burrow depths of the pocket gophers varies with the seasons and temperature ranges. For this study, depths were taken at random at three different stations. Checks were made about once every two weeks. Table III shows the results of these checks, which began on November 4, 1946, and ended April 8, 1947. These measurements seem to indicate that the gophers burrow deeper in cold weather than in warm weather. Figure 4 is a graph illustrating the burrowing depth and temperature relationship.

The most prolonged cold spell occurred in late winter and it was at this time that the average burrow depths were the greatest. Other data such as that which follows seems to bear out this statement.

Results of Depth Studies

Table III Depth measurements of burrows and dates on which the measurements were taken.

Date	Random Station Depths (inches) 1	2	3	Average Depth
Nov. 4	4	6	6	5 1/3
Nov. 16	6	5	6	5 2/3
Dec. 4	6	6	6	6
Dec. 17	5	6	6	5 2/3
Jan. 15	8	6	8	7 1/3
March 21	8	8	8	8
April 8	6	6	8	6 2/3

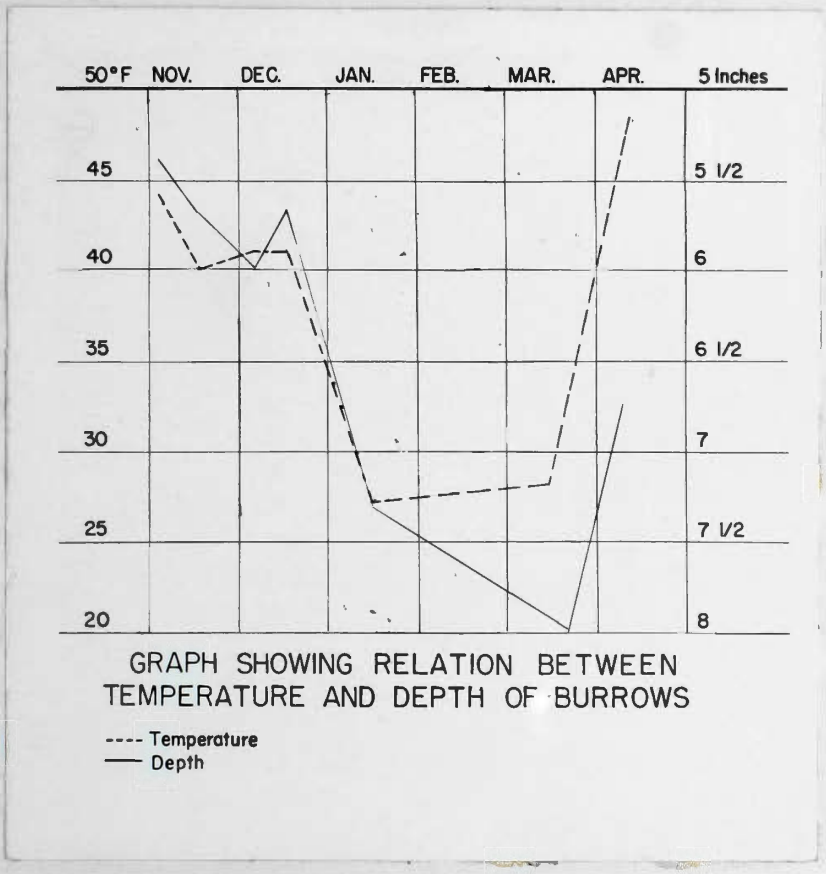


Figure 4. Graph showing the temperature, soil-depth relationship.

On November 4 the average depth was 5 1/3 inches, with the three stations showing depths of 6 inches, 5 inches and 5 inches.

November 16 showed an average depth of 5 2/3 inches, with the stations having depths of 6, 6, and 5 inches.

On December 4 the average depth was 6 inches, with depths of 6, 6, and 6 inches.

December 17 showed a decrease to an average of 5 2/3 inches with depths of 6, 5, and 6 inches. This decrease may have been due to the series of warm days which occurred at that time.

January 15 showed an increase in depth to 7 1/3 inches. The colder weather which prevailed after Christmas was likely the cause. Station depths were 6, 8, and 8 inches.

The greatest depth average occurred on March 21. The average was 8 inches, with each station being 8 inches. This was also the first day of visible activity for a period of 65 days (January 15 to March 21 inclusive).

