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This publication (No. 44) combines some new information about the plains pocket gopher in Kansas with selected information previously known, and practical suggestions for regulating the numbers of this rodent that is of economic importance to landowners.

The Pocket Gopher in Kansas

BY

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INTRODUCTION

The plains pocket gopher, *Geomys bursarius* (Shaw), a native rodent, is of considerable importance in Kansas because its burrowing- and eating-habits are beneficial in some situations and harmful in others.

Many characteristic features of the animal can be seen in its likeness on the front cover. The adult male in Kansas is 10½ to 12 inches in length, of which the sparsely haired tail constitutes one-fourth. A fur-lined external cheek pouch (entirely outside the mouth) opens anteriorly at the side of the mouth. The two cheek pouches are used in carrying food to storage chambers but are not used in transporting soil. The anteriormost teeth (incisors), two in the upper jaw and two in the lower jaw, also are functionally outside the mouth; the lips close behind these teeth. They are used for digging in the soil as well as for cutting roots and other parts of plants into sections short enough to fit in the cheek pouches. The front surface of each upper incisor has a longitudinal groove

on the outer side of the median line and a slight groove close to the inner border. These grooves are absent in gophers of the genus *Thomomys* of the western United States.

Soil loosened by the foreclaws and incisors is pulled backward by means of the forelimbs and packed underneath the body. Then the gopher turns around and uses its face and forepaws to push the soil out of the inclined tunnel onto the surface of the ground. Successive loads of soil are pushed out making a fan-shaped mound. In some situations the freshly excavated earth is pushed into abandoned underground tunnels.

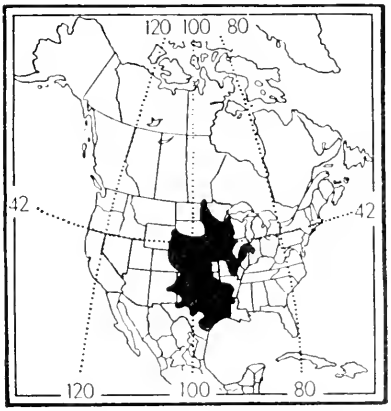


FIGURE 1. Geographic distribution of the plains pocket gopher.

How the pocket gopher manages to turn completely around within the diameter of one of its tunnels was studied by Dr. W. J. Breckenridge (1929) who learned that the gopher rolled forward and executed a half twist thus completing the movement in an upright position.

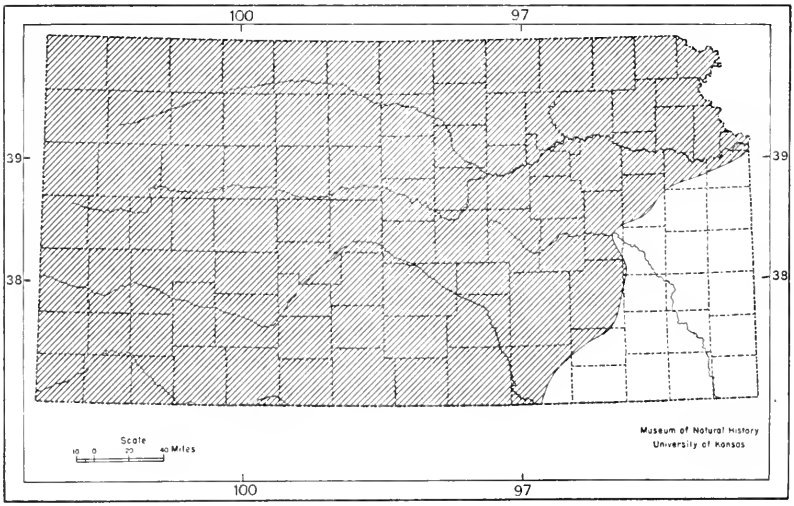


FIGURE 2. Geographic distribution in Kansas of the Plains pocket gopher. Pocket gophers occur in the shaded area and are absent in the unshaded area.

Within Kansas the plains pocket gopher occurs throughout the state except in the southeastern part (see Fig. 2).

AIMS

The aims of the study here reported on were the following:

1. Learn why the pocket gopher does not occur in southeastern Kansas (see page 5).
2. Learn how much (volume and weight) soil per acre a pocket gopher deposits on the surface of the ground in the course of one complete year (see page 13).
3. Record some other information obtained incidental to work on aims 1-2 (see pages 19, 20) because it is new or because it is thought to be otherwise pertinent.
4. Provide directions on the best method for removing plains pocket gophers from areas where they are unwelcome (see pages 28-30).

FACTORS AFFECTING DISTRIBUTION

Composition of Soil

Composition of the soil, second only to the presence or absence of plant food, is the most important factor in determining the presence and absence of the plains pocket gopher in the eastern third of Kansas. To state our conclusion first: the gopher, so far as we know, occurs only in soils having a low content of clay (less than 30%) and a high content of sand (more than 40%). Conversely, the gopher, so far as we know, is absent from soils having a high content of clay (more than 30%) and a low content of sand (less than 40%). The silt content (fraction) of the soil does not seem to affect the presence or absence of the plains pocket gopher. Figure 4 portrays the findings as to percentages of sand, clay, and silt in soils in which the gopher lives and in soils in which it does not live.

Turning now to the sequence of observations that led to, and evidence for, the conclusion stated above we can record that Cockrum (1952: Fig. 37, p. 138) graphically delineated the part of Kansas lacking pocket gophers by extending a line from Fort Leavenworth southwestward to a point three miles southwest of Lyndon, to a point eight and one-fourth miles southwest of Toronto to a point three miles south of Arkansas City. He (1952:17), in an indirect fashion, pointed to composition of soil as determining the presence or absence of pocket gophers when he stated that southeast of the mentioned line, chert was present in many places, lime needed to be applied to improve yields of cultivated crops (*fide* Hide, 1946:33), and gophers were absent. Still earlier, Davis *et al.* (1938:414) opined that a minimum of six inches of top soil (horizon A) was necessary to support plains pocket gophers. Other observers had referred more or less casually to the abundance of plains pocket gophers in sandy loam.

In order to learn where pocket gophers occurred and where they were absent in Douglas County, Kansas, one of us (Downhower) drove on roads, most of which are section lines, and plotted on a map the places where gophers had expelled mounds of loose earth onto the surface of the ground. By this means the pocket gopher was found to be absent southeast of a line extending approximately from the south edge of the town of Eudora to the southwest corner of Douglas county.

At a later date 28 samples from the upper two inches of the soil were saved from 26 of the sites of pocket gopher activity. Twenty-seven samples from the upper two inches of the soil were saved from 26 other sites having the same vegetative cover as the first 26 but at places where pocket gophers were absent (see Fig. 3).

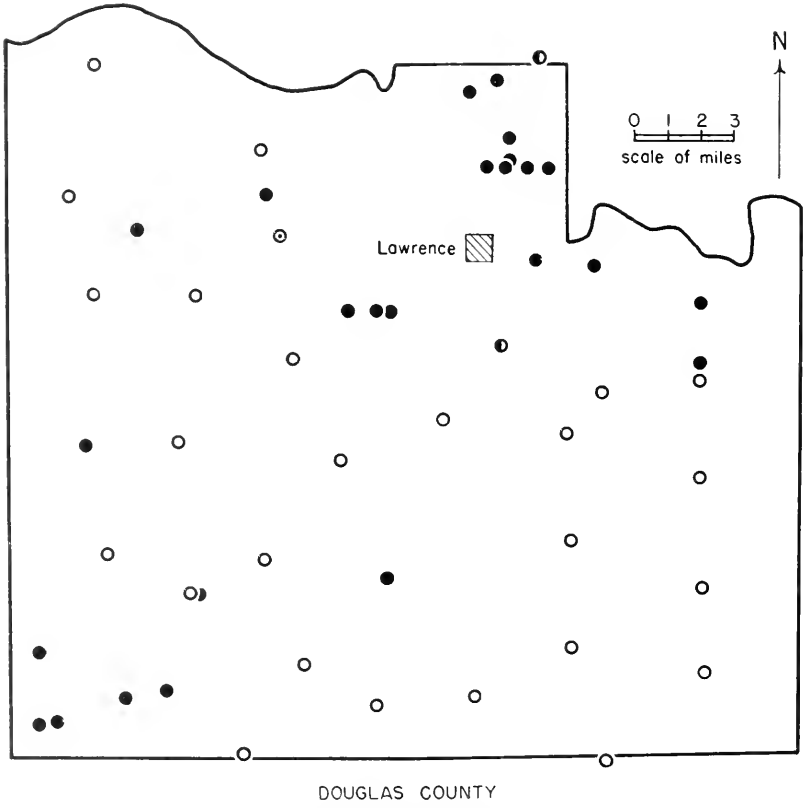


FIGURE 3. Localities from which soil samples were taken in eastern Kansas. Dots represent localities at which pocket gophers were present. Circles represent localities at which pocket gophers were absent. The circle with a dot inside represents a locality where two soil samples were taken, one from a place where pocket gophers were present and one from a place where they were absent. Half-dots represent two localities where pocket gophers were introduced.

