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An Evaluation of Control on the Pocket Gopher, *Thomomys talpoides*, on the Cache National Forest, Utah

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AN EVALUATION OF CONTROL ON THE POCKET GOPHER, *THOMOMYS TALPOIDES*, ON THE CACHE NATIONAL FOREST, UTAH

by

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Voit B. Richens

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ABSTRACT

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by

Voit B. Richens, Doctor of Philosophy

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Major Professor: J. B. Low
Department: Wildlife Resources

The Monte Cristo area of the Cache National Forest has consistently supported a heavy pocket gopher infestation for many years. In 1957, and several succeeding years, infested range was treated with poisoned grain for pocket gopher control. Nearby range (also infested) was not treated. Thus, gopher-controlled range became available for comparative study, with periods of successive annual control of 1, 2, 3, 4, and 5 years. Within each of these areas (designated as treatments) were located two study sites in 1961 and three in 1962. Within each study site were three sample areas, and just outside each study site were two trap blocks.

Half-acre trap blocks were saturated with snap traps for 3-consecutive days to give a 3-day population index; this was converted to population per acre by treatments for use with regression analysis. Mound and cast counts, which have been widely used as indicators of the relative abundance of gophers were made on the 1-acre sample areas of each treatment. Within these sample areas line-plot transects were used to obtain information on perennial plant numbers and yield, annual plant abundance, and "bulbed plant" abundance.

INTRODUCTION

Pocket gophers are fossorial rodents of wide distribution and diverse adaptation. They occupy thousands of square miles in the United States and are most prevalent on the western rangelands. Pocket gophers have frequently been considered to be a detrimental influence on range, but they also have been regarded as being beneficial and/or neutral in this respect. Thus, the question has arisen and still remains to be answered, as to whether the presence of these rodents is the cause or the result of range deterioration. But because pocket gophers frequently occur in large numbers on livestock ranges in poor condition, control measures have been developed and extensively used.

Much of the Wasatch Mountains of northern Utah is grazed by large numbers of domestic livestock as well as by mule deer (*Odocoileus hemionus*)[1] and elk (*Cervus canadensis*). A large proportion of this summer range is heavily infested with pocket gophers (*Thomomys talpoides*). These gophers are herbivorous and thus are assumed to be competitive with the domestic livestock and game animals for the available food. During the winter only the gophers remain on this range, at which time they continue to forage.

The Monte Cristo area of the Wasatch Mountains has consistently supported a heavy infestation of pocket gophers for many years. This high gopher population has existed concurrently with frequent fail-

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[1]Scientific names of animals in this manuscript were taken from Burt and Grossenheider (1956).

ures in the seeding of these high-mountain parklands to grass, and with increasingly poor range conditions.

In 1957, a cooperative program for gopher control was initiated on the Monte Cristo area by the U. S. Forest Service; the Bureau of Sport Fisheries and Wildlife; and Nick Chournos, livestockman. Infested range was first treated with poisoned grain for pocket gopher control in 1957. Each following year, 1958 through 1960, additional infested range was treated; once begun on an area the treatment was repeated annually. Large tracts of nearby range, also infested with pocket gophers, were not treated and served as a check. This program provided five treatments (0, I, II, III, IV) for comparative study.

It has never been determined how many years of annual treatments would be required, nor the cash outlay needed, for effective gopher control of infested ranges. The availability of range for comparative study, with annual control periods of 0, 1, 2, 3, and 4 years presented a rare and excellent opportunity to evaluate a program of gopher control.

The objectives of this study were: (1) to determine the effect of successive annual control (1 to 4 years) on pocket gopher populations, vegetation density, plant species composition, and forage yield, and (2) to evaluate the costs and effectiveness of an annual gopher-control program.

REVIEW OF LITERATURE

Since pocket gophers occur on many overgrazed ranges of the west, they have been associated with range deterioration. As a result, pocket-gopher control has been commonly thought of as the "cure" for poor range conditions. Although the need of control has often been questioned, many range managers and livestockmen have long advocated the control of pocket gophers. The first control program began in 1914 on the Ochoco National Forest in eastern Oregon (Moore and Reid, 1951). Since then the control of pocket gophers has been an accepted range practice, although the results of such control have not been clearly determined.

There has been considerable difference of opinion as to the effects of gophers on rangeland. Keith, Hansen and Ward (1959) stated:

> Currently, there are two broad viewpoints, *each supported to a degree by research findings*. One contends that pocket gophers have little effect on rangeland, since removal of the animals from experimental plots resulted in no significant improvement in the plant cover. . . .The other, widely held by ranchers and land administrators, is that gophers are a detriment to rangeland and its improvement and should be controlled. (Italics mine, Keith, Hansen and Ward, 1959, pp. 137-138)

Tryon (1947, p. 3) said: "The position of the pocket gopher in relation to range has long been a cause for controversy, mainly because no critical study has been as yet brought to a successful conclusion."

The proponents of gopher control point out that gophers reduce range productivity by covering plants and plant portions with soil, by cutting roots and underground stems while burrowing, and by consuming the root, crown, and stem portions of plants as well as by causing erosion (Day, 1931; Crouch, 1942; Moore and Reid, 1951, Mickle, 1957; Howard and Childs, 1959; Julander, Low and Morris, 1959). Those who feel that gopher control is not necessary or that gophers are actually beneficial to range, list loosening and mixing of the soil, increased water infiltration and percolation, and increased soil fertility as important contributions by gophers (Kalmbach, 1949; Ingles, 1952, Ellison and Aldous, 1952; Aldous, 1956).

Moore and Reid (1951) showed that pocket gophers in mountain meadows of eastern Oregon kept a depleted range in a depleted condition for 8 years. Contrariwise, the introduction of 16 pocket gophers per acre onto range in fair condition, although causing some plant-cover change, did not adversely affect the range for sheep use in an 8-year period. They stated:

> Thus, pocket gophers clearly had an adverse effect on the poor condition range. . . .They encouraged an increase in low-value annual weeds. They retarded or prevented the increase of most perennial grasses and perennial forbs or weeds. . . . On the other hand, the total vegetation density, the density of worthwhile perennial grasses, and the density of valuable perennial forbs were much greater where gophers were absent. (Moore and Reid, 1951, pp. 17-18)

The total production of vegetation on controlled as well as on uncontrolled plots was noted to change very little in an 8-year study in central Utah (Ellison and Aldous, 1952), although changes in composition were observed. These investigators, like Moore and Reid, were of the opinion that annuals were somewhat encouraged by gophers. Aldous (1956) at the completion of his study in central Utah, concluded:

> The fact that after nine years of gopher control on one plot, the vegetative density was found to be slightly less than it was on the companion plot where the gophers were not molested, tends to substantiate my contention that the

> gophers on this sub-alpine area have had little effect on the vegetation. . . . (Aldous, 1956, p. 9)

Aldous' opinion that gophers had little effect on vegetation, and Ingles' view (1952) that gophers in mountain meadows may actually be of benefit economically are not shared by Fitch and Bentley (1949). In an 8-year study at the San Joaquin Experimental Range in California, they concluded that a population of 32 gophers per acre had reduced the potential forage yield of a quarter-acre pen by an average of 25 percent. The use of forage at this level would indicate considerable economic loss.

Two studies point out some effects of gophers on re-seeded range of the west. Garrison and Moore (1956) explained that:

> . . .old-drill-row plants in 9 to 11-year-old plantings of crested wheatgrass were not greatly affected by current gopher burrowing and feeding. Establishment of natural reproduction between drill rows, however, was definately impaired. (Garrison and Moore, 1956, p. 184)

In a study on the Cache National Forest, Julander et al. (1959) observed that grass yields on a gopher-controlled area were 2.4 to 6.4 times as great as on an uncontrolled area over a 5-year period. They also found that the grass density was greater and the annual plant abundance was much lower on the plot where gophers were controlled. The difference in the grass stand was in large part due to destruction of plants by gophers.

According to Moore and Reid (1951), gophers gradually remove favored food plants from the vegetation, and these are replaced by plants of lower palatability and nutritive value. They also explain that mounds are barren areas and provide good seed beds on which other plants, usually annuals, can become established. This results in a constant fluctuation of vegetation on gopher-infested areas.

Some of the differences in these reports are due to differences in the degree of initial depletion by overgrazing, the species of plants involved, the choice of foods of the particular species of gopher, and variations in soils as well as some differences in gopher populations. Keith et al. (1959, p. 137) stated that, ". . .the net influence of gopher activity is not yet clear."