April 8 was the last date that the measurements were taken. The average depth was 6 2/3 inches, or a decrease of 1 1/3 inches from March 21.

In all cases the measurements were taken from the most recent workings that were present. Table IV is a table showing the relative depth measurements and temperature.

Table IV The various burrow depth measurements taken and the average mean temperatures for the dates on which the measurements were taken.

Date from	to	Mean Temperature Degrees Fahrenheit	Average burrow Depths (inches)
Nov. 1	Nov. 4	44 1/4	5 1/3
Nov. 4	Nov. 17	40	5 2/3
Nov. 17	Dec. 4	41	6
Dec. 4	Dec. 17	41 1/9	5 2/3
Dec. 17	Jan. 15	27 1/4	7 1/3
Jan. 15	Feb. 28	27 3/4	No measurement
Feb. 28	March 21	28	8
March 21	April 8	48 1/3	6 2/3

General Observations

Periods of Greatest Activity

The greatest activity period occurs usually during the season of autumn. In the autumn gophers work constantly storing food, excavating burrows and throwing out mounds. Individual gophers have been observed to have thrown out as many as five mounds in one day.

Cold weather invariably slows down the gopher activity, and during periods of extreme cold they may throw out no mounds for long periods. During the 65 days from January 15 to March 21, there were no mounds thrown out on the test area. However, in areas eighty to a hundred miles west the gophers were fairly active, chiefly in alfalfa fields. This may be explained by the fact that the species west of here is the yellow pocket gopher (Geomys lutescens) while the species in this area is Geomys bursarius.

Spring is a fairly active period for gophers if there are some fairly mild temperatures. This spring was late and wet so the gophers were late in appearing this year. In the spring months the gophers either move into new territories or give the old territories a thorough house cleaning. In either case, vast amounts of earth and debris are thrown out in the form of mounds. Roots and shoots of young growing plants are avidly sought during this time.

Consequently, rather extensive areas may be affected by the action of these burrowing rodents.

With the coming of summer, the activity is again slowed down. High temperatures and dry soils retard the activity to quite an extent. During periods of warm moist temperature, however, gophers may become exceedingly active. Often just before a shower these animals may be seen throwing out mounds. After a relatively light shower they are also usually active. In case of a heavy rain, they may remain idle for several days.

Natural Enemies

The gopher's habit of carrying on most of its activity during twilight and darkness hours particularly favors certain natural enemies. Owls and cats are chiefly night prowlers and take quite a toll of gophers. The barn owl takes exceedingly large numbers of pocket gophers as indicated by owl pellets. House cats, which become addicted to the gopher habit, have been known to cause appreciable decreases in the gopher numbers. The little spotted skunk is reported to enter the burrows of the gophers and consequently should be mentioned as an important enemy.

The two most important natural enemies, said to hold the pocket gopher in check more than all others, are the weasel and bullsnake. In most parts of Kansas the weasel is too scarce to be much effect; but the bullsnake

is common enough to serve as a very important natural check. The writer has witnessed the entrance of a bullsnake through a closed mound into the runway of a gopher. In the case mentioned, the plug of the lateral was sufficiently loose to allow the snake to push through and worm its way into the burrow. It is very doubtful if the snakes could force their way through tightly plugged laterals.

Coyotes and badgers are enemies of all rodents. Numerous instances have been noted where badgers have presumably dug out pocket gophers. All the above mentioned animals are important as natural checks of rodent populations, however, the bullsnake and barn owl probably serve as most important for the control of pocket gophers in this area. It is quite possible that by encouragement of these natural enemies, such methods of control as trapping, poisoning, or flooding would prove unnecessary.

Breeding and Food Habits

There is very little data concerning the breeding habits of pocket gophers. The habits vary with different species and in different localities. Barrington (1942) is one of the few persons who has witnessed the birth of young Geomys. From observations it is believed that the gophers of Ellis County breed sometime during the winter

months of January or February. The gestation period is probably from 28 to 30 days. The number of young varies from three to seven (average five). The young are helpless at birth, they are hairless and the pockets are not developed other than appearing as a fold of skin.

It is difficult to obtain reliable data on the amount of food consumed by gophers. They are strictly vegetarians and subsist on roots and shoots of plants. Other than being noted as voracious eaters, no attempts were made to calculate the amount of food they consumed.