The texture of the soil in each of the samples was analyzed by the hydrometer method, which includes the following steps. The organic matter is removed by oxidation with hydrogen peroxide. Next the clumps of particles are reduced and separated by a dispersing agent. Thereafter the sample is shaken until no particles are at rest. A hydrometer then is placed into the solution. A particle falls through a medium at a rate dependent upon the viscosity of the medium, the size of the particle, and the temperature of the medium. Hydrometer readings taken at predetermined times measure the weight of solid material still in solution. The size of the particles remaining in solution is ascertained by the length of time the solution has been allowed to settle. The medium used was distilled water. The temperature was maintained at 20° C (see Piper, 1944:77-79).

A variety of textural scales are available for classifying particles as clay, silt, or sand, but the International scale was used. On that scale, clay particles are no more than 0.002 mm. in diameter, silt is more than 0.002 mm. but less than 0.02 mm. in diameter, and sand is 0.02 to 2.0 mm. in diameter.

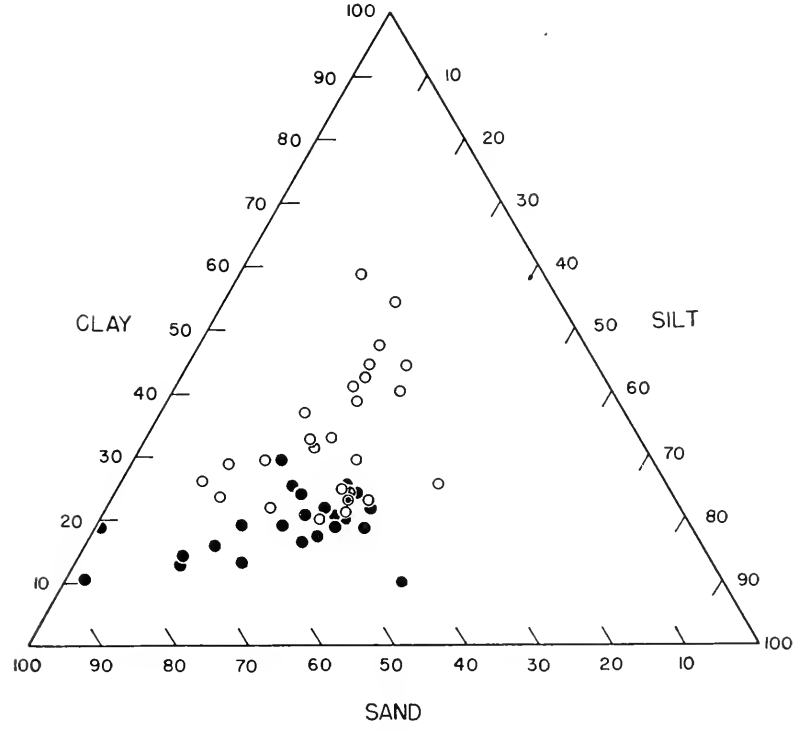


FIGURE 4. Soil triangle representing the percentages of clay, silt, and sand in samples of surface soil taken from localities (see Fig. 3) in eastern Kansas. Dots represent soils in which pocket gophers were present; circles represent soils from which pocket gophers were absent. The circle with a dot inside represents two samples of the same composition, one from a place inhabited by pocket gophers, and the other from a place at which pocket gophers were absent.

No attempt was made to classify the samples nomenclaturally. The percentages of clay, silt, and sand were treated statistically to determine the role, if any, played by each fraction in the distribution of the pocket gophers.

The results of "t" tests (a comparison of the amount of each textural component in the two samples; see Steel and Torrie, 1960:72) indicate that both the clay fraction and sand fraction of the soils in which pocket gophers occur differ significantly from those fractions in soils in which gophers are absent ($p = .01$). The "t" value was 4.31 for the clay fraction and 2.73 for the sand fraction. The "t" value for the silt fraction was 0.4 and hence not significant. In all three tests 53 degrees of freedom were used (degrees of freedom $= N_1 + N_2 - 2$, where $N_1 =$ the number of samples from localities having pocket gophers and $N_2 =$ the number of samples from localities lacking pocket gophers; see Steel and Torrie, 1960:18 *et sequenter*).

In Douglas County, Kansas, pocket gophers occur in alfalfa fields, prairie hay fields, orchards, and pastures. Most of the localities at which pocket gophers were absent but from which soil samples were taken, were alfalfa fields and prairie hay fields. Consequently the vegetation was comparable to that on many of the areas that had pocket gophers and from which soil samples were saved.

Observation suggested that the single major ecological factor that varied was the soil type. Therefore, if pocket gophers were absent in a given area their absence was thought to be due primarily to unfavorable composition of the soil or to inaccessibility of the area to gophers. The latter possibility was not measured. The conclusions stated on page 3 about the kind of soil that the plains pocket gopher (*Geomys bursarius*) lived in and the kind that the gopher did not live in were drawn from soil analyses.

TABLE 1. Textural Composition of Surface Soil at Localities in Eastern Kansas Where Pocket Gophers Were Introduced.

	% clay	% silt	% sand
Locality 1*, pasture	36.02	20.35	43.61
alfalfa field	19.53	24.90	55.56
Locality 2†, north field	32.62	27.83	39.53
south field (center)	27.26	24.49	48.24
south field (edge)	15.87	25.68	58.44

* The numeral 1 denotes the locality 5½ miles north and 2 miles east of Lawrence, Kansas (in Jefferson County). [The City Hall at 11th and Massachusetts streets in Lawrence is used as the point of reference in computing distances from Lawrence.]

† The numeral 2 denotes the locality 4 miles south and ½ mile east of Lawrence, Kansas (in Douglas County).

Attempts by one of us (Downhower) to introduce pocket gophers at places where none lived by releasing them at two localities were more nearly successful in soils having a low clay content than in soils having a high clay content (see Table 1). Only one of the 12

attempts to introduce the species could be considered successful; one individual that was introduced into an area did persist there but for only six weeks (Nov. 2-Dec. 13) before disappearing.

Attempted introductions of pocket gophers at the two sub-localities of locality 1 (5½ miles north and 2 miles east of Lawrence, Kansas, *in* Jefferson County) in 1962 were unsuccessful but for two different reasons. Both sub-localities were reseeded in 1957 to bluestems (*Andropogon gerardi* and *A. scoparius*), to Indian grass (*Sorghastrum nutans*), and switch grass (*Panicum virgatum*). In the period intervening between reseeding and introduction of the pocket gophers the pasture had been moderately grazed annually by cattle and the alfalfa field had not been mowed or grazed. Introductions into the pasture appear to have been unsuccessful owing to the high clay content of the surface soil (35.02%). Within the alfalfa field the clay content was much lower (19.53%). This soil was underlain by a heavy clay subsoil that prevented drainage and caused a heavy runoff resulting in sheet erosion despite its vegetational cover (H. Dickey, personal communication). The surface soil remained wet due to the "artificial" raising of the water table by the subsoil.