The use of 2,4-D is reported by Keith et al. (ibid.) as a gopher-control measure. The production of perennial forbs was reduced 83 percent on a sprayed area while grass production increased by 37 percent. The great reduction (87 percent) in gopher numbers appears to have been caused by a scarcity of forbs, as the pocket gophers changed their diet from 85 percent forbs and 18 percent grass to equal amounts of forbs and grass. Howard and Childs (1959) state:

> At the conclusion of the major part of the study, the forage in the northeastern corner of the plot was killed with herbicides and then burned. This greatly reduced the number of animals in the area. Some of the borderline individuals made a slight shift of their territory while others in the middle of the bare spot disappeared. Whether the influence was due primarily to the loss of feed or to the loss of cover was not determined. (Howard and Childs, 1959, p. 336)

The usual methods of pocket-gopher control are by poisoning and trapping as reported by Wight (1918), Crouch (1942), Howard (1953), Eadie (1954) and others. Crouch (1942) states that poisoning and trapping are the most practical and efficient control methods but gives no idea of the effectiveness to expect. According to Moore and Reid (1951), an efficient gopher-control crew should be able to obtain a 90-percent kill of gophers by poisoning. Kepner et al. (1962)

estimated that an 80-percent kill should be obtainable by the use of the U. C. mechanical gopher-bait applicator (Blackwelder or California burrow builder). A control of 95 percent was reported by Ward et al. (1960) by the use of a gassing probe, but these same authors reported only a 30- to 40-percent control using a surface baiting technique.

The costs of gopher control on rangelands have not been given for most control programs. Yet a knowledge of costs is highly important if large acreages of low-value rangelands are to be treated, as it would not be economically sound to spend more for control than the value of the additional forage due to treatment. A cost of 40 cents per acre for the more accessible areas was given by Moore and Reid (1951), but they conceded that costs may be several times this amount under different conditions. They estimated that succeeding years of treatment should only cost about 10 percent of the initial treatment.

If treatment can be done by use of the Sneidmiller or Colorado burrow builder, one man can treat about 50 acres per day at a cost of $1.50 per acre (Colorado Cooperative Pocket Gopher Project Technical Committee, 1960). Kepner et al. (1962) estimated that one man can cover 5 to 10 acres per hour with the California burrow builder; no costs are given but they would probably be similar to those estimated for the Colorado burrow builder. The use of these machines is limited, however, to flatter lands which are free from trees and rocks.

DESCRIPTION OF STUDY AREA

The study area (Figure 1) is within the Monte Cristo Division of the Cache National Forest and private land in the Wasatch Mountains of northern Utah. Most of this area is between 8,000 and 9,000 feet elevation and consists mainly of high tablelands dissected by tributaries of the Blacksmith Fork River.

The winters of this area are characterized by deep snows and low temperatures, while the summers are rather warm and dry. Prevailing winds are from the southwest, and they cause much drifting of snow in the winter and drying out of the ground in spring and early summer. Summer storms may be convectional and can cause considerable erosion (usable climatological data are not available).

Soils of the study area vary considerably in texture, structure, depth, and estimated fertility. They occur in two main color phases (grey and red) of many different hues. Most of the soils have the property of becoming hard following wetting and drying as illustrated by rock-like gopher casts.

The Monte Cristo range, included in the present study, has been overgrazed in the past and is considered by local range managers to be in poor condition. The vegetation[2] of the area consists mainly of an interspersion of two major types (Figure 2); these are the aspen-coniferous woodland and the mixed parkland.

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[2]Scientific names of plants are after Holmgren (1948).

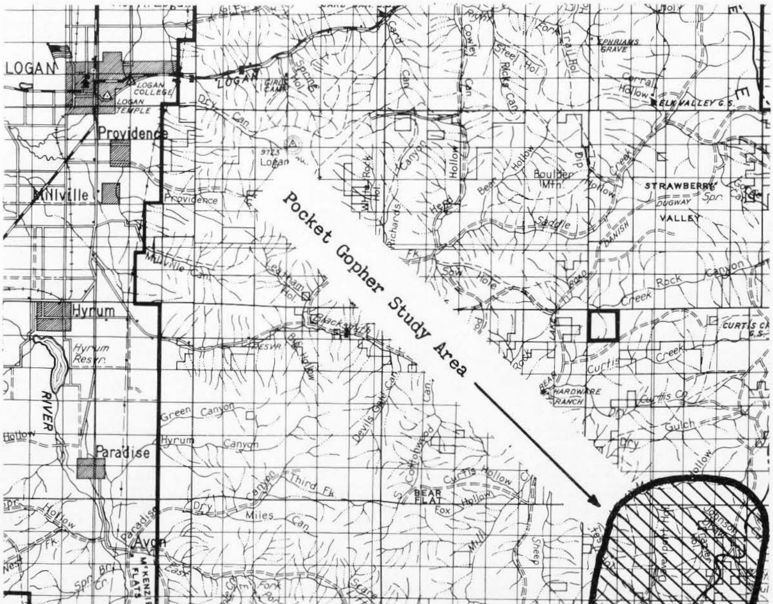

Figure 1. Map of a portion of the Wasatch Mountains of northern Utah showing the location of the pocket gopher study area. 1961-62

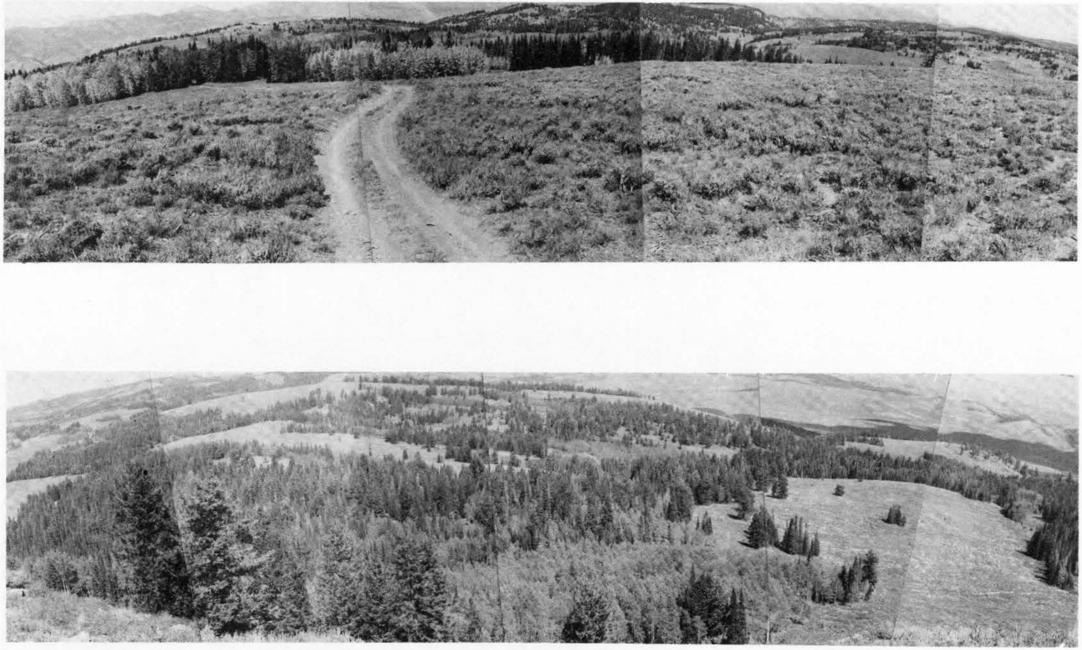

Figure 2. Views showing the two major vegetation types and typical topography of the study area. The upper photo is on the western edge of the study area, while the lower photo is on the eastern and northern edge.

The aspen-coniferous woodland is dominated by Engelman spruce (Picea Engelmanni), alpine fir (Abies lasiocarpa), and quaking aspen (Populus tremuloides), and often contains a good understory of grasses and such forbs as niggerhead (Rudbeckia occidentalis).

The conspicuous shrubs of the mixed parkland are big sagebrush (Artemisia tridentata), snowberry (Symphoricarpus spp.), green rabbitbrush (Chrysothamnus viscidiflorus), and bunchberry elder (Sambucus microbotrys). The most abundant forbs in this type include larkspur (Delphinium occidentalis), geranium (Geranium Fremontii), bluebell (Mertensia ciliata), senecio (Senecio serra), yarrow (Achillea lanulosa), skunkweed (Polemonium albaflorum), eriogonum (Eriogonum umbellatum), and horse mint (Agastache urticifolia).