Some Anatomical Adaptations

Cheek Pouch Muscles

There are five principal muscles associated with the cheek pouch of the pocket gopher.

(1) The retractor muscle or more specifically the retractor muscle of the pouch is a long, bandlike muscle which arises from the spinal processes of the last thoracic and first and second lumbar vertebrae. This muscle passes cephalad and ventrad over the shoulder muscles and is inserted at the caudal end of the pouch. Its function is to retract the pouch.

(2) The protractor (of the pouch) muscle consists of fibers arising from the masseter muscle fascia. These fibers pass ventrad and caudad and spread out over the

mesial and lateral surfaces of the pouch. The function of the protractor is to support and assist in the drawing forth of the pouch to empty it.

(3) The levator (of the pouch) muscle arises along the caudad half of the nuchal ligament and passes laterad and cephalad to insert on the pouch. Its function is to support and elevate the caudal end of the pouch.

(4) The sphincter muscle arises on the skull anterior to the eye and inserts to the pouch opening just laterad of the mouth. Its function is to close the mouth of the pouch.

(5) The ventral retractor of the cheek pouch arises from the sternum and is inserted on the caudal-ventral surface of the mesial wall of the pouch. Its function is to draw the lower end of the pouch mesiad beneath the chin.

All of the pouch muscles are superficial muscles and care must be taken when skinning the animal to preserve them.

Muscles Associated with Digging

Some of the more important muscles which are associated with the digging habit of pocket gophers are as follows.

(1) Cutaneous maximus is the first muscle to be encountered on the removal of the skin. It forms a thin sheet

over the back, flanks and abdomen. It arises from subcutaneous fascia and joins in the form of two sections at the dorsal and ventral midlines. At the anterior end the fibers converge to form a thick band which joins the pectoralis muscles and is inserted to the mesial-anterio surface of the humerus. This is a superficial muscle.

(2) The trapezius muscles are divided into three parts and are very well developed. The anterior part arises from the mesial third of the lambdoid ridge of the skull, from the entire length of the nuchal ligament, from the spines of the first, second and third thoracic vertebrae, and from the supraspinous ligament.

The middle part arises from the spinal processes of the fifth and sixth thoracic vertebrae and from the supraspinous ligament. This muscle passes cephalad and laterad to be associated with the thoracic part of the trapezius into a common insertion.

The thoracic part or posterior muscle arises from the spinal processes of the eleventh and twelfth thoracic and the first lumbar vertebrae, and from the supraspinous ligament.

All three muscles of the trapezius insert on the scapula and function chiefly as rotators of the scapula.

(3) The latissimus dorsi is found beneath the retractor muscle of the pouch and the middle and thoracic muscles of the trapezius. It arises from the lumbar fascia,

from the supraspinous ligament and from the spinal processes of the sixth to the twelfth thoracic vertebrae inclusive. It appears as a flat triangular sheet over the sides of the thorax and is inserted into the mesial side of the humerus just below the lesser tuberosity. This muscle is one of the largest and most strongly developed in the gopher, and greatly exceeds in comparative size the latissimus dorsi of any other rodent. Functionally it is a strong adductor and flexor of the foreleg and helps to produce the downward and backward stroke used in digging.

(4) The powerful pectoralis muscles are of great importance in the gophers. The pectoralis consists of four muscles, all of which arise from the sternum. The insertion is well down on the humerus. This increases the leverage and renders a more powerful downward and backward stroke of the foreleg.

(5) The triceps, which is especially well developed, furnishes most of the power for extending the foreleg. The triceps consists of three heads. (1) Caput longum (triceps longessimus) which arises from the axillary border of the scapula, is the bulkiest of the three and has its insertion near the olecranon process on the ulna. (2) Caput laterale (triceps latissimus) arises from the posterior and lateral surfaces of the humerus. It is intermediate in size and inserts on the lateral surface of the olecranon process. (3) Caput mediale (triceps medialis)

arises from the posterior mesial surface of the humerus and inserts on the Cephalic surface of the olecranon process. This muscle is more or less fused with the caput longum.

(6) The biceps muscles have two heads in the pocket gophers. They are Caput longum, or the glenoid head, and Caput breve, or the coracoid head. These two muscles are separate nearly to the point of insertion, where they unite to form a common tendon. The insertion is to the ventral surface of the ulna and slightly to the radius. The biceps muscles serve as the principal flexors of the foreleg.

