Long-term Effects of Pocket Gopher Control on Vegetation and Soils of a Subalpine Grassland

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Highlight: *In the half of an exclosure where pocket gopher populations were uncontrolled, dandelion was eliminated from the community and the aboveground peak standing crop of slender wheatgrass, mountain brome, Michaux sagewort, and Rydberg penstemon increased between 1942 and 1973. In the half of the exclosure where gophers were controlled yearly, most species of annuals were absent in 1973, Letterman needlegrass decreased, and slender wheatgrass increased. Tall forbs, mainly Oregon fleabane and sticky geranium, increased in both areas, but the greatest increase occurred where gophers were controlled. Soils within the exclosure were significantly higher in total porosity and significantly lower in bulk density in 1973 than soils in the adjacent area grazed by sheep. Organic matter, nitrogen, and phosphorus contents of the soil were significantly higher where gophers were present in the exclosure than where gophers had been controlled.*

Pocket gophers play a dual and sometimes conflicting role on mountain rangelands. Gopher populations usually are low on ranges in good condition, and their burrowing activities are believed to be largely beneficial through the mixing and deepening of soils (Grinnell, 1923). They also may improve infiltration rates (Ellison, 1946) and possibly increase fertility through excrement deposits and decay of underground food caches (Taylor, 1935).

Gopher populations often increase on ranges depleted by overgrazing and the resulting high populations have been reported to perpetuate large amounts of ephemeral and annual plants because of excessive soil disturbance (Richens, 1965); increase soil erosion (Ellison, 1946); harvest large amounts of forage and thus compete with livestock (Julander et al., 1969); destroy range seedings (Garrison and Moore, 1956; Julander et al., 1959); and keep ranges in poor condition even after grazing pressure has been reduced or eliminated.

Several studies have shown effects on vegetation of reducing or eliminating pocket gophers from native mountain rangelands. Periods of control have been 13 years (Branson and Payne, 1958); 11 years (Turner, 1969, 1973); and 9 years (Moore and Reid, 1951; Ellison and Aldous, 1952).

This paper reports the effects of the presence and absence of northern pocket gophers (*Thomomys talpoides*) on the vegetation and soil of a subalpine grassland in central Utah protected from livestock grazing for 31 years. Ellison and Aldous (1952) reported the results of the first 9 years of the study.

Methods

The study site was located at an elevation of about 10,000 ft (3,050 m) near the top of the Wasatch Plateau in central Utah. A 4-acre (1.6 ha) area was fenced in 1942 to exclude livestock on a subalpine grassland type previously grazed heavily by domestic sheep for years. The exclosure was divided into two parts; in the north half, gophers were removed by

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trapping at least twice yearly from 1942 through 1956. Since that time gophers have been poisoned at least once a year by bait placed in active burrows. The south half of the exclosure remained untreated. In 1948, a gopher-proof fence was constructed between the two areas. Control in the north half never completely eliminated gophers, but reduced populations markedly. For convenience, the north half will be referred to as "gophers absent" and the south half as "gophers present."

Vegetation was sampled on permanent 1- by 3-m plots, 41 in the "gopher absent" area and 36 in the "gopher present" area. Plots were sampled by the weight estimate method (Pechanec and Pickford, 1937) to determine aboveground peak standing crops of herbage in the late summer of 1942, 1944, 1950, 1956, 1972, and 1973. The 1942 records were obtained before gopher control and thus represent pretreatment conditions. Only 1942, 1956, and 1973 data are presented here. Herbage samples of each of the major species were dried to convert weights to an air-dry basis. A more detailed description of the study site, methodology, and trends in vegetation during the first 9 years of the study was reported by Ellison and Aldous (1952).

In 1973 the vegetation of the adjacent range, which had been grazed yearly by domestic sheep, was sampled using the weight estimate method on 50 temporary plots, each 0.45 m^2. The outside plots were adjacent to the exclosure, but at least 15 m from the fence to avoid any influence from the fence or from the gopher control operations in the north half of the exclosure. In 1973, in addition to the weight estimates, the percentage of the surface covered by the aerial projection of plants, exposed litter, total bare ground, and fresh gopher mounds formed the current summer was estimated on all plots.

In October 1972, soils were sampled at 30 locations: 10 in the area where gophers were present, 10 in the area where gophers had been controlled, and 10 in the area grazed by sheep outside the exclosure. At each location, core samples were taken at the 0- to 5-cm and 5- to 10-cm level to determine bulk density and soil porosity (Hoover et al., 1954). The same number of bulk soil samples also were taken at depths of 0–5, 5–10, 10–15, and 15–30 cm to determine soil texture and organic matter, total nitrogen, total phosphorus, and potassium contents. Although the lack of replication of treatments limited interpretations, the various soil properties were subjected to variance analysis considering depth and treatment as fixed effects. Differences among treatment means ($P<.05$) were compared using Duncan's (1955) multiple range test.