Slender wheatgrass (Agropyron trachycaulum), and mountain bromegrass (Bromus polyanthus) are the most prominent grasses of the area. Small annuals are extremely abundant on the study area; the four most common species are collomia (Collomia linearis), knotweed (Polygonum spp.), tarweed (Madia glomerata), and gayophytum (Gayophytum spp.). Some small plants of the study area have fleshy root parts and as they are used for food by gophers, are very important. Starwort (Stellaria Jamesiana), oreocarya (Oreocarya flavoculata), spring beauty (Calytonia lanceolata), and woodland star (Lithophragma spp.) are the most important ones. With the exception of starwort these are ephemerals; they are called "bulbed plants" in this manuscript.

METHODS AND PROCEDURES

Gopher Control Program

In 1957, an area well delimited by natural borders and/or roadways was chosen for gopher control. This was marked on a map of the general area. Three men systematically covered this area on foot, placing approximately one handful of whole oats treated with 0.125 percent compound 1080 (sodium fluoroacetate) into each gopher burrow system. Where individual burrow systems were not well defined bait was placed in tunnels near each cluster of new mounds. Additional range was similarly chosen, mapped, and covered each following year (1958-1960) and range treated the previous year was re-treated.

Techniques used in locating the main gopher tunnels and in the dispensing of bait etc. are described by Crouch (1942), Mickel (1957) and the Colorado Cooperative Pocket Gopher Project Technical Committee (1960). The control program was carried on each summer during the snow-free-period, usually from late June to late September.

Establishment of Study Units

Treatments

The term "treatment" applies to those areas of rangeland that have been treated with poisoned grain for pocket-gopher control (Figure 3) and nearby range which has not been treated. Each treatment is designated according to the number of years of consecutive treatment (Table 1).

Table 1. Designation of treatments on the Monte Cristo study area

Treatment designation	Years treated
0	Not treated
I	1960
II	1960, 1959
III	1960, 1959, 1958
IV	1960, 1959, 1958, 1957

Although each treatment includes both the aspen-coniferous woodland and the mixed parkland vegetation types, this study was restricted to the latter.

Study sites

Two study sites of approximately 10 acres each were chosen within each treatment in 1961; one additional study site was chosen for each in 1962. This provided two and three replications, respectively, of each treatment. As a result, there was a total of 10 study sites in 1961 and 15 in 1962. The study sites were chosen to be as nearly alike as possible (Plate I, Appendix) in respect to topography, type of vegetation, and soil characteristics. Study-site boundaries were marked with posts and bright plastic streamers that were highly visible. The writer made no attempt to influence the sheep-grazing intensity on the study sites; the grazing intensity exerted during the

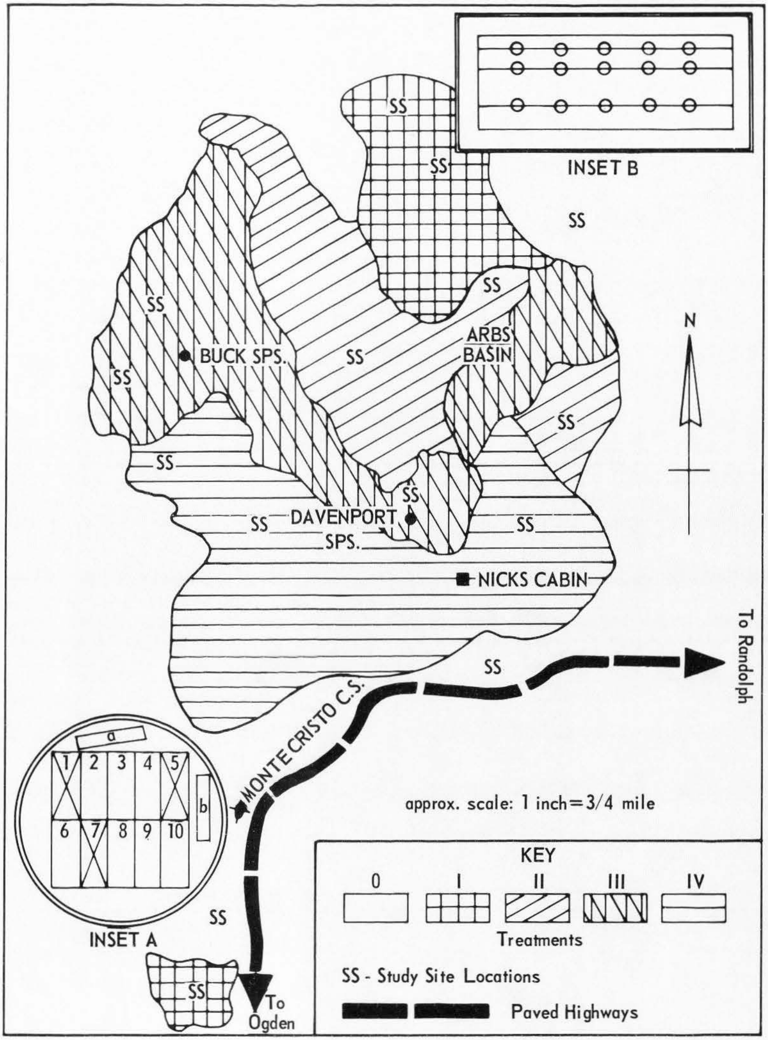

Figure 3. The pocket gopher study area at Monte Cristo showing treatments and location of study sites. Inset A illustrates a study site with its' ten possible sample areas, a random selection of three of them, and two nearby trap blocks (a & b). Inset B illustrates the placement of vegetation transects and circular plots as might occur on a sample area.

study period appeared to have been equal to the grazing intensity in the past several years and equal to that on the range as a whole.

Sample areas

Three replicate sample areas of one acre each (2 by 5 chains) were chosen at random within each study site (Figure 3, A). Sample-area boundaries were well marked by means of posts and colored flags, and a numbered identification tag was attached to one corner stake of each sample area. There were 30 sample areas in 1961 and 45 in 1962.

Trap blocks

Two replicate trap blocks of 1/2 acre each (1 by 5 chains) were established outside but near each study site (Figure 3, A). This made a total of 20 trap blocks in 1961 and 30 in 1962. Trap-block boundaries were marked in the same manner as described above for sample areas.

Gopher Population Studies

Trap catches

Population studies made by Dice (1931, 1938, 1941), Goodnight and Koestner (1942), Stickel (1946, 1948), and Manville (1949) were reviewed by the writer and a method of trapping developed and used as described below.

The trapping period for 1961 was August 4 to September 12 inclusive, while that for 1962 was August 10 to September 8 inclusive. The order in which the trap blocks were trapped was determined at random. Two trap blocks were saturation-trapped (the term "saturation" implies that at least one trap set was made per gopher tunnel system) simultaneously in 1961 and three in 1962 for three consecutive days. In each succeeding 3-day period additional blocks were trapped until all blocks were trapped each year.

The total number of gophers caught on each trap block was recorded and this figure converted to a per-acre basis. For each treatment, the sum of its trap block catches divided by the number of its trap blocks gave a 3-day population index for 1961 and again for 1962. Gophers of all ages and both sexes were included in the population figures.

Traps were set in tunnels under both old and new mounds. They were checked twice the first day and once each following day. All traps which contained gophers were re-set. Trap sets were made as described by the Colorado Cooperative Pocket Gopher Project Technical Committee (1960), except that no cover was replaced over the set hole (Plate II, Appendix).

Mound counts

Three types of mound counts were used in this study. These were: (1) periodic mound counts on sample areas, (2) cumulative mound counts on trap blocks and, (3) 72-hour mound counts on trap blocks. Periodic mound counts were counts made at 2-week intervals and were begun shortly after snowmelt in the summers of 1961 and 1962. Four counts were made in 1961 and five in 1962. The initial sequence of periodic mound counts was determined from a table of random numbers and each succeeding count followed in the same order as the initial count. Cumulative and 72-hour mound counts were made once each year in early August. Cumulative counts included all mounds which had been formed between the time of snowmelt and 3 days prior to the 72-hour counts. The latter count included all mounds formed in the 72-hour period immediately following the cumulative count and before trapping.

A mound count is defined as a count of all gopher mounds on each of all the sample areas or trap blocks. As each mound was counted it was leveled to reduce counting errors and the time required for original and subsequent counts. My interpretation of a mound is all soil that has been pushed above the ground level from one gopher hole. Earth plugs, as described by Miller (1948), were not counted as their presence was much more difficult to detect on some sample areas and trap blocks than on others.

Cast counts

A cast count is a count of all casts occurring on each of all sample areas. Cast counts were made once each year; this was just prior to the first mound count of each summer. They were counted on the sample areas in the same sequence as were the mounds. As the casts were counted they were broken up to prevent double counts and/or under counts. A cast is defined as a continuous ridge of earth resulting from gopher activity under the snow, and which contains no turns of 90 degrees or more. Although this definition is distinctly arbitrary it did assure a standard interpretation of casts on different sample areas. As nearly all casts were well defined and still rock-like when counted, the cast counts were probably quite accurate.