(7) The rhombiodeus muscles are exposed by the removal of the trapezius muscles. They are in two parts, but are so closely united that they appear as one muscle. The rhomboideus minor arises on the nuchal ligament and inserts to the vertebral border of the scapula. The rhomboideus major arises from the supraspinous ligament and the spinous processes of the third and fourth thoracic vertebrae. It inserts on the scapula. The function of the rhomboids is to draw the scapula forward and to rotate the glenoid end backward.

(8) The deltoid muscles consist of two distinct parts and are powerful muscles. (1) The acromio-deltoideus arises from the outer ventral surface of the clavicle and the tip of the acromion of the scapula.

It inserts to the deltoid tuberosity of the humerus. (2) The spinodeltoideus arises from the spine and acromion of the scapula and a common insertion with the acromiodeltoideus. The principal function of the deltoid muscles is to abduct and draw the humerus forward.

(9) The flexors and extensors of the forefeet are all relatively powerful and aid to a large extent in digging.

(10) The masseter muscle is large and powerful and serves in the use of the powerful jaws for digging and tearing away of roots.

Structural Adaptations

The ability of the gopher to use its large upper incisors for digging and root tearing, while the lips are closed, is an important structural adaptation. As previously mentioned, this is the only North American rodent in which this is possible.

The long badger-like front claws serve a useful function in digging. In gophers, which are caged or held in captivity, these claws become greatly elongated. Thus it may be surmised that the claws grow continually and it is only by frequent use that they are kept from growing too long.

The sensitive tail serves as an important tactile organ. Gophers can move backward as rapidly as they can

forward. The tail helps in this respect to compensate for the poor eyesight of the gopher.

One of the most important structural adaptations is the ability of the gopher to turn a complete somersault in a space of its own bodily width. This is accomplished by a flexible pelvic girdle which is characteristic of all pocket gophers. In digging a burrow the gopher loosens the soil with the forelegs and pushes it behind. After a quantity of soil has been loosened, the gopher turns a somersault and pushes the loosened soil out of the burrow with its head and front quarters.

CONCLUSION AND SUMMARY

The Ellis County pocket gopher (Geomys bursarius) is a powerfully built burrowing rodent. In color it may range from a dark brown to a light tan. Numerous white hairs scattered over the head, shoulders and back are quite common on the gophers in this area.

The pocket gopher is so constructed anatomically as to carry on an effective underground burrowing existence. The large incisor teeth, which cannot be concealed within the lips, serve as a structural adaptation to aid in the digging and tearing away of roots and soil. Other structural adaptations include such adaptations as long badger-like claws, a flexible pelvic girdle, and a sensitive tail which functions as an important tactile organ.

The habitat preference of the pocket gopher was observed on five different vegetative types. The following types were present: lowland, shortgrass, wheatgrass, cultivated land and timber. The wheatgrass type was the preferred year around habitat with seasonal preferences of some of the other types. The lowland type had the fewest gophers possibly because of frequent floodings.

Very little was discovered concerning the breeding and food habits of the gophers. It is believed that the breeding period occurred between January 15 and March 21, however no visible activity was observed during that time. The gestation period is probably from 28 to 30 days. The food preference is definitely roots. Some kinds of roots seem to be preferred over other kinds. This study showed that such rhizomatous roots as western wheatgrass were the most preferred.

Burrowing has a decided effect upon the vegetation as well as on the soil. The vegetation growing over an old gopher mound is darker green in color and is taller than the surrounding vegetation. This increased height may be a result of increased soil moisture content, improved soil structure or the addition of organic matter to the soil. The darker color is without a doubt due to increased nitrogen content of the soil. Burrowing may tend to retard the growth of the vegetation at first but the later effects are definitely favorable stimuli for increased plant growth

and vigor. It must be remembered, however, that only on wild lands are these benefits recognized.

The five most effective means of controlling the gopher are: (1) poisoning; (2) trapping; (3) flooding; (4) fumigation; and (5) encouragement of the gopher's natural enemies, especially the barn owl and the bullsnake. Four things necessary to poison gophers successfully are: (a) an effective poison such as strychnine; (b) succulent bait that will be relished by the gopher; (c) a bait large enough so that it must be eaten at once; and (d) placing of the bait in the main runway.

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