Results and Discussion

Vegetation in Exclosure, 1942–1973

When the study was started in 1942, Ellison and Aldous (1952) characterized the site as having been degraded by years of heavy sheep grazing because of the preponderance of Letterman needlegrass (*Stipa lettermani*),[1] dandelion (*Taraxacum officinale*), and rhizomatous species such as Rydberg penstemon (*Penstemon rydbergi*), Michaux sagewort (*Artemisia michauxiana*), and yarrow (*Achillea millefolium*) on the site. Ellison (1954) believed that the original "mixed upland-herb association" of the Wasatch Plateau consisted of 70% to 88% perennial forbs, 1% to 21% grasses and sedges, and few annuals.

Total aboveground peak standing crops of herbage in both areas inside the exclosure were essentially the same in 1973 as in 1942, but the 1973 data indicated an upward trend in vegetal composition (Table 1). Trends for some classes of vegetation were the same: amount of herbage of tap-rooted and ephemeral species decreased and amount of tall forbs increased in both areas. Total standing crops of grasses and grasslike species and rhizomatous forbs increased where gophers were present but remained unchanged where gophers were absent.

In the absence of sheep grazing, the trend in vegetation composition has been toward the climax community described by Ellison (1954), but even after 31 years of protection, progress has been slow. The short growing season and other severe climatic factors, and possibly the heavy clay soils, make secondary succession slow on these high elevation rangelands. Tall forbs, which Ellison (1954) believed dominated the original community, have increased in both areas in the exclosure, but even in 1973 they comprised only 8% to 15% of the total peak standing crop. Amounts of almost all species of tall forbs increased in both areas in the exclosure. Where gophers had been controlled, Oregon fleabane (*Erigeron speciosus*) and sticky Geranium (*Geranium viscosissimum*) increased the most both in standing crop and frequency of occurrence. Feeding by gophers may have been a factor in slowing the increase of tall forbs. Even though sticky geranium, Oregon fleabane, Porter ligusticum (*Ligusticum porteri*), and leafy polemonium (*Polemonium foliosissimum*) are not highly preferred gopher foods in the area, they are eaten (Aldous, 1951). When they occur infrequently on the range, even light feeding pressure from gophers may slow their spread. These species are also palatable to deer (personal communication, O. J. Julander), and feeding by deer in the exclosure also could be a factor in slowing their spread.

Dandelion showed the greatest change in amount of herbage for any one species. Gophers in the absence of grazing almost eliminated dandelion from the community, probably because of selective feeding. Dandelion roots are a preferred food of gophers on mountain rangelands (Aldous, 1951; Ward, 1973). Ellison and Aldous (1952) reported that, in the first 9 years of this study, amount of dandelion herbage increased where gophers were absent and decreased drastically where gophers were present. The decline where gophers were present continued; amount of dandelion herbage was less than 1 lb per acre in 1973 compared with 289 lb in 1942 and 241 lb in 1944. Frequency of occurrence on the permanent plots dropped from 100% in 1942 to 6% in 1973. Large reductions of dandelion by gophers in the absence of grazing have also been reported by Branson and Payne (1958), Moore and Reid (1951), and Turner (1969, 1973).

Where gophers were controlled, the peak standing crop of dandelion increased from 1942 through 1956, but then decreased. Frequency of occurrence on the permanent plots where gophers were absent dropped slightly from 95% in 1942 to 85% in 1973. The other main tap-rooted species, pale agoseris (*Agoseris glauca*), increased in both areas until 1956 and then decreased to slightly below original levels.

The doubling of peak standing crops of grass and grasslike plants by 1973 where gophers were present was the result of a large increase in slender wheatgrass and a smaller increase in mountain brome (*Bromus carinatus*). Amount of Letterman needlegrass decreased in both areas between 1942 and 1973, but the decrease was greatest where gophers were controlled.

For rhizomatous forbs the pattern of change was quite different in the two areas. Where gophers were present, peak standing crop increased, largely due to a doubling of amount

[1] Nomenclature of vascular plants follows Holmgren and Reveal (1966).

Table 1. Amount of herbage (lb/acre aboveground peak standing crop) in 1942, 1956, and 1973, and species frequency (%) in 1942 and 1973 in an exclosure where gophers were allowed to remain in one half and controlled yearly in the other half; and production in 1973 on grazed range outside the exclosure where gophers were not controlled.