In that connection the study that Ingles (1949:348, 349) made of another species of pocket gopher, *Thomomys monticola,* in California is pertinent because he found that a high water table ex-

TABLE 2. Data on 12 Pocket Gophers Introduced in 1962 at Two Localities in Eastern Kansas.

Sex	Weight (in gm.)	Locality	Date released	Date disappeared
♀	169.0	1*—pasture	16 Oct.	22 Oct.
♀	206.5	1 —alfalfa field	26 Oct.	29 Oct.
♀	231.0	1 —alfalfa field	2 Nov.	6 Nov.
♀	301.2	2†—south alfalfa field	2 Nov.	13 Dec.
♀	213.5	2 —north alfalfa field	2 Nov.	5 Nov.
♀	.....	2 —north alfalfa field	6 Nov.	23 Nov.
♀	369.0	1 —alfalfa field	12 Nov.	15 Nov.
♀	190.0	1 —pasture	12 Nov.	15 Nov.
♀	249.0	2 —south alfalfa field	12 Nov.	13 Nov.
♂	.....	2 —north alfalfa field	5 Dec.	14 Dec.
♀	.....	2 —north alfalfa field	14 Dec.	17 Dec.
♂	300.0	2 —north alfalfa field	18 Dec.	19 Dec.

* The numeral 1 denotes the locality 5½ miles north and 2 miles east of Lawrence, Kansas (in Jefferson County).

† The numeral 2 denotes the locality 4 miles south and ½ mile east of Lawrence, Kansas (in Douglas County).

cluded the species from areas that it otherwise presumably would have occupied. *T. monticola* was absent from soils where the water table was consistently less than 4.3 feet from the surface, but the gophers of that species would explore into areas where the water table came to within six inches of the surface provided that areas were accessible where the water table was deeper than 4.3 feet.

Two gophers were introduced into two alfalfa fields at the second locality (4 mi. S, ½ mi. E Lawrence). Both fields were high in clay content (see Table 1). The introductions were made into the centers of these fields. The introductions into the north field were unsuccessful, we now think owing to the high clay content of the surface soil. The first individual introduced into the south field (Table 1) moved from the center of the field to the eastern edge where it excavated a burrow system and remained for six weeks. The eastern edge of the south field had a shallow cap of soil in which the clay content was only 15.87 per cent.

Moisture

In the western part of its geographic range, in eastern Colorado, where the annual precipitation is slight, the gopher in spring usually lives in swales. Plant growth is more abundant there because of the greater amount of soil moisture than is to be found in adjoining land. But, in the eastern part of its geographic range, in northeastern Indiana, where the annual precipitation is considerable, the gopher usually lives on hillocks that rise four to 25 feet above the surrounding wetland—presumably because of better drainage than in the moister flat land. Plant growth appears to be sufficient for the gopher's needs on both the hillocks and in untilled flat land. Amount of soil moisture is a factor regulating occurrence of the plains pocket gopher, but it chooses a site having enough in preference to a site having too much or too little.

But, in both the east (for instance the heavy soils in Newton and Jasper counties, Indiana) and in the west (for instance the Ordway soils in Crowley County, Colorado) soils appearing to have a high clay content are not inhabited by plains pocket gophers regardless of amount of precipitation. Inferentially, such soils when wet are too sticky for the plains pocket gopher to dig in and so those soils are uninhabited in dry weather as well as in wet weather.

Shallowness of Soil

Much of the burrowing, and we think most of it, by the plains pocket gopher is in the A horizon, the topsoil, where it is developed. The presence of soil horizons reflects age and history of the site. In an area where the soil is newly deposited, such as bottom land in a river valley, no horizons are to be seen.

In Kansas, where snowfall normally is light and periods of freezing cold in some winters last several weeks, the frost line is deeper than in areas where a heavy blanket of snow is present. The snow acts as an insulator. Smooth-toothed pocket gophers, genus *Thomomys,* are active throughout the year in mountainous areas of California where the snow cover is deep and frost penetrates only three to four inches into the ground. In winter those gophers construct tunnels and nests in the snow as much as four feet above ground (Ingles, 1949:347). Also, they bring soil above ground in winter and dispose of it by completely filling many of the tunnels in the snow. *Geomys bursarius,* on the other hand, does not do that so far as we know. When the ground is frozen several inches deep, *G. bursarius* does not throw out any soil in the snow or on the surface of the ground, and does not appear on the surface of the ground in cold periods so far as we know. We think the plains pocket gopher does not burrow in frozen soil and may be unable to live in it for long. Consequently, low temperatures in winter may exclude the plains pocket gopher from some thin soils.

The cap of soil low in clay content mentioned in the second paragraph on page 10 was limited in extent and depth, being 20 feet wide, 60 feet long, and 18 inches deep. In Douglas County, Kansas, the soil has frozen to a depth of 34 inches in a severe winter. With the onset of winter, the shallow cap of soil at this locality may not have offered sufficient protection to allow the animal to remain.

Certainly there is, for the plains pocket gopher, a minimum depth of soil in which he will live. Five miles northwest of McClave in Bent County, Colorado, on April 10, 1963, pocket gophers were abundant on top of a hill in soil only six to seven inches deep underlain by Green River Limestone. Biscuitroot, a plant attractive to gophers, was abundant at that place at that time, was being eaten by the gophers, and probably accounted for the pocket gophers living there instead of in deeper soils a hundred yards to the west. The occurrence may have been seasonal; in Douglas County of

eastern Kansas we would not expect to find pocket gophers in soil so shallow as six inches. Unfortunately, no specimen was obtained 5 mi. NW of McClave in order to make certain that the pocket gopher there was *Geomys bursarius* instead of *Cratogeomys castanops,* which has an even stronger preference for deep soil in that part of Colorado than does *Geomys bursarius.*

In Douglas County, Kansas, the subsurface burrows vary from six to 12 inches in depth below the surface of the ground.

Cultivation of the Soil

The depth below ground of six to 12 inches of the subsurface burrows of the plains pocket gopher in Douglas County also is the range in depth to which soils there are plowed by farmers. Most of the plowing is six to eight inches in depth. In a colony of gophers 2⅝ miles north and ⅛ mile east of Lawrence, Kansas, the population density was estimated at six individuals per acre. A plowed field, lacking pocket gophers, adjoined this colony. Analysis of the topsoil revealed that it was essentially the same in the colony and field (Colony—Clay, 15.00%; silt, 14.75; sand, 70.26. Plowed field—clay, 16.60%; silt, 9.85; sand, 73.54).

When an alfalfa field 2½ miles north and ⅛ mile east of Lawrence, Douglas County, Kansas, was plowed in October of 1963, the number of pocket gophers therein was reduced from 12 to one. There was, perhaps, some mortality due to the plowing. Excepting the individuals, if any, that were killed by the plow, and excepting the one that remained in the field, the gophers soon moved their sites of activity to the undisturbed periphery of the field. The populations of pocket gophers within a cemetery that adjoined the north part of the field increased, as was evidenced by a proliferation of lines of mounds within the cemetery. The increase may have resulted from some individuals moving there from the field that was plowed or may have resulted from young being born there, or from both sources.

Another colony of pocket gophers lived three miles north and ¾₁₀ mile east of Lawrence, Douglas County, Kansas, within the boundary of a plowed field, but no well-drained, undisturbed areas were present within a quarter of a mile of this locality and we suppose the colony was there previously when alfalfa was growing on the land.

The local distribution of pocket gophers is determined, to a considerable extent, by the degree to which the land is disturbed.

Pocket gophers are absent from most lands that are intensively cultivated, and live on land that is less disturbed. Relict populations within cultivated fields appear to be confined to limited areas and in the few fields in which they persist at all do so because of a lack of suitable habitat nearby.

SOIL BROUGHT ABOVE GROUND

No evidence of pocket gopher activity in the form of mounds of earth expelled from underground burrows was found in the 56-day period, December 20, 1962-February 13, 1963. In each of the other 309 days (Feb. 14-Dec. 19, see Fig. 5) one or more pocket gophers under observation did bring soil up onto the surface of the ground, and the amounts were recorded. Much less was brought up in the hottest part of the summer than at any other time in the 309-day period. The amount brought up per year varied from gopher to gopher depending on age, sex, and distance between underground rootstocks and rhizomes that are relied upon as food by the gopher. On any day when the amounts of soil deposited on the surface of the ground by two or more gophers were recorded, an average was computed for that day.