Vegetation Studies

Within each sample area three transects were randomly spaced and were established in the direction of greatest apparent variability. Along each transect five circular plots, each 9.6 square feet in area, were mechanically spaced at equal intervals (Figure 3, B).

Perennials

Green forage weight of the perennial plants was estimated for each species (Pechanec and Pickford, 1937) on these plots; a training period preceded taking of data. Visual estimates were checked for each transect by estimating, clipping, and weighing. Plant clippings were dried and weighed by species for each study site so that estimates could be converted to an air-dry basis. Only the current years' growth was estimated for shrubs. Individual plants of important forage species were counted and tabulated on each plot to give information on composition.

Annuals

All annual plants irrespective of species were grouped and their relative abundance estimated on each plot, based on the numbers of plants present per square foot. The abundance classes, in numbers of plants per square foot were: 40 plus, 20-40, 10-20, 0-10. These classes were assigned numerical values of 4, 3, 2, and 1, respectively. Frequency of the abundance classes was recorded, and a combined frequency-abundance index computed by multiplying each class numerical value by its respective frequency of occurrence. The sum of the products gave a coded value for each treatment. Their coded values were then used in the analysis of variance, regression, and correlation computations.

Bulbed plants

Small plants with fleshy root parts, mostly ephemerals, were counted and rated as to their relative abundance on the same basis as were the annual plants. They were also coded as described for annuals.

RESULTS

Gopher Population Studies

Trap catches

The population index for each treatment of this study was determined from results of trap catches on 1/2-acre blocks. Trap catches were converted to a population index per acre (Table 2) for comparative and analytic purposes.

Table 2. Pocket gopher population index per acre, 1961-62

Treatment	No. of trap blocks		Mean no. of gophers/acre ± (SE)	
	1961	1962	1961	1962
0	4	6	27.0(1.3)	39.3(1.4)
I	4	6	14.0(0.8)	30.0(1.2)
II	4	6	14.5(1.3)	29.3(1.6)
III	4	6	13.5(0.9)	26.0(1.6)
IV	4	6	12.5(0.9)	28.0(1.3)

The analysis of variance (Steel and Torrie, 1960) showed population differences among treatments to be highly significant[3] (Table 3) for both years. Duncans' New Multiple Range Test (Harter, 1960), however, showed that significant differences in gopher numbers existed

[3]The terms significant and highly significant will be used throughout this paper to designate the 5 percent and 1 percent probability levels.

Table 3. Analysis of variance of trap catches (population index), cast counts, perennial plant yields, annual plant abundance, and bulbed plant abundance for this study, 1961-62

Year	Source of variation	DF	Mean squares: Trap catches	Cast counts	Perennials	Annuals	Bulbed plants
1961	Treatments	4	145.3**	54,988.5*	371,536.9^{ns}	455.0*	--
	Experimental error	5	6.2	6,686.6	128,876.7	65.0	--
	Sampling error	20[a]	3.8	3,570.4	24,559.5	18.1	--
1962	Treatments	4	159.2**	396,595.8**	466,580.0^{ns}	1,448.7**	2,349.9*
	Experimental error	10	14.7	39,537.9	203,744.4	90.5	237.8
	Sampling error	30[b]	8.0	5,775.1	46,601.7	13.3	--

[a]The DF for trap catches is 10.

[b]The DF for trap catches is 15.

*Significant at the 5 percent level.

**Significant at the 1 percent level.

^{ns}Not significant.

only between treated and untreated range. There was little difference in gopher density on areas treated for one or more consecutive years (Table 2). The gopher population, then, was greatly reduced after the first year of treatment but subsequent years of treatment were not effective in reducing it further.

Comparison of the population indices of 1962 with those of 1961 suggests that the gopher population on the treated areas approximately doubled in 1 year after cessation of treatment. The gopher density also increased on untreated areas but to a lesser degree, likely because their densities were much closer to the carrying capacity of the range.

During the control program, only tunnels under newly-formed mounds received poisoned grain, yet many tunnel systems under clusters of older mounds contained gophers. Trapping records show that 20 to 30 percent of the gophers trapped during the two years (621) were caught under old mounds, well away from new ones. The confidence limits (Snedecor, 1956) are 21.5 to 33.0 (P=0.01) for the combined data of both summers ($\bar{x}$=310).

Mound counts

The periodic mound counts were always highest on the untreated range (Table 4) but varied among areas of range treated from one to four years. The difference in counts between treated and untreated range was highly significant (Table 5).

Each set of periodic mound counts by date was made in a 3-day period, beginning on the date given in Table 3. The first periodic mound count of each year represents the period of time between snowmelt and that count, about 5 weeks in 1961 and 4 weeks in 1962. Thus, the first periodic counts of each summer represent longer time periods than do

Table 4. Periodic mound counts from 1-acre sample areas, 1961-62. Six sample areas were used per treatment in 1961 and nine in 1962

Year	Treatment	Mean number of mounds/acre ± (SE)				
		July 10	July 24	Aug. 7	Aug. 21	Sept. 4
1961	0	--	835(34.3)	648(13.4)	470(13.3)	302(33.3)
	I	--	466(23.9)	313(27.5)	144(18.5)	166(20.2)
	II	--	410(41.4)	301(34.8)	213(15.8)	169(24.0)
	III	--	282(40.4)	200(23.9)	207(23.1)	112(18.4)
	IV	--	365(37.9)	191(28.8)	148(35.8)	119(30.0)
1962	0	1,044(58.6)	714(53.4)	725(72.9)	789(64.1)	600(40.6)
	I	442(30.3)	417(46.9)	426(85.5)	438(51.8)	475(40.0)
	II	414(23.6)	445(47.7)	422(46.6)	488(34.8)	360(15.1)
	III	394(30.8)	333(21.3)	292(21.5)	415(35.5)	313(21.7)
	IV	396(39.0)	312(52.2)	279(21.7)	330(37.3)	291(33.2)

Table 5. Analysis of variance for periodic mound counts from 1-acre sample areas, 1961-62

Source of variation	1961 DF	1961 Mean squares	1962 DF	1962 Mean squares
Treatments	4	539,855.0**	4	1,470,688.9**
Error 'a'	5	11,727.8	10	203,370.0
Dates	3	504,107.9**	4	118,712.5**
Treatments by dates	12	28,999.9**	16	48,136.6**
Error 'b'	15	5,769.8	40	12,594.1
Sampling error	80	4,189.6	150	7,434.3

**Significant at the 1 percent level.

subsequent counts; this accounts, in part, for the highly significant differences noted by dates. Significant differences existed between all dates in 1961 but only between the first and the following dates in 1962.

An analysis of periodic mound counts was also made of treatments by dates (Table 5); the differences were highly significant. There were many real differences and plotting of these showed considerable interaction both years between mounds per acre and the treatments on given dates (Figures 4 and 5).

Two interesting phenomena on the periodic mound-count data are apparent on Figures 4 and 5. They are: (1) the decline of mound counts throughout the season in 1961 and, (2) the increased mound counts of August 21 of 1962. A seasonal decline in gopher activity can be caused by increasingly dry conditions and/or continued high temperatures,

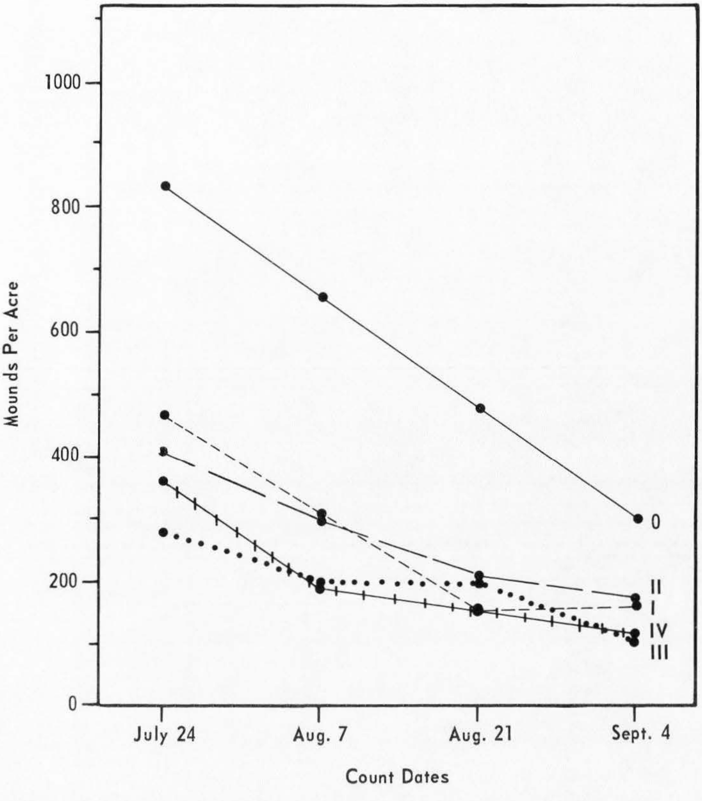

Figure 4. The mean number of mounds for each periodic count and each treatment (0, I, II, III, IV) on the study area, 1961.