	Herbage production (lb/acre)							Frequency (%) on plots (exclosure)			
	Exclosure						Grazed range				
	Gophers absent			Gophers present			Gophers present	Gophers absent		Gophers present	
Species	1942	1956	1973	1942	1956	1973	1973	1942	1973	1942	1973
Grass and grasslike											
Agropyron trachycaulum	14	3	85	26	62	175	97	73	98	94	100
Bromus carinatus	0	0	1	1	5	27	2	0	7	6	36
Stipa columbiana	7	18	14	6	77	15	12	56	73	75	75
Stipa lettermani	230	166	142	69	86	33	110	100	100	100	92
Others	3	1	2	9	5	8	7	–	–	–	–
Total grass	254	188	244	111	235	258	228	–	–	–	–
Tap-rooted											
Agoseris glauca	9	36	5	10	38	8	29	71	68	72	61
Taraxacum officinale	65	125	13	289	5	T[1]	19	95	85	100	6
Others	4	12	2	6	2	14	1	–	–	–	–
Total tap-rooted	78	173	20	305	45	22	49	–	–	–	–
Rhizomatous											
Achillea millefolium	77	6	30	131	6	14	21	100	98	100	97
Artemisia michauxiana	336	147	314	167	257	380	157	95	95	97	100
Penstemon rydbergi	149	128	200	300	396	307	132	66	80	97	97
Vicia americana	15	18	11	5	21	19	16	98	98	97	100
Others	6	19	26	15	60	68	24	–	–	–	–
Total rhizomatous	583	318	581	618	740	788	350	–	–	–	–
Tall forb											
Erigeron speciosus	2	2	39	1	0	5	0	10	46	17	6
Geranium viscosissimum	1	9	49	T	4	14	8	17	61	3	17
Ligusticum porteri	1	8	8	1	10	11	0	7	29	7	31
Potentilla gracilis	4	11	16	4	10	15	38	27	34	41	44
Thalictrum fendleri	19	41	25	28	58	31	40	66	66	67	72
Others	1	T	8	2	T	12	T	–	–	–	–
Total tall forbs	28	71	145	36	82	88	86	–	–	–	–
Annuals & ephemerals											
Collomia linearis	4	T	0	13	2	16	4	85	0	97	67
Other annuals	5	0	T	10	T	T	5	–	–	–	–
Viola nuttalli	40	48	2	17	2	0	3	100	37	78	0
Other ephemerals	9	1	3	8	1	2	4	–	–	–	–
Total annuals & ephemerals	58	49	5	48	5	18	16	–	–	–	–
Shrubs											
Chrysothamnus viscidiflorus	T	1	1	0	0	0	0	2	2	0	0
Total production	1,001	800	996	1,118	1,107	1,174	729	–	–	–	–

[1] T=Trace (< .5 lb/acre).

of herbage of Michaux sagewort. The presence of gophers apparently favored Michaux sagewort and the widespread occurrence and high production of this species may have inhibited other more desirable forbs. Where gophers were controlled, rhizomatous species declined almost 50% from 1942 through 1956, but then increased to their original level by 1973. Both Michaux sagewort and Rydberg penstemon followed this pattern where gophers were controlled. As reported by Ellison and Aldous (1952), Rydberg penstemon increased where gophers were present, but the increase continued only until 1956; then amount of herbage of this species dropped to its original level. Yarrow decreased in both areas, but the largest change occurred where gophers were present.

The number of plant species recorded on the quadrats totaled:

	1942	1956	1973
Gophers present	44	31	33
Gophers absent	38	31	35

Rockjasmine (*Androsace septentrionalis*), which produced little aboveground biomass, was present on more than 70% of the quadrats in both areas in 1942 and completely absent in 1973. Other species which occurred in both areas in 1942 but were absent in 1973 were yellow evening primrose (*Oenothera flava*) and tuber starwort (*Stellaria jamesiana*). Mountain spring parsley (*Pseudocymopteris montanus*), blue pennycress (*Thlaspi fendleri*), and Nuttall violet (*Viola nutalli*) were present in 1942 but were not found on the quadrats in 1973 in the area where gophers were present.

The annuals, narrowleaved collomia (*Collomia linearis*), lambsquarters (*Chenopodium album*), and Douglas knotweed (*Polygonum douglasi*) were abundant in 1942 in both areas, but were not found on the quadrats in 1973 where gophers were absent. Others have reported the role of pocket gopher disturbance in maintaining native annuals in the community (Moore and Reid, 1951; Laycock, 1958). Annuals remained a part of the vegetal composition where gophers were present inside the exclosure but amount of herbage decreased from 1942 to 1973. Species which had not been recorded in 1942 but were found in 1973 in the area where gophers had been controlled were mountain brome, showy elkweed (*Frasera speciosa*), and skyrocket gilia (*Gilia aggregata*).