On that basis, one gopher in one year transports to the surface of the ground two and one-fourth tons (actually 4,465.7 lbs.) of soil, which amounts to 52 cubic feet! At this rate, seven gophers on an acre could cover the surface of the ground with a layer of loose soil one inch deep in 10 years, or six inches deep in 60 years. This amount of soil deposited on the surface will remind our readers of Darwin's classical study of the role played by earthworms in the formation of soil in England. There is a parallel (and it is the more significant) in western Kansas because earthworms are rarer there than in other parts of the state.

The soil collected and measured after it had been brought to the surface of the ground by pocket gophers was from five localities as follows:

1. Five and one-half miles north and two miles east of Lawrence, Kansas, in Jefferson County. The pocket gophers were in an alfalfa field and a pasture. Both the alfalfa field and the pasture had been reseeded to little bluestem, big bluestem, Indian grass, and switch grass.

2. Four miles south and one-half mile east of Lawrence, Douglas County, Kansas, in two alfalfa fields.

3. One-half mile south and one and one-half miles east of Lawrence, Douglas County, Kansas, in an orchard.

4. Two and one-half miles north and one-tenth mile east of Lawrence, Douglas County, Kansas, in two alfalfa fields separated by a road.

5. One-half mile north and six miles west of Lawrence, Douglas County, Kansas, in native prairie.

At localities number 1 and 2, pocket gophers were introduced in 1962. Pocket gophers had been reliably reported as previously present at both of these general localities, but had been absent for five years from locality 1 and for 15 years from locality 2. Twelve live-trapped individuals taken from a colony at locality 5, were used to stock the selected sites in 1962. The periods of time for which the introduced individuals persisted in the fields where they were released are summarized in Table 2.

At localities number 3, 4, and 5, established colonies were present and workings (mounds) of distinct individuals within each of these colonies were plotted. Throughout the study qualitative information on soil brought to the surface of the ground by pocket gophers was obtained also by observation of other colonies throughout Douglas County.

The soil pushed out of its burrow by an individual pocket gopher was collected, measured, and weighed in the field, by means of a hand scale at three- to seven-day intervals. In the field the average weight of soil, packed by hand was 11.5 pounds per gallon. A soil sample was taken at the time the soil was measured. Later the sample was dried in an oven to determine the amount of moisture in the soil. Moisture content varied between 10 and 20 per cent, depending on how recently it had rained and on the type of soil. The average weekly ambient temperature and the average weekly weight of dried soil moved were calculated and are plotted in Figure 5.

The amount of soil brought up onto the surface of the ground by pocket gophers has been estimated by various authors. Buechner (1942:346-347) estimated that *G. bursarius* in Texas brought up 0.36 of a ton of soil per acre per year in a tall grass area, whereas in a slightly overgrazed "Yaupan oak," grass area the annual amount of soil brought up was 7.08 tons per acre.

Seasonal variation in the amount of soil brought up onto the surface of the ground has been attributed to increased soil moisture following autumnal rains (Miller, 1948:43, in *Thomomys*), but Miller and Bond (1960:474-475) found no such correlation and attributed the seasonal variation to behavioral changes induced by the breeding season. They associated periods of apparent inactivity in bringing up soil with involvement in caring for the young. Laycock (1957) did not think that caring for the young would account for inactivity of males and concluded that periods in which soil was not deposited on the surface of the ground were not indicative of total inactivity since the pocket gopher may have been actively excavating new tunnels and pushing the excavated soil into old underground runways rather than to the surface.

Mosier (Master's thesis, 1946, Fort Hays Kansas State College) concluded that depth of tunnel systems depended on temperature—the higher the temperature the shallower the tunnel. Although he had few data his conclusion may have been correct. Our measurements were all made in late summer. They indicate that tunnel depth varied from individual to individual, with a mean depth of eight and three-fourths inches and extremes of 12 and six inches. Diameters of tunnels averaged three and three-fourths inches with extremes of six inches and two and one-half inches. These measurements exceed the limits of variation noted by Mosier for the entire year.

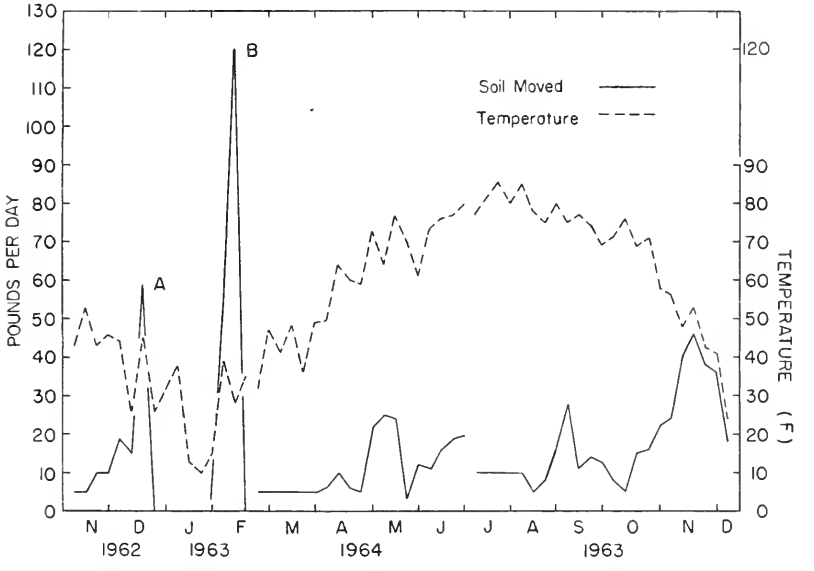


FIGURE 5. Pounds of soil brought to the surface of the ground and air-temperatures for a composite year. Data are grouped for seven-day intervals. Weight of soil brought to the surface of the ground is the average daily weight for a seven-day interval. The average mid-range temperature for any seven-day period was computed by summing the means of the extreme daily temperatures for that seven-day interval and dividing by seven (the number of days in the period). For clarity the continuum of months are separated where data are drawn from different years.

Points A and B represent peaks of activity following periods in which the average temperature was below freezing.

Further data required by anyone wishing to combine the information presented in Figure 5 with data that may be collected in the future is as follows: Amount of earth shown as brought up onto the surface of the ground in the period November 6-December 19, 1962, is the average amount brought up by four individuals. The individuals are:

Female (270 mm. total length; 301.2 grams) released on November 2, 1962, at Locality No. 2, brought up 349 pounds of soil in the period November 14 through December 10. See Table 2.

Female (not measured or weighed) released on November 6, 1962, at Locality No. 2, brought up 49.4 pounds of soil in the period November 6 through November 19. See Table 2.

Male (280 mm. total length) released on December 5, 1962, at Locality No. 2, brought up 62.5 pounds of soil in the period December 5 through December 11 (no soil brought up December 12-14; gopher gone on 14th). See Table 2.

An individual of unknown sex (not measured or weighed) at Locality No. 3 brought up 175 lbs. of soil December 17-19, 1962.

No soil was brought up at Locality No. 3 in the period December 19, 1962, through February 13, 1963. The ground was frozen in that period to a depth of several inches.

Amount of soil shown as brought up in February of 1963 represents the finding of 852.5 lbs. of freshly excavated soil on February 22, 1963, at the same place (Locality No. 3) where the individual worked that brought up soil in the period December 17 through December 19, 1962. Presumably the same gopher made both sets of mounds. No freshly excavated soil was at this place on February 14 or after February 22.

Amount of soil shown as brought up onto the surface of the ground in the period February 22, 1964, through April 8, 1964, is the average of amounts of soil brought up at Locality No. 4 by two individuals that were not handled; consequently their sex, age, and weight are unknown. The individual on the north side of the road brought up 218 lbs. and the one on the south side brought up 180 lbs. in that period. On the south side of the road this same gopher brought up onto the surface of the ground 182 additional pounds of soil in the period April 9, 1964, through May 4, 1964.