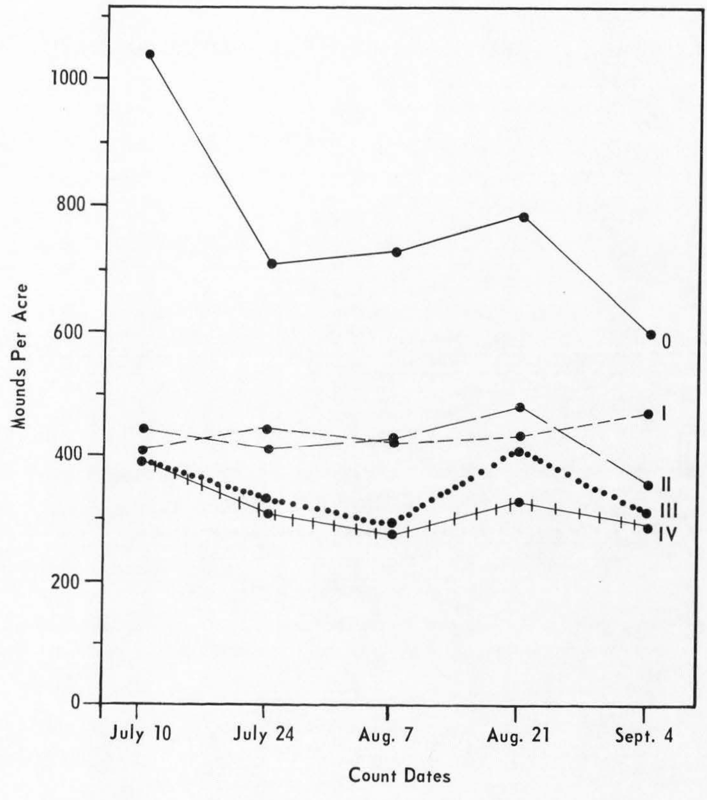

Figure 5. The mean number of mounds for each periodic count and each treatment (O, I, II, III, IV) on the study area, 1962.

as gopher activity greatly declines in hot, dry weather (Miller, 1948; Howard and Childs, 1959). During the summer of 1961 there were a number of light showers and at least two heavy ones at Monte Cristo. It might appear that this should cause an increase in gopher activity, but Miller (1948, p. 41) states: "burrowing activity, especially the rate of mound formation, seems to be a function of the *amount of moisture in the soil*. . . ." (Italics mine.) The amount of precipitation was either so insufficient or occurred in such short periods of time (with a heavy runoff) that there was no obvious increase in soil moisture at the depth at which these gophers dig for food (3.5 inch average). As a result, the continued decline of soil moisture may have been the cause for a seasonal decrease in mound counts for 1961.

As there was little precipitation at Monte Cristo in the summer of 1962, the moisture content of the soil that summer must have declined similar to that in 1961. Yet, the mound count (Figure 5) in 1962 did not decline as in the previous year, but fluctuated about a more or less constant level; this suggests that there were several factors working in a complex interrelationship.

The increase in the number of mounds per acre as reflected in the count of August 21, 1962, parallels the noticeable increase in the proportion of juvenile gophers which were trapped from a 1/2-acre plot at my campsite on Monte Cristo the same year. Aldous (1956) found that in central Utah young gophers leave parental burrows to establish burrow systems of their own in the latter part of August. In Montana, Tryon (1947, p. 20) said: "By August 25 juveniles were no longer found in the parental burrows but had started construction of their own." The increased count of August 21, 1962 could be due, then, to large numbers of juveniles beginning their own tunnel systems. A similar increase in mound numbers did not occur in 1961; this could be the result of low juvenile survival in 1961 but there was no evidence for this.

The grazing of sheep on the area, the occurrence of occasional showers, and the obstruction of the observer's vision by vegetation were the main factors affecting mound-count results. Of these, the first two factors were most important. In general, these factors did not seriously affect mount-count results. Mound-interpretation difficulties were much less for periodic than for cumulative mound counts. Most of the mound counts of the sample areas were not affected by sheep trampling as these animals were not on the sample areas during the count periods.

Periodic and cumulative mound counts of the two summers show a good positive correlation with the gopher population index derived from trapping (r = 0.83, Figure 6; r = 0.82). This close relationship suggests that mound numbers can be used to estimate the gopher population.

In 1962 a mound count was made on all trap blocks 72 hours after the cumulative count and immediately before trapping to compare the relationship of mound numbers to gopher numbers for short periods of time (3 days) with those representing longer periods. The correlation of 72-hour mound counts with the gopher-population index was 0.41; this suggests that 72-hour counts at this time of year are of no

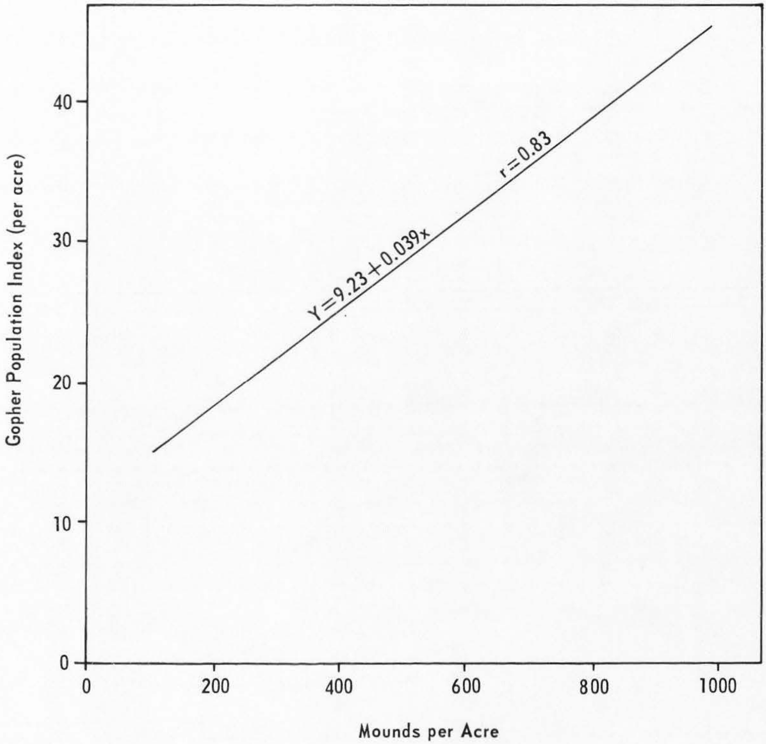

Figure 6. Relationship of mounds to the gopher population index, 1961-62. The regression line was plotted by individual points for each study site for both years.

value in estimating a gopher population.

In Colorado, Reid (1962) found a correlation of 0.80 between the number of new mounds and peep holes formed in a 48-hour period and the number of gophers trapped. Reid concluded (p. 6): ". . .it appears that counts of new mounds and earth plugs made at 48-hour intervals have promise as a method of approximating pocket-gopher populations." The disagreement between my data and Reid's may be due to the difference in time of year in which the counts were made. Reid's counts were made in September, a month later than mine.

Cast counts

The casts per acre (Table 6) were derived from cast counts made in a 3-day period each year. As the cast count was made early in the growing season, vegetation presented no problem in counting casts accurately. Sheep did not affect the count as they had not yet arrived on that portion of the range when the count was made.

Table 6. Cast counts from 1-acre sample areas, 1961-62

Treatment	No. of sample areas		Mean number of casts/acre ±(SE)	
	1961	1962	1961	1962
0	6	9	2369(30.1)	7037(28.3)
I	6	9	1754(18.0)	3852(68.6)
II	6	9	1380(27.5)	2933(18.0)
III	6	9	1096(36.7)	2732(12.1)
IV	6	9	932(12.1)	2420(43.4)

Analysis of variance indicated a significant difference among treatments in 1961 and a highly significant difference in 1962 (Table 3). Nearly all of these differences, however, were between the untreated and treated range. These differences were fairly comparable to the differences among mound counts. Cast counts show a good positive correlation with the gopher population indices (r = 0.80, Figure 7). This suggests that the number of casts may have value as an index of the early summer gopher population.