Table 2. Summary of ground cover (%), 1973.

Type of cover	Exclosure: Gophers absent	Exclosure: Gophers present	Grazed: Gophers present
Plant	68	70	51
Litter	15	11	14
Bare ground	17	19	35
Fresh gopher mounds[1]	4	11	18

[1] Mounds were a subdivision of the bare ground figure.

Vegetation of Area Grazed by Sheep, 1973

No direct comparisons since 1942 could be established for the grazed area, because it was sampled only in 1973. However, if we assume that the vegetation in the grazed area was similar to that inside the exclosure when it was built in 1942, some conclusions can be drawn. Changes have occurred under continued sheep grazing which has been at a much lower intensity than in the early years of the century and in the presence of a rather high population of gophers. These trends generally were in the direction of the mixed upland-herb association described by Ellison (1954), but did not represent a very large change.

Aboveground peak standing crops and species composition of grasses and grasslike species were nearly the same on the grazed area in 1973 as they were in the area where gophers were absent inside the exclosure (Table 1). Slender wheatgrass appears to have increased considerably and Letterman needlegrass appears to have decreased since 1942, both on the grazed area and inside the exclosure. Comparison with the 1942 data indicates that rhizomatous and tap-rooted forb species probably have decreased on the grazed area. Peak standing crops of ephemerals and annuals on the grazed range in 1973 were similar to those in the area where gophers were present inside the exclosure.

Ground Cover

Where gophers had been controlled, only 4% of the gound surface was covered by fresh (current summer) gopher mounds in 1973, indicating a small population of gophers (Table 2). Where gophers had not been controlled, fresh mounds covered 11% of the ground inside the exclosure and 18% on the grazed area. Plant and litter cover estimates were similar for the two areas inside the exclosure. The area grazed by sheep had considerably less plant cover and more total bare ground than either area protected from grazing.

Soil

The soil was classified as a clay texture with particle sizes ranging from 41% to 57% clay, 27% to 43% silt, and 11% to 24% sand. The averages were 49% clay, 34% silt, and 17% sand. Gravel content (particles larger than 2 mm) ranged from 9% to 12%. All areas had similar soil texture but with some differences in percentages of sand, clay, and gravel (Table 3).

Regardless of the presence or absence of gophers, soils within the exclosure were significantly higher in total porosity and significantly lower in bulk density than soils in the area grazed by sheep. The presence of gophers and their burrowing activities in the absence of grazing apparently helped maintain soil tilth. Ellison and Aldous (1952) made the following observations about the study site: "The soil of the south side of the experimental area, where gophers are present, is much looser and softer than the soil of the north side where gophers are absent. . . . The difference is even more marked between the south side and the adjacent range where gophers are also present."

The soil samples taken in 1972 confirmed and quantified these differences. Bulk density was significantly lower and noncapillary porosity was significantly higher where gophers were present in the exclosure than where they were absent. On the grazed area, compaction caused by sheep grazing on these clay soils evidently more than offset the loosening effects of the burrowing activities of gophers and resulted in lower total porosity and higher bulk density on the grazed range.

In the absence of grazing, gophers apparently had other beneficial effects on the soil. Organic matter, total nitrogen, and total phosphorus were significantly higher where gophers

Table 3. Summary of soil data, 1972.