Amount of soil shown as brought up onto the surface of the ground in the period May 2, 1964, through July 10, 1964, was the work of a young female (KU 98163, total length 244 mm., weight 148 grams, no placental scars, thought to have been less than one year old) at Locality No. 5. In this period she brought 1,040 lbs. of soil up onto the surface of the ground. Locality No. 5 is a U-shaped field of native prairie on a slope. The land above the prairie is cultivated and lacks pocket gophers. A horizontal stratum of limestone crops out at the lower edge of the prairie and the soil is thinner there than higher up. Pocket gophers are more abundant on the upper part of the slope than lower down where the soil is thinner.

Amount of soil brought up onto the surface of the ground in the period July 11, 1963, through December 13, 1963, is the average of soil brought up at Locality No. 4 by four individuals, all on the north side of the road. The individuals were loosely aggregated and the string of mounds of soil made by one individual was well separated from the string of mounds made by any other individual. Consequently it was possible to observe the work of one individual over a considerable period of time. The four individuals are listed immediately below.

Male, adult (KU 96936, 314 mm. total length; 416 grams) brought up 2,344.25 lbs. of soil in the period July 11 through December 13.

An individual of unknown sex (not measured or weighed) brought up 1,530.25 lbs. of soil in the period July 11 through November 11.

Another individual of unknown sex (not measured or weighed) brought up 441 lbs. of soil in the period September 10 through October 14.

A third individual of unknown sex (not measured or weighed) brought up 134 lbs. of soil in the period September 26 through October 19.

The information collected by us on seasonal activity and amount of soil brought up onto the surface of the ground illustrates some of the trends in activity of pocket gophers in eastern Kansas. Two periods of inactivity or relative inactivity in bringing up soil were noted, one in winter and the other in midsummer.

Cessation of activity in winter appears to be related to the freezing of the soil. In the winter of 1962, in an initial cold period the average weekly temperature was below freezing. In this period the pocket gophers of the colony under observation brought no soil up onto the surface of the ground. In the following week the average temperature rose above freezing and, after the ground had thawed, a peak amount of 59.7 pounds of soil per day (point A on Fig. 2) was brought up. In the following week, temperatures again dropped below freezing and no soil was brought up. Two weeks later the temperature again rose above freezing but no soil was brought up at that time.

In the first week in February temperatures again rose above freezing and the ground began to thaw. After the ground had thawed there was a higher peak of 121.6 pounds of soil per day brought up (Feb. 23-Mar. 1) (point B on Fig. 2). Deposition of soil on the surface of the ground at this colony ceased no later than March 23, 1963. The reason for no more soil having been brought up is not definitely known but the colony was in an apple orchard where several kinds of insecticide sprays were used (some for the first time) in the late winter and spring of 1963. The sprays that fell on emerging vegetation possibly killed the pocket gophers.

During July the average weekly temperature remained in the 80's. Soil brought to the surface of the ground in this period averaged less than 10 pounds per day. Beginning in mid-August the average temperatures began to drop and they declined rapidly from mid-October through November. During this period the amount of soil brought up onto the surface of the ground gradually increased and, in the third week of November, reached a peak of 45 pounds per day. (Average weekly temperature was obtained by adding the highest temperature in each day in the week and the lowest temperature for each day in the week and dividing by 14.)

Temperatures of the subsurface runways in late summer varied only slightly from the ambient temperature, due to the shallowness of these runways and probably this relationship applies the year around. The frost line extended to a depth of 12 inches in rock crevices in 1954 in eastern Kansas (Fitch, 1956:471) and, due to

the lack of extensive snow cover that would serve as insulation, the ground in some winters has frozen to a depth of almost three feet (34 inches in 1930-31, *fide* Harold Eberhart). At a depth of three to four feet, the level at which most nests of the plains pocket gopher are situated, temperatures vary only slightly except possibly in severe winters. The nest and deep runways may serve as refugia where extreme temperatures in winter and summer are avoided.

Rainfall in the period November, 1962-December, 1964, was less than average for the area concerned. It is difficult to correlate accurately the amount of soil moved up onto the surface of the ground with changes in amount of soil moisture. It appears (Fig. 5) that as the temperature in its annual cycle changes from cold in winter to hot in summer and back to cold again, the deposition of soil on the surface of the ground by the plains pocket gopher changes from a low rate or none in winter to a higher rate in spring, to a low rate in summer, and to a high rate in autumn. There may be an optimal temperature at which these animals are most active, but the data at hand are not extensive enough to warrant a definitive statement. The possible behavioral effects of the breeding season cannot be overlooked, although they are poorly understood because the pocket gopher is concealed below ground and unavailable to observers.

In the spring of 1964 the post-winter rains were much heavier than in 1963. Probably because of the increased moisture, the rate of deposition of soil on the surface of the ground was remarkably low. After an especially heavy rain in early April two individuals in a lowland colony two and one-half miles north and one-tenth mile east of Lawrence, Douglas County, Kansas, apparently were flooded out of their burrows. As much as four days later the ground in this area was still moist.

At the beginning of our study, by starting a record of the amount of soil brought up onto the surface of the ground by each of several pocket gophers we hoped to be able to ascertain the total amount brought up by at least one individual in the course of one complete year (in the span of 365 consecutive days). For reasons beyond our control this hope was not fulfilled. Had it been, we hoped to capture the individual pocket gopher in order to ascertain its size, weight, sex and age. So far as we know, no investigator has yet done what we unsuccessfully attempted to do.

NATURAL HISTORY

Pocket gophers have their center of abundance in the western part of North America. The climate there is characterized by alternating dry and wet seasons. Linked with this climate is a larger number of kinds of plants having thickened and enlarged roots (the better to sustain the plants in the dry season) than occur east of the Mississippi where moisture is distributed more or less evenly in all seasons. These thickened and nutritious underground parts of plants are the major food of pocket gophers.

As we know from study of their fossilized remains, pocket gophers became increasingly better equipped for digging as the underground structures of plants became enlarged by natural selection over millions of years in response to increasingly arid conditions. Gophers took advantage of an increasing but unused underground food source. Now they have reached a stage at which, in certain seasons, all of their food is obtained below ground. As Grinnell (1923:139) has written, a pocket gopher spends at least 99 per cent of its existence below ground. Its world is limited by the earthen walls of a cylinder dug by itself. In one direction this cylinder brings safety from several enemies and in the other direction brings accessibility to food.

The extensive digging is mostly to reach food, principally the underground parts of plants. The pocket gopher is so specialized for a life underground that it does not get along well above ground. The structure of the limbs makes it impossible for the gopher to run or leap rapidly on the surface of the ground. Its sight is poor. Sounds made by potential enemies probably are not heard readily from afar. The gopher seems instinctively to avoid fully exposing itself above ground. If the plains pocket gopher sometimes comes out of his burrow to eat leaves and stems of low-growing plants, and if he behaves as do adults of his western relatives (smooth-toothed pocket gophers, genus *Thomomys*), he ventures only as far from the mouth of his burrow as he can go while keeping his hind quarters in the burrow. Otherwise the plains pocket gopher keeps the entrances to its burrow closed by soil firmly packed into the terminal parts of the lateral tunnels except when the gopher has pushed out onto the surface of the ground one load of soil and has returned below ground for another load. Even so, many are snatched up by owls and predators.

The plains pocket gopher does not hibernate and does not require water to drink; enough free water is obtained from the plant food. In some seasons cut sections of roots are stored in chambers underground for use in ensuing season(s) when many plants are dormant. Smith (1948) found sunflower roots (*Helianthus tuberosa*) so stored by the plains pocket gopher. We have found underground caches of roots of several kinds of plants including alfalfa. One cache of sorghum seed was found.

Although *Geomys bursarius* penetrates farther eastward, even into the tall-grass prairie region, than do species of other genera of pocket gophers, and thereby occurs in some areas receiving precipitation in all seasons, the animal relies heavily on the underground parts of plants for food.