As casts are made only in the winter, cast counts are actually a measure of the mean winter gopher population and as a result cannot be expected to measure the summer population as accurately as should mounds. The use of cast and periodic mound counts, which themselves are highly correlated (r = 0.93), to estimate the winter and summer gopher populations, respectively, may give estimates of nearly equal value. I feel that mounds are more easily interpreted than are casts, and hence favor the use of mounds as an index of the summer gopher population. Moreover, casts would be much less durable on areas of loose soils than at Monte Cristo and the interpretation difficulties would be greatly increased.

Vegetation Studies

Perennials

Data were obtained on numbers of plants and pounds of perennial forage per acre (Table 7). However, the variation in numbers of plants (within treatments) per acre was so great that no attempt was made to correlate it with the gopher population.

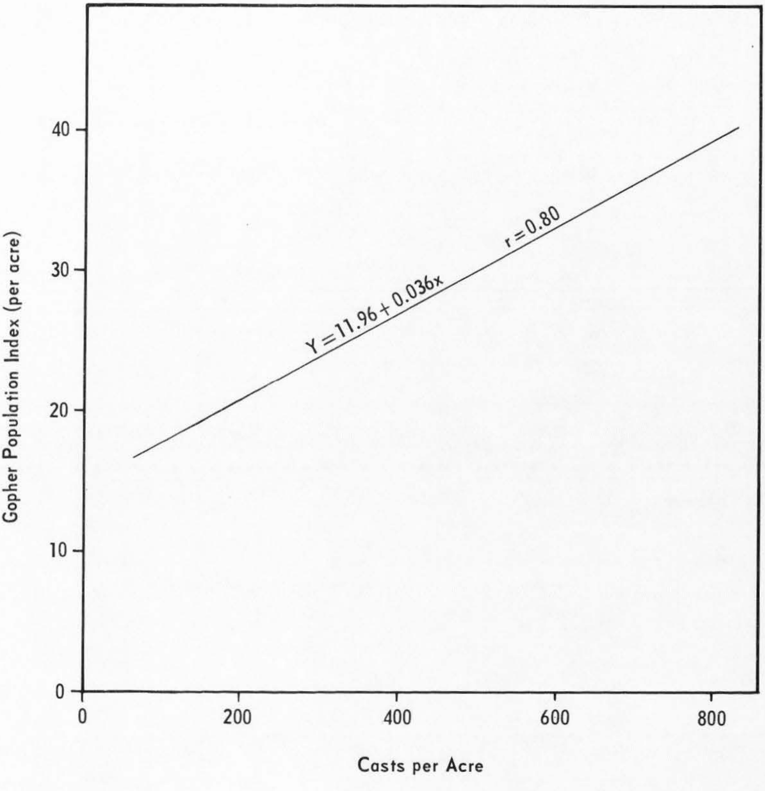

Figure 7. Relationship of casts to the gopher population index, 1961-62. The regression line was plotted by individual points for each study site for both years.

Table 7. Abundance and yield of perennial plants (per acre, air dry) from 1-acre sample areas, 1961-62. The range for plant numbers and yield is in parentheses, abundance in thousands and yield in hundreds

Treatment	Number of plants per acre		Average lbs. forage per acre (air dry)	
	1961	1962	1961	1962
0	47,265 (9.5-120.7)	47,896 (16.9-81.1)	271.8 (1.93-4.34)	449.2 (1.90-7.70)
I	36,350 (27.8-46.4)	49,241 (25.4-101.9)	376.1 (1.77-6.41)	456.5 (1.70-9.30)
II	47,644 (31.5-58.1)	38,835 (31.5-51.1)	638.3 (3.47-8.12)	577.0 (2.77-8.44)
III	54,958 (28.7-92.3)	30,888 (23.0-39.3)	487.8 (2.40-6.58)	610.4 (2.98-12.96)
IV	80,313 (45.4-131.3)	63,491 (36.3-143.7)	909.5 (5.87-14.99)	1,006.6 (6.11-18.59)

The yield of air-dry forage in pounds per acre, though not so variable as plant numbers, nevertheless exhibited considerable variation within treatments. The treatment sums of 1962 increase consecutively from the 0 treatment to treatment IV, but most of the differences are very small. Treatment IV, however, has more than twice the yield of the 0 treatment in 1962, and in 1961 it was more than three times as great.

The differences in yield among treatments were not significant (Table 3). Although the correlation of perennial plant yield with the gopher population is a low negative one in this study (r = 0.13), observations on older established plots in this area indicate that there may be a strong negative correlation. Ward, Hegdal, and Hanson (1963), however, reported a strong positive relationship between perennial forbs and the gopher population in Colorado. Whether the correlation is positive or negative depends upon whether the control is applied to the vegetation or to the gophers. If perennial forbs are reduced, a subsequent lack of food may reduce the gopher population (Keith, et al., 1959), but if the gopher population is reduced the decreased consumption of perennial forbs results in forb increase, apparent in the Monte Cristo study.

Annuals

The coded values are highest for the untreated range and get successively smaller with increased years of treatment, although some of the differences are rather small (Table 8). The differences among treatments are significant in 1961 and highly significant in 1962 (Table 3) but most of these differences are between treated and untreated range.

Table 8. Frequency and abundance of annual plants on the sample areas, 1961-62

Year	Treatment	Frequency of the abundance classes of annual plants[a]				Coded value of abundance and frequency
		40+	20-40	10-20	0-10	
1961	0	65	16	7	2	324
	I	12	62	16	0	266
	II	22	44	21	3	262
	III	2	34	45	9	209
	IV	0	23	56	11	191
1962	0	108	21	6	0	507
	I	30	62	26	17	375
	II	17	36	63	19	321
	III	7	32	57	39	277
	IV	2	8	46	79	203

[a]Assigned numerical values of classes are 4(40+), 3(20-40), 2(10-20), and 1(0-10). The sum of these values multiplied by their respective frequencies give the values in column 7.

Annuals were much more highly correlated with the gopher population in 1962 (r = 0.86) than in both years together (r = 0.33); this difference may be due to differences in the weather between years.

Bulbed plants

Data on bulbed plants were obtained only in 1962. These species (except for starwort) are ephemerals and are only available for observation during a short period in the spring. Since this study was initiated late in the summer of 1961, no data were taken on bulbed plants that year.

The abundance-class frequencies for the bulbed plants (Table 9) were coded as for annuals in order to make the necessary computations. The difference among treatments was of similar magnitude but inverse to that of annuals; the coded value of annuals, by treatment, decreased with additional years of treatment whereas the coded value of bulbed plants increased.

The difference among treatments were not great but were significant in 1962 (Table 3) and a strong negative correlation (r = -0.85)

Table 9. Frequency and abundance of important bulbed plants on the sample areas, 1962

Treatment	Frequency of the abundance classes of bulbed plants[a]				Coded value of abundance and frequency
	40+	20-40	10-20	0-10	
0	0	13	61	61	222
I	2	38	64	31	281
II	11	70	45	9	353
III	32	79	20	4	409
IV	33	82	19	1	417

[a]Assigned numerical values of classes are 4(40+), 3(20-40), 2(10-20), and 1(0-10). The sum of these values multiplied by their respective frequencies give the values in column 6.

was noted between bulbed-plant abundance and the gopher population index.

Gopher-Control Evaluation

This control program involved the treatment of a total of 5,070 acres of sub-alpine rangeland. There were few gophers on rocky ridges and in pure stands of coniferous timber but many in the aspen, mixed aspen-conifer and mixed parkland vegetation types. In general, the gopher population seemed to be high.

Cost of control

The total cost of control on the 5,070 acres was $10,328.74 of which about 86 percent was for labor, 6 percent for transportation, and 8 percent for bait. The average cost per acre was $1.13 for initial treatment and $0.51 for re-treatment, while the total cost per acre was $2.95 for the area treated 4 years. Though the cost for labor seems high the actual cost per man-hour was only about $1.36.

The cost per acre of re-treatment decreased successively for 3 years (1958-60) in this study (Table 10). Perhaps 35 cents per acre for re-treatment and 85 cents for initial treatment are the expected cost minima for a program of this type, on similar areas of equal gopher populations.