Site	Depth (cm)	Organ. matter (%)	Total N (%)	Total P (%)	K (ppm)	Bulk density (g/cc)	Capillary porosity (%)	Non-capillary porosity (%)	Total porosity (%)	Texture: Sand (%)	Texture: Silt (%)	Texture: Clay (%)	Gravel (> 2 mm) (%)
Exclosure– gophers absent	0–5	7.5	.34	.15	8,800	.86	41.8	20.0	61.8	20.5	33.1	46.4	12.0
	5–10	6.0	.28	.14	–	.99	41.9	15.1	57.0	16.5	34.6	48.9	11.8
	10–15	5.1	.25	.13	–	–	–	–	–	15.3	34.7	50.0	11.8
	15–30	5.0	.24	.13	–	–	–	–	–	14.5	34.8	50.7	11.3
Average		5.9[a][1]	.28[a]	.14[a]	8,800[a]	.92[b]	41.8[a]	17.6[a]	59.4[a]	16.7[a]	34.3[a]	49.0[ab]	11.7[a]
Exclosure– gophers present	0–5	8.7	.38	.16	9,600	.82	38.3	25.0	63.3	17.0	32.6	50.3	9.2
	5–10	7.4	.34	.16	–	.84	39.0	19.6	58.6	15.2	34.6	50.2	10.5
	10–15	5.9	.31	.16	–	–	–	–	–	16.3	34.3	49.4	9.0
	15–30	6.0	.29	.15	–	–	–	–	–	14.2	34.3	51.5	9.5
Average		7.0[b]	.33[b]	.16[b]	9,600[a]	.83[a]	38.6[b]	22.3[b]	60.9[a]	15.7[ab]	33.9[a]	50.4[b]	9.6[b]
Grazed– gophers present	0–5	7.9	.35	.14	9,400	1.01	39.2	15.6	54.8	19.3	33.3	47.4	9.2
	5–10	6.7	.31	.15	–	1.03	37.5	15.5	53.0	17.2	35.3	47.5	9.9
	10–15	5.6	.27	.14	–	–	–	–	–	16.0	36.8	47.2	7.6
	15–30	4.3	.24	.14	–	–	–	–	–	16.8	33.8	49.4	10.2
Average		6.1[a]	.29[a]	.14[a]	9,400[a]	1.02[c]	38.3[b]	15.6[a]	53.9[b]	17.3[b]	34.8[a]	47.9[a]	9.2[b]

[1] For each column, treatment means were averaged over all depths sampled and compared using Duncan's (1955) multiple range test. Means followed by the same letter are not significantly different at the 5% level.

were present inside the exclosure than in the other two areas. This may have been the result of burial of plant material and litter as mounds were formed, decay of unused underground food caches, and distribution of excrement throughout the burrow system. Taylor (1935) and Greene and Reynard (1932) reported similar changes in soil due to the burrowing activities of other rodents.

The increase in soil fertility was not reflected in the total amount of herbage produced; both areas inside the exclosure had similar aboveground peak standing crops in 1942 and in 1973. Perhaps the disturbance to the vegetation by the burrowing activities plus the material harvested and consumed by the gophers offset the increased fertility of the soil.

Organic matter, total nitrogen, and total phosphorus were not significantly different between the area grazed by sheep and the area where gophers had been controlled inside the exclosure. Potassium content at the 0–5 cm depth did not differ significantly among areas.

Organic matter and total nitrogen decreased significantly with depth of sampling, but the total phosphorus content remained relatively constant with depth. Silt and clay increased significantly with depth but gravel content was unchanged. Bulk density was significantly lower and noncapillary and total porosity were significantly higher at the 0–5 cm than at the 5–10 cm depth. The interaction between treatment and depth of sampling was not statistically significant for any of the soil properties measured.

Summary

Pocket gophers were controlled in one half and left undisturbed in the other half of an exclosure built in 1942 on depleted subalpine grassland on the Wasatch Plateau in central Utah. Total aboveground peak standing crop in both areas inside the exclosure was the same in 1973 as it had been in 1942. Trends in vegetal composition were generally toward the "mixed upland-herb association" described by Ellison (1954). Tall forbs, mainly Oregon fleabane and sticky geranium, were quite scarce in the area in 1942 and have since increased in both areas inside the exclosure. Selective feeding by gophers may have been a factor in the rate of increase because tall forbs increased more in the area where gophers were absent than where gophers were present.

Total peak standing crop of grasses increased where gophers were present in the exclosure as a result of increases in slender wheatgrass and mountain brome. Letterman needlegrass decreased in both areas inside the exclosure and on the grazed range, but where gophers had been controlled, the decrease was offset by an increase in slender wheatgrass.

The peak standing crop of dandelion decreased on both ungrazed areas and on the grazed range but, where gophers were present inside the exclosure, feeding pressure almost eliminated dandelion from the community, Michaux sagewort increased in the exclosure where gophers were present. Where gophers had been controlled, Michaux sagewort and other rhizomatous forbs decreased from 1942 through 1956 but then increased to original levels by 1973. Ephemeral species declined in all areas. Annuals were scarce in 1973 in the exclosure where gophers had been controlled but were maintained in the stand by the digging activities where gophers were present.

The clay soils of the study site varied only slightly in texture among the areas sampled. Exclusion of sheep grazing resulted in significantly higher total porosity and lower bulk density of the soil. Where gophers were present in the exclosure, noncapillary porosity, organic matter, total nitrogen, and total phosphorus were higher and bulk density was lower than where gophers were absent or on the grazed area. Potassium content of the soil did not differ among areas.

The increased soil fertility where gophers were present was not reflected in total peak standing crops. Damage to vegetation by consumption or burrowing activities of the pocket gophers may have offset the increased fertility.

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