The pocket gopher in Kansas seems ordinarily to have only one litter per year consisting of from one to six young (Scheffer, 1910: 205) and mostly born in March and April. The average number of embryos found by him was a fraction more than four in 95 females. For most of the year pocket gophers are solitary. Only a few multiple occupancies of burrows have been recorded, and they were in spring—the season when a male and a female would be expected in one burrow, if only briefly, for mating. Also, spring is the season when partly grown young would be in the mother's burrow.

Longevity in free-living plains pocket gophers has yet to be ascertained; a continuing study for the State Biological Survey by Mr. Robert Wimmer, whose final report has not yet been received, shows that maximum ages attained in the wild state exceed seven years.

Natural enemies are the carnivorous mammals, including the long-tailed weasel, spotted skunk, and coyote. Raptorial birds, including some hawks but especially the Barn Owl and, in Kansas, the Great-horned Owl, capture many pocket gophers. Part of the annual increase in the gophers is harvested by the gopher snake, also termed bull snake. This reptile throws a loop of his body around a fresh gopher mound, and removes a part of the loose soil (see Hisaw and Gloyd, 1926:200-205). He repeats this maneuver until the tunnel is reached and then works his head and neck down the earth-filled tunnel into the main burrow. Once inside, the snake constricts, kills, and swallows the pocket gopher.

Pocket gophers have their quota of parasites and commensals—animals that live with or on the gophers. Commensals were present in all three nests recovered from burrow systems. In a nest unearthed six miles west and four-tenths of a mile north of Lawrence the following families of mites and chiggers

were present: LAELAPTIDAE (*Androlaelaps*, blood-sucking; *Hypoaspis*, free-living, present in large numbers), MACROCHELIDAE (predaceous, common in litter), UROPODIDAE (feed on decaying matter), PYEMOTIDAE (plant feeders and insect parasites), TROMBIDIIDAE (predaceous), ACARIDAE (feed on decaying material; many adults and immature individuals present), HERMANNIIDAE, PHTHIRACARIDAE and EPILOHMANNIDAE (all three families feed on decaying material and fungi).

Both ecto- and endo-parasites were collected from 12 individuals. Ecto-parasites (mites) were present on all 12 individuals and were of two kinds: *Hirstionyssus geomydis* (first report: Keegan, 1946) and *Androlaelaps glasgowi* (first report: Conaway, 1947, MS. Cornell Univ.).

Nine of the 12 individuals examined for endoparasites were infested with the cestode *Aprostatandrya macrocephala* (first report: Douthitt, 1915). This cestode was present in both the hindgut and the caecum. Usually one to four cestodes were present. One individual, a female, contained more than 20 tapeworms. For a more detailed account of some of the above-mentioned parasites, see Ubelaker and Downhower (1965:206-208). None of the parasites have been found to infect man.

BURROW SYSTEMS

Three burrow systems were excavated. Two (see Fig. 6) were next to an alfalfa field two and four-tenths miles north and two-tenths of a mile east of Lawrence, Douglas County, Kansas. One of these was that of an adult female and the other that of an adult male. Total length, length of tail, length of hind foot, and weight of the female and male were, respectively, as follows: 246, 270; 62, 74; 32, 35; 222.6 gm., 246.9 gm.

A third burrow system, only 14 feet long, of an individual of unknown sex and size, was excavated along a roadside 11½ miles east and four miles south of Alma, Wabaunsee County, Kansas.

Before a burrow system was excavated the mounds associated with it were flagged and the distances between them measured. Depths of the tunnels were measured where the depth changed and adjacent to mounds. When excavations were made in order to set traps, additional depths were measured at the junctions of laterals and the main tunnel. Height (greatest distance from floor to ceiling of tunnel) and depth (greatest distance from floor of tunnel to surface of the ground) were recorded.

When a burrow system was being excavated commensals found in the tunnels were saved for identification. Nests and food caches were removed and sealed in plastic bags. The nest materials were processed through Berlese funnels as a means of extracting and collecting the commensals. Both the plant materials and invertebrates were identified as far as was practicable.

Descriptions of two burrow systems of the plains pocket gopher (*G. bursarius*) have been published (Scheffer, 1940; Smith, 1948). Each burrow was that of a female. A comparison of those burrow systems with three excavated by one of us (Downhower) is given in Table 3.

Smith (1948:314) noted that the feces were deposited in the laterals and subsequently covered with soil. We have noted feces in mounds, in the plugs of earth in lateral tunnels, and also in the nest. Feces probably are

dropped wherever the animal happens to be, rather than in a special defacatorium. We suppose that as the pocket gopher pushes the excavated soil through the burrow, the loose feces become intermixed with the soil and are deposited in the mound and plug of the lateral tunnel. Soil excavated by gophers in winter is deposited in lateral tunnels and this could make it appear that feces are buried in a purposeful manner.

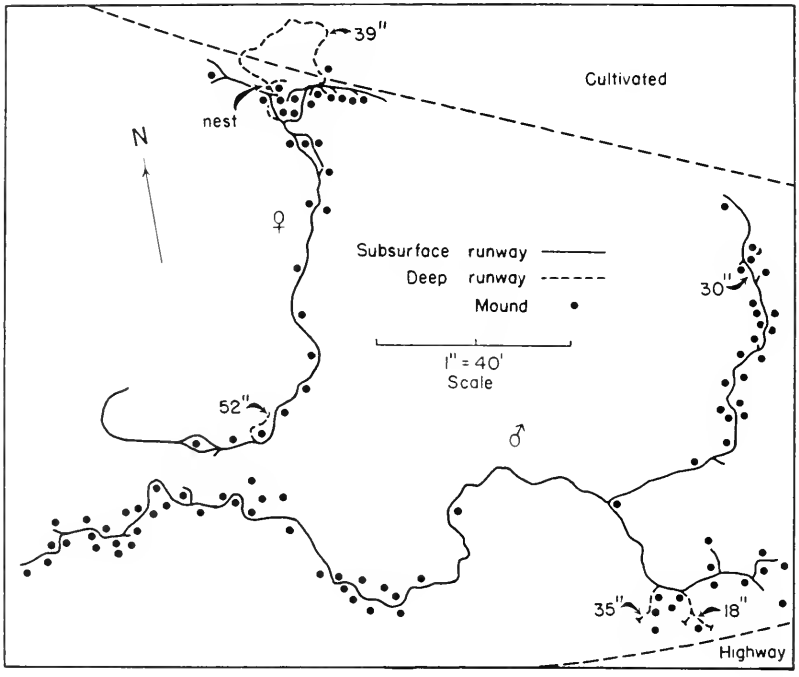


FIGURE 6. Two burrow systems at a locality two and four-tenths miles north and one-tenth mile east of Lawrence, Douglas County, Kansas, laid open in the period October 31 to November 15, 1963. The system on the right is that of a male, and the one to the left is that of a female. The maximum depths reached by the tunnels are given in inches.

The burrow systems of the plains pocket gopher consist of two kinds of runways (Fig. 6), deep and subsurface. The subsurface runways, some of which are several hundred feet long, are the more extensive. Usually there is a single major subsurface runway with shorter runways branching off of it. Mounds on the surface of the ground are thrown out from short lateral tunnels. Some subsurface runways are associated with food caches and nests, but the nests found appeared to be primarily associated with deep runways.

The subsurface runways of the two burrow systems north of Lawrence (Fig. 6) were less than 10 feet apart at one place in the area where they

were more or less parallel for 20 feet. Mounds of the same age as those associated with the two systems were present between the two runways making it appear that the two systems were connected. But, excavations in this area revealed a tunnel, plugged with soil, leading from the burrow of the female toward that of the male and a similar plugged tunnel leading from the male's burrow toward the female's. Whether these two had indeed ever joined could not be determined.

TABLE 3. Some Characteristics of Five Tunnel Systems of the Plains Pocket Gopher (*Geomys bursarius*) Excavated in Eastern Kansas. The Three to the Right Were Excavated by Jerry F. Downhower. Linear Measurements are in Inches Unless Feet Are Indicated.