Moore and Reid (1951) estimated the costs of large-scale control programs on areas of high accessibility and moderate gopher populations to be 40 cents per acre for initial treatments. They recognize that costs may be several times as great, however, under less favorable conditions as were encountered in this program. But wage-

Table 10. Costs[a] of a pocket gopher control program conducted for a period of 4 years on a subalpine area of the Cache National Forest, Utah, 1957-60

Year treat-ed	Acres treated		Costs			Average cost/ac	
	New	Retreated	Labor	Trans-portation	Bait	New	Retreated
1957	1985	--	$2381.75	$138.18	$266.06	$1.41	--
1958	1325	1985	2567.06	105.25	183.22	0.99	$0.78
1959	930	3310	1880.00	130.20	170.50	0.85	0.42
1960	830	4240	2081.69	260.32	164.51	1.27	0.34
Sums	5070	9535	$8910.50	$633.95	$734.29		
Means						$1.13	$0.51

[a]The corresponding costs of treatment of nearby range in 1961 were $0.86 for new treatment and $0.38 for re-treatment.

scale differences are also important factors in the level of control costs. Their estimate of 10 percent of the original treatment cost annually for re-treatment is not realistic under this type of control project. It is rather unlikely, in view of this program, that such a low re-treatment cost could be attained even if the original treatment were highly successful. The average annual re-treatment cost for this project was in excess of 45 percent of the initial treatment cost. The expense of re-treatment would have been lower, however, if the initial treatment had been more successful.

With one exception perennial forage production (air dry) increased with each year of additional treatment. After 4 years of gopher control the forage production had increased by 638 pounds per acre in 1961 and by 557 pounds per acre in 1962. The yield increase in 1962 was 13 percent less than the previous year. At this rate the forage yield of treatment IV would decline to the level of the 0 treatment within 7 years after cessation of the control program. The yield increase in forage indicated above is a composite of perennial forbs, perennial grasses, and the current year's growth of shrubs.

I estimated the forage yield to have consisted of about 75 percent forbs, 15 percent grass, and 10 percent shrubs. Stoddart and Smith (1955) list average percent-utilization figures of 26, 17, and 39 for forbs, grass and shrubs, respectively (for sheep). These writers list 3 pounds of air dry forage as the daily consumption rate for sheep. Using the above figures there would have been 1.8 sheep months per acre for 1961 and 1.6 for 1962. At a value of 34 cents per sheep month, the increased value of forage after 4 years of control is 61 and 54 cents per acre for 1961 and 1962. Thus, the increase of forage value due to gopher control at Monte Cristo is slow which is in agreement with the results of the study conducted by Moore and Reid (1951). These investigators, studied the value of pocket gopher control as a range improvement practice for 17 years, after which time they concluded:

> While the increase in forage value due to gopher control was slow, the estimated cost of control measures was amortized within a few years. Beginning with the fifth year of this study, the value of the increased grazing capacity for any one year was equal to or greater than the estimated cost of control. (Moore and Reid, 1951, p. 33)

Effectiveness of control

The method of treatment used in this project is typical of pocket gopher-control programs conducted by the Division of Wildlife Services, Bureau of Sport Fisheries and Wildlife (Owen Morris, personal communication). The control crew inserted poison grain only into tunnels under new mounds, leaving tunnels under old mounds untreated. The numbers of old and new mounds vary with conditions; sometimes a small and at other times a large proportion are old.

Trapping records of the two summers for the five treatments showed that an average of 20 to 30 percent of all gophers trapped (621) were from tunnels under old mounds. This suggests that 20 to 30 percent of the gopher population was missed by the control program used at Monte Cristo. Gopher activity is sporadic and periods of inactivity are often of sufficient duration for mounds to become old. Howard and Childs (1959, p. 286) state this idea as follows: "Since burrowing is done irregularly, it is often necessary to look for burrows in the vicinity of old mounds." Rains and sheep trampling were most important in the ageing of mounds at Monte Cristo.

The conditions which prevailed while the areas were being treated were often unsatisfactory and sometimes made even moderate success difficult to achieve. Several times sheep herds were moved onto range just previously treated with poisoned grain. The sharp hoofs of the sheep readily caved in portions of these tunnels which prevented gophers from finding the bait.

During much of the warm summer period the soil was very dry and the surface became powdery and loose or compact and hard, depending on the area. Soils that were loose shifted easily and grain baits placed in tunnels in such soils were sometimes covered by the sifting-down of soil from the probe hole. On the other hand, soils which were compact and hard were commonly difficult to penetrate. Much of the difficulty in tunnel location on hard soils was caused by having to apply great pressure to the probe to penetrate the crust; after going through the extremely hard crust, the probe suddenly dropped giving the same sensation as that received when hitting a tunnel. Some tunnels were not located at all and some grain was mistakenly placed in old tunnels filled with loose soil, in old root channels, or in subsurface cracks. An excessive amount of time and effort was frequently required to locate "active" runways.

Under these adverse conditions and using this particular technique, the degree of control attained was reduced much below the ideal of about 90 percent as commonly suggested in literature; often a control of 50 to 60 percent seemed to be all that was attained. The gopher-population figures for the treatments of this project show a marked reduction after 1 year of control but little or no reduction in succeeding years. On the basis of the trapping results, the retreatment merely held the gopher population down to a rather constant level from which a rapid recovery resulted in 1 year.

DISCUSSION AND CONCLUSIONS

The determination of an absolute gopher population-per-acre figure is difficult to obtain (Stickel, 1946), if it is to be reliable. And an absolute population figure has no particular advantage when used for comparing different treatments. For these reasons a 3-day population index was used in this study; this was easily obtained through an uncomplicated trapping program, and it seemed to be equally valuable for all treatments. The consistency of the numbers of gophers trapped from 1/2-acre trap blocks of the same treatment indicates that the gopher population-index figures were useful in evaluating the results of this control program.

Mound counts have been widely used for a number of years for estimation of gopher populations (e.g. Ellison and Aldous, 1952; Julander et al., 1959) with little actual evidence that such use is justified. This study shows that periodic mound counts on 1-acre sample areas and cumulative mound counts on 1/2-acre trap blocks have a good correlation with the gopher population ($r = 0.83$, and 0.82 respectively). Either type of mound count would give a satisfactory population estimate. The periodic mound count, however, involves too much work and time for practical field use. Time of cumulative counts should be adjusted to the locality and conditions; the earlier the mound count is made in the summer the less the interpretive and counting difficulties (in general) but it appears that there is also a tendency to lessened correlation of the count to actual gopher numbers.

At Monte Cristo, rains have a much less destructive influence on mounds under an aspen and forb cover than on mounds of the parklands. As a result, a rather accurate and consistant cumulative mound count can be made here at the end of the season under aspen (Odell Julander and J. B. Low, personal communication).

Cast counts are also usable as an index of gopher populations. They should, however, be used to estimate the mean gopher population in the winter whereas the mound counts should be used to estimate the gopher population in the summer. Cast counts cannot be made periodically on areas of heavy winter snows as were mound counts.

Because mounds are evidence of gopher activity and one gopher is assumed to be as active as another it seemed that a usable relationship might be easily established between gopher numbers and mound or cast numbers. In the course of this study two major difficulties became apparent in the use of counts as indices. The first difficulty was that of accurately counting all mounds or casts on an area, because counts of gopher workings accumulated over a long period involves such problems as erosion and settling, obliteration by animals, and obstruction of the observer's vision by vegetation. The second difficulty is that individual gophers are sporadic in their mound-building activity; they often do not form any mounds for periods of a week or more, and their activity varies with many environmental factors.

Despite these difficulties, periodic and cumulative mound counts, and cast counts appear to give useful estimates of the gopher population in this area; in contrast, 72-hour mound counts in early August do not appear to be very useful in this respect. Reid (1962) indicated that the peak in gopher activity on Black Mesa, Colorado was around the first of September, and 48-hour mound counts during this period had a good correlation with the gopher population. As Monte Cristo has a similar altitude and vegetation cover, the possibility exists that 72-hour mound counts there in early September may have a good correlation with the gopher population as opposed to the results obtained in early August.

Gopher numbers in late summer are increased greatly by the current year's reproduction and numbers at any time are decreased by mortality. Gophers have short life expectancies and this helps promote rapid population changes. Hence, population estimates for gophers should be related to time of year and time of censusing.

An examination of the experimental study sites by Dr. Raymond F. Miller (of the Soils Department at Utah State University) revealed no obvious relationships between soil structure, texture, depth, and estimated fertility, and the gopher population index or mound and cast counts. So, neither gopher numbers nor activity appear to have differed due to noticeable soil differences.

Since gophers are herbivorous, the effect of different gopher population levels, associated with a number of years of treatment, on vegetation was investigated. The correlation of annual plant abundance with the gopher population differed greatly between years. Because annual plant abundance varies greatly from year to year due to moisture and weather conditions there is difficulty in measuring the abundance of annual plants in terms of controlling gophers.