Sex	♀ [1]	♀ [2]	♀	♂	?
Tunnel diameter	3.75	2.75	3.0	3.25	3.0
Average depth of tunnel	7.5 [3]	no more than 10	8.4	9.6	6.0
Greatest depth	38	65	52	30	6
Total length	206 ft.	510 ft.	200 ft.	320 ft.	14 ft.
Nest, depth below ground	24	19	30	.....	6
dimensions	7x3.5x6.5	dia. 7	dia. 6	.....	4x6
Number of mounds	25	105	28	76	1

1. Smith, C. F. 1948. Trans. Kansas Acad. Sci., 51:313-315.
2. Scheffer, T. H. 1940. Trans. Kansas Acad. Sci., 43:473-478.
3. Author lists range of six to nine inches.

Depth of subsurface runways below the surface of the ground averaged slightly more than nine inches at the junction of the lateral and the main runway in 20 of the burrow systems in which traps were set. At this junction the distance of the roof from the surface of the ground averaged slightly less than five inches. The subsurface runs of the three burrow systems excavated varied in depth from six to 10 inches except that the tunnel of the male's burrow was more than two feet deep where it passed under a root of a cottonwood tree and again where the tunnel approached the embankment of the road.

The deep runs led to the nests or ended blindly and attained a depth of four and one-half feet. They were not connected to the surface except through subsurface runs. In the course of excavating these deep runs the gopher had pushed soil several feet vertically and 40 to 60 feet horizontally in order to bring it to the surface.

Most nests are not in the deepest parts of tunnels but are a foot or so higher. The nest is usually lined with grasses and approaches a sphere in shape but is slightly flattened, five inches high and seven inches wide. Only one nest was found in any one burrow system. After a nest is abandoned, the tunnel leading to it, according to Smith (1948), is plugged and a new nest is constructed.

One tunnel from the nest descends and may come to a dead end or may wind around and rejoin the subsurface run at a point remote from the point at which the deep run connects with the nest. This deepest tunnel possibly functions as a sump that drains other tunnels, including the one in which the nest is situated. The orientation and junction of the deep and subsurface runs form a circular pathway whereby the occupant may leave the nest by a variety of routes. This arrangement appears to be characteristic of well-established tunnel systems.

The female's tunnel system excavated north of Lawrence (see Fig. 6) possessed such a circular deep run (also, see, Scheffer, 1940). She seemed to have been excavating a second branch of the deep run to the surface. The deeper runs of the male may have joined and may have led to a nest or males may not construct nests. If in fact his deeper runs joined, they did so somewhere under the highway (Fig. 6).

The small isolated burrow system excavated in Wabaunsee County appeared to have been abandoned after a short occupancy. The burrow was in a road embankment and extended under the road in gravelly soil. One nest and three food caches were recovered from the burrow system, which was 14 feet long and consisted of a main tunnel with several short branches. The nest was composed of plants commonly found along a semi-weedy roadside in an area of cultivated or pastured farmland. A great variety of weedy and grassy materials was present, most of them too fragmentary to yield positive identifications through ordinary means (T. M. Barkley personal communication). At one end of the burrow system several hundred seeds of *Sorghum* had been cached. Many of the seeds had sprouted and gave that section of the tunnel the appearance of a subterranean garden.

ECONOMIC IMPORTANCE TO MAN

For man the plains pocket gopher is either an asset to be left alone, or a hindrance to be reduced in numbers (or eradicated), depending on the use man makes of a given land area.

Less is commonly known about benefits conferred than about nuisance aspects of the animal. Therefore, some of the beneficial aspects are enumerated first.

Beneficial Activities

The burrowing activities of pocket gophers on native grasslands, in seeded pastures and meadows, and on other uncultivated lands, as pointed out by Grinnell (1923) for another species in California, has beneficial effects for man as follows:

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

"2. The subsoil is . . . 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 . . . to contribute to the upbuilding of . . . fertile valleys . . . .

"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 . . . run-off is retarded and the supply to the streams . . . 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.

"5. A porous moist soil produces a fuller vegetational cover . . . 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."

Other ways in which pocket gophers benefit soils and cause more water to enter the ground could be mentioned. For example, the loosening of the soil by gophers conteracts the packing effect of hooves of domestic livestock in pastures, and counteracts the compaction of soil by tractor tires in alfalfa fields. The burrows "pipe" water underground thereby raising the water table and the water issues forth as springs elsewhere.

Grinnell's summation of the beneficial results of the burrowing activities of gophers of the western genus (*Thomomys*) applies in equal fashion to our plains pocket gopher (*Geomys bursarius*) with two qualifications. *G. bursarius* occurs widely in the Chernozemic soils of the Great Plains (see Kellogg, 1936:31, and Simonson, 1957); these soils generally are deep; consequently *G. bursarius* less often burrows into the subsoil than does *Thomomys* of the far western states where other types of topsoils in many places are relatively thin mantles over contrasting types of subsoils. Second, *G. bursarius* less often than *Thomomys* persists in, or reinvades, cultivated land.

In an earlier publication one of us (Hall, 1955:104) remarked that in Kansas "when pastures are overgrazed the grasses are partly replaced by weeds with large roots. These large roots are one of the special adaptations permitting these plants to live under adverse conditions. These large roots constitute an abundant food supply

for pocket gophers which thrive and multiply. The action of the pocket gophers in 'plowing' the soil and actually destroying the weeds hastens the return of grass if the overgrazing is controlled. With the return of the grass the pocket gophers decrease . . . ." in number.

On page 13 of the present booklet it was pointed out that on an area having seven pocket gophers per acre—not an unusual number on overgrazed or otherwise abused land where dock, dandelion, dog fennel and other thick, tough-rooted plants have replaced native vegetation—pocket gophers cover the ground with a layer of loose earth six inches deep in 60 years. Six inches is a common depth to which a farmer plows. The plowing by the gophers creates a favorable seedbed for grasses and the gophers destroy particularly the obnoxious weeds by eating their roots. On healthier grassland where only one-seventh as many plains pocket gophers might live, the turnover of the soil would be only one-seventh as rapid. Even at that rate, in the 1,200,000 years *Geomys bursarius* and its immediate ancestors have occupied the Great Plains area, they have turned over 1,429 cubic feet per acre—the equivalent of 2,858 plowings to a depth of six inches.

Although a wide margin of error, either way, is inherent in computations of this sort, the plains pocket gopher has brought, and continues to bring, tremendous amounts of soil up onto the surface of our uncultivated land. About one-third of Kansas is uncultivated. By reason of contributing to the health and fertility of the soil the pocket gopher, for man, is a good citizen and on our grasslands deserves to be let alone as a normal member of the grassland community.

Harmful Activities

The burrowing activities and eating habits of pocket gophers on cultivated lands of the Trans-Mississippi West have caused these mammals to be labeled as harmful to some of man's agricultural enterprises.

In Kansas, much of the plains pocket gopher's bad reputation stems from his having been confused with the smaller smooth-toothed pocket gophers, Genus *Thomomys*, that live in the intermountain west and along the Pacific Coast. *Thomomys* has been widely publicized as harmful, and has been especially troublesome where irrigation instead of summer precipitation is relied upon to provide the moisture necessary for the growth of cultivated crops;

the burrows in some porous soils can divert, below ground, the water intended for surface irrigation, and the burrows in ditch banks and earthen canals can cause breaks through which water is lost, requiring expensive repairs. Smooth-toothed pocket gophers are said to damage some plants in truck gardens, garden flowers that have bulbous roots, and have been known to kill fruit trees (orange) by cutting the roots and, in a few instances, by girdling trees just below the ground level.

In Kansas, instances of damage of the kinds noted above have rarely, if ever, been a problem because our single species, the plains pocket gopher, does not live in plowed fields. The plowing, discing, and other tilling of the ground for planting wheat, corn, milo, and soybeans causes the plains pocket gopher to disappear, we suppose partly owing to destruction of tunnels and partly owing to elimination of plants that provide food relished by our plains pocket gopher. Also, as noted at the outset, no pocket gophers at all live in the 16 or more southeastern counties.

About the only valid complaint in Kansas against the plains pocket gopher stems from damage it does to alfalfa plants and/or the nuisance it constitutes in alfalfa fields. Eating the roots of alfalfa can kill plants although most of them survive by growing new roots, except in drouth years. More serious damage results from the gopher gnawing on the root crowns.