Mounds and casts are periodically left on the ground surface as a result of gopher activity at certain periods of the year and such workings may weaken or kill established perennial plants. The casts and mounds themselves are available for establishment of annuals. Later in the season newly established annuals are often smothered by subsequent mounds.

Where conditions are conducive, perennials eventually replace annuals, but this replacement is often inhibited as gophers may attack root, crown, and stem portions of perennial plants. The fleshy roots of gopher forbs are removed, stored, and eaten by gophers so that as the gopher population increases the bulbed plants tend to decrease in abundance (Table 9) becoming scarce at consistently high gopher populations; if the gopher population declines these plants can increase again. As perennial and annual forbs decrease more space is left for other plants such as grasses, while the converse may also be true. Annuals, perennials, and bulbed plants all suffer mortality when their roots are clipped by gophers constructing their feeding tunnels, especially during dry periods; the course of many feeding tunnels can sometimes be followed along the ground surface by the "trails" of dead plants. These effects on vegetation vary with fluctuations in the gopher density. Thus, there is a complicated interaction between numbers of gophers, and vegetation composition and density.

The cost and effectiveness of a gopher-control project varies with: the gopher population, the amount and kind of vegetation, the condition of the soil, the terrain, the time of year, the temperature, the humidity, the type of bait, the control personnel, and the method (wight, 1918; Crouch, 1942; Howard, 1953; Mickle, 1957; Ward et al., 1963).

Control effectiveness might well be increased and costs reduced at Monte Cristo, under a different control program. To achieve better results emphasis should be placed on: (1) treatment of tunnels under all ages of mounds, (2) treatment during favorable weather and soil conditions, (3) treatment during periods of most intensive gopher activity and, (4) the use of larger control crews to take advantage of shorter favorable periods of time.

Gopher control should be regarded as a long-term, range-improvement practice. Besides the additional forage made available to livestock, gopher control must be considered for its watershed-protection and soil-stabilization values. But it should be used only to the point at which some other management measure will begin to pay greater dividends.

Any range benefit from control will result only if the population is held down through an annual control program. The results show that it takes several successive years of control for the vegetation to recover. Hence, those who contemplate gopher control as a range-improvement technique must plan on successive years of control, as cessation of control results in quick recovery of the gopher population.

Experiments conducted on Grand Mesa in Colorado suggest that the reduction of the gophers' food supply may be more effective as a control measure than the direct reduction of gopher numbers. They indicated that some degree of gopher control might be expected for 5 years on areas when a good kill of perennial forbs is obtained using 2,4-D (Ward et al., 1963).

On ranges such as Monte Cristo, sheep use requires the retention of the range in primarily perennial forb cover. On such ranges treatment with 2,4-D is not permissible, and an annual poisoning program might be needed for many years. The development of control methods of maximum efficiency and minimum cost is especially desirable in this case. On cattle ranges grass cover is usually desirable. A grass cover is not conducive to high gopher numbers (Ellison and Aldous, 1952) and an intensive control program would be necessary only until a good stand of grass was attained, after which control could be discontinued in association with proper grazing practices.

SUMMARY

This study was conducted on the Monte Cristo Division of the Cache National Forest near Logan, Utah. It was designed to investigate the effect of control on pocket gopher populations, vegetation density, plant species composition, forage yield, and related control costs.

A 3-day population index determined by trapping was used to measure the pocket gopher population on five different treatments replicated twice in 1961 and three times in 1962. The population index per half acre was converted to population index per acre for use with regression analysis. Additional years of control beyond the initial year did not significantly reduce the gopher population.

Analysis of variance indicated that differences among treatments were significant (or highly significant) for gopher populations, periodic and cumulative mound counts, cast counts, annual plant abundance in 1962, and bulbed plant abundance but was not significant for perennial plant yields. The Duncan's New Multiple Range Test showed most of these differences to be due to the difference between the untreated and treated range.

Perennial plant yield showed a low negative correlation with the gopher population, whereas the 1-year's data on bulbed plant abundance showed a high negative correlation. Periodic and cumulative mound counts and cast counts had a good positive correlation with the gopher population but 72-hour mound counts did not.

Periodic and cumulative mound counts are believed to give good estimates of a gopher population in the summer under most conditions.

Cumulative mound counts may give an exceptionally good estimate when under an aspen canopy. Cast counts give a good estimate of average gopher numbers in the winter and of numbers in early summer.

Cast counts and cumulative mound counts involve much less work and time than periodic counts and hence are more practical for field use.

The gopher-control program at Monte Cristo was conducted in a manner typical of large-scale projects by personnel of the Bureau of Sport Fisheries and Wildlife, Division of Wildlife Services. Only tunnels under new mounds were treated and as a result there was an average estimated 20 to 30 percent loss in control effectiveness. Effectiveness of control was also reduced due to adverse environmental conditions present during treatment. Costs of control (for 4 years) averaged \$1.13 per acre for initial treatments and \$0.51 for re-treatment.

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APPENDIX

Plate 1. Photos of study sites with treatments of zero, one, two, three, and four years of control (in the order named from left to right and from top to bottom).

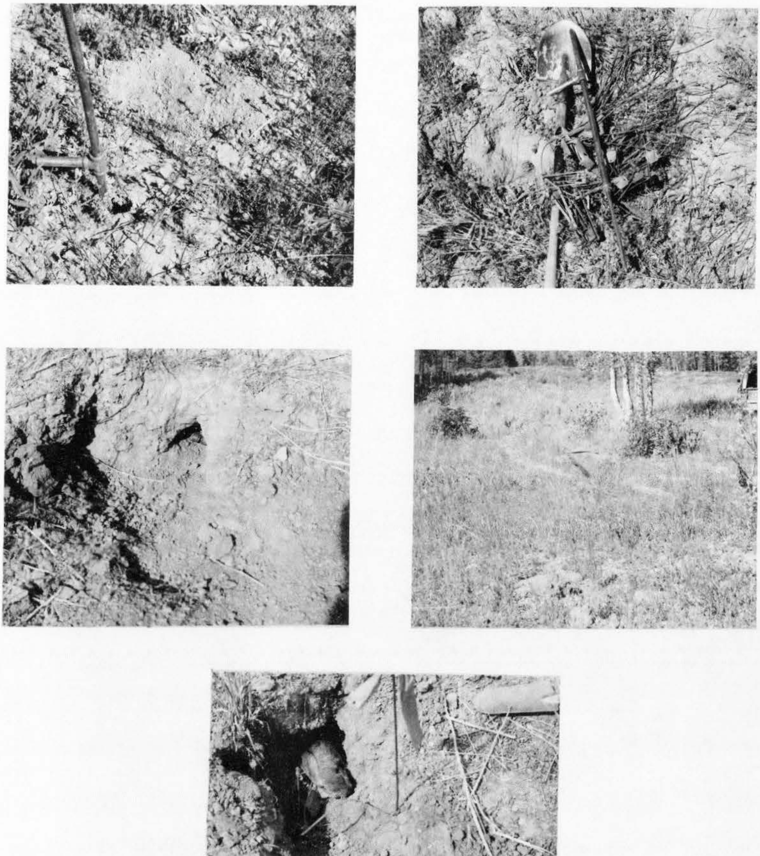

Plate 2. Some steps in trapping pocket gophers on the study area. Upper left, location of main tunnel with steel probe about 15 inches away from the side of mound with horseshoe-shaped depression; upper right, tunnel dug out and ready for trap set; middle left, traps set in main tunnel; middle right, location flag anchoring traps; bottom, a successful catch of a gopher showing trap wired to stake.

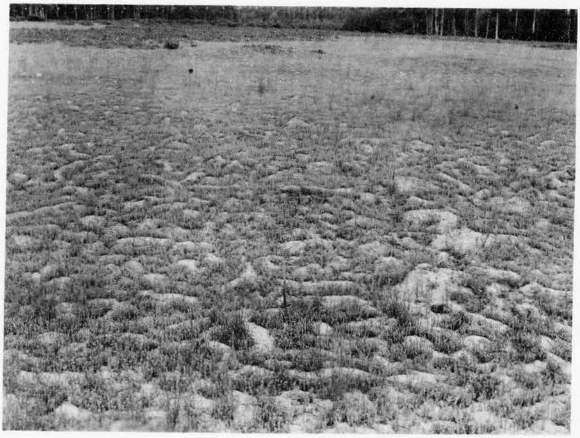

Plate 3. Photos of typical mounds and casts on gopher infested range (upper photos) and their effect on range cover when the infestation is heavy (lower photo).