Just how much this damage reduces the eventual yield is unknown; stands of alfalfa deteriorate after the first year and the fields ordinarily are plowed and reseeded every fifth year anyhow or are planted to some other crop. The mounds of soil thrown out on the surface of the ground may kill some alfalfa plants and the person operating a mower dislikes to see his sicklebar cut through the mound because of his feeling that the sections on the sicklebar are thereby dulled more rapidly than otherwise would be the case.

Even so, only a few farmers ever are concerned enough to take the time themselves to remove the gophers. Some farmers have recommended that the township or county pay a bounty on pocket gophers. This, of course, is ineffective and also expensive once it is put into practice. Furthermore, it removes some pocket gophers from grasslands where they are doing no harm and some good. Details on the ineffectiveness and disadvantages of the bounty system are summarized by Cockrum (1952:138-140) in his publication readily available at no charge from the state library

in Topeka, and ought to be consulted by any Kansas township trustees or county commissioners who are considering authorizing the disbursement of public funds for paying bounties.

Numerous governmental bulletins contain directions for preparing poisoned baits to introduce into gopher burrows but we do not recommend poison because it is dangerous to harmless and beneficial wildlife.

Means of Control

When damage or inconvenience warrants reducing a population of pocket gophers, or eradicating them in a field, we recommend Macabee gopher traps in pairs—each of two traps set in opposite directions in the main underground tunnel.

One trap set in the lateral tunnel leading to the mound is not half

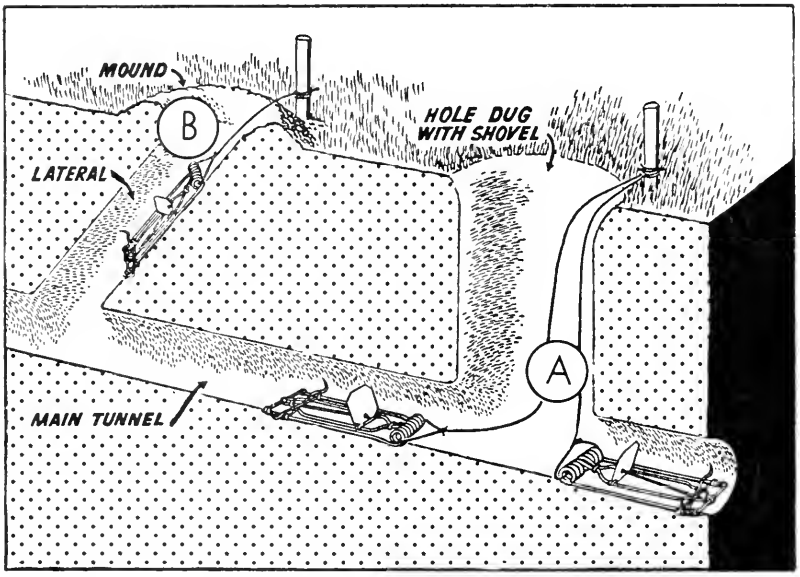


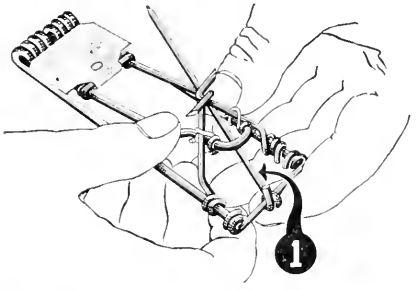
FIGURE 7. Two methods of placing traps for pocket gophers: *A*, in hole dug with shovel, place two traps set in opposite directions in main tunnel; *B*, set single trap in lateral tunnel. Fasten each trap by means of a wire or cord to a stake tall enough to be seen easily in the field. *A* is the preferred method.

so effective as two in the main tunnel because a trap in a lateral tunnel often is sprung by a load of soil pushed over it by the gopher.

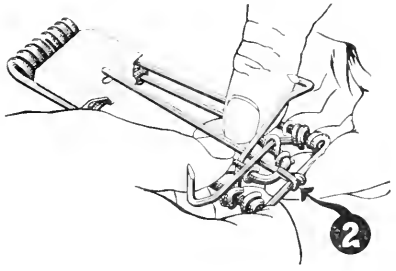
Each trap should be attached by means of a cord, or better, a light wire, to a conspicuous stake, in order to mark the location of the trap. This arrangement prevents the trap from being dragged out of reach in the burrow by a wounded gopher and saves many traps that otherwise would be carried away by some carnivorous mammals that decided to eat the trapped gophers.

Autumn is the best season to trap because gophers then are most active in bringing soil up onto the surface of the ground and, as a result, can most easily be located. Traps should be set at "fresh workings." Also, in autumn plants grow less rapidly than in summer and therefore are less likely to conceal the stakes by means of which the traps are to be found when inspected. The next best season is spring and additional trapping then can eliminate individuals missed in autumn and any others that have migrated into the field since the preceding autumn. In order to keep pocket gophers out of sandy loam in an alfalfa field some trapping in each autumn and each spring is required.

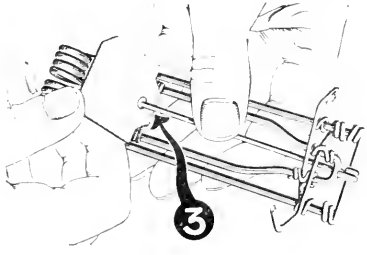
FIGURE 8. Directions for Setting Trap.



Hold Trap Exactly as in Illustration. Be Sure Left Index Finger Holds Trigger (1) in Upright Position.



Press Thumbs Down; With Left Index Finger Guide Hook on Trigger (2) Over End of Frame of the Trap.



Still holding Frame Down, Place the Other End of the Trigger (3) in the Small Hole in the Plate.

Macabee gopher traps are obtainable through any hardware dealer or can be ordered direct from "Macabee Gopher Trap Company, Los Gatos, California." The traps come in different sizes. For the plains pocket gopher in Kansas the size of trap having a three-inch spread across the opened jaws is best. The cost for traps of this size in December of 1963 was $7.00 per dozen. Many other brands of traps that operate on the same general principle as the Macabee trap are available, but each is less effective than the Macabee trap.

Of course protecting owls and gopher snakes is a common-sense measure because they can keep the population of gophers at a moderate level below which no additional reduction may be necessary. Also, for the person who wishes further to reduce or eliminate the population of pocket gophers in an alfalfa field, the toll taken by owls and gopher snakes leaves him far fewer gophers to catch than otherwise would be the case. Owls and gopher snakes almost never eliminate the last gopher from a large field.

ACKNOWLEDGMENTS

The results of research reported upon here can be credited to the help of many people. Raymond Pine, Edward Gilbreath and Raymond Williams generously permitted the collecting and study of pocket gophers on their land and we thank Arnold LeBombarb of the Kansas Highway Commission for permission to excavate some burrows along roadsides. Gary L. Phillips helped in June of 1964 with collecting data on soil movement. An analysis of soils would not have been possible without the aid of Harold Dickey of the United States Soil Conservation Service and Prof. David Simonett. Parasites were identified by A. B. Amerson and John Ubelaker, and plants by Roy Johnson and Prof. T. M. Barkley (Kansas State University). Special thanks are due to graduate students Jon C. Barlow, Charles L. Douglas, Robert Merz, and John Vandermeer, and to R. R. Patterson of the Museum of Natural History, University of Kansas, for various kinds of assistance extended to one of us (Downhower). Professor Henry S. Fitch critically read most of the manuscript.

As regards the bipartite authorship, Downhower wrote the first draft of the principal, longer sections. He served as a halftime Research Assistant on the State Biological Survey from September, 1962, through May, 1964, did almost all of the field work, and all of the laboratory work on soils. Hall, Director of the State Biological Survey, added some observations on *G. bursarius* in Colorado and Indiana, wrote the part on removing pocket gophers from places where they are not wanted, gave editorial attention to the entire manuscript, and in the field measured the earth brought above ground by one gopher in the period May 2, 1964, through July 10, 1964, at locality five (5).

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