Responses of Mountain Grassland Vegetation to Gopher Control, Reduced Grazing, and Herbicide[1]

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Highlight

Deteriorated mountain grassland range on Grand Mesa in western Colorado improved slowly during 19 years of nonuse. It improved almost as much under light grazing. In contrast, grass production increased markedly within a short time after competition from forbs and shrubs had been reduced by herbicide. Pocket gopher control for 9 years increased production of certain plant species and decreased production of others.

Efficient management of mountain grasslands for grazing, recreation, or watershed purposes calls for increased knowledge of responses of the vegetation to different management practices. This paper reports responses of grassland vegetation on Grand Mesa to: (1) exclusion of livestock; (2) reduction in livestock grazing; (3) control of pocket gophers; and (4) herbicide. The study was conducted by the Rocky Mountain Forest and Range Experiment Station between 1941 and 1960 in cooperation with the Bureau of Sport Fisheries and Wildlife, U. S. Department of the Interior, and the Grand Mesa-Uncompahgre National Forest, Forest Service, U. S. Department of Agriculture.

Study Area and Methods

Grand Mesa is located near Grand Junction, Colorado, between the bordering valleys of the Gunnison and Colorado Rivers. Capped with basalt, it slopes gently upward from an elevation of 9,800 ft at its western edge to over 10,500 ft at its eastern extremity. The terrain is generally flat to rolling. Though rich in organic matter and fertile, soils are generally rocky and shallow. Average annual precipitation is estimated to be about 30 inches. From November through May the ground usually is snow covered; the snowpack commonly attains a depth of 4 to 6 ft.

Near the western edge of the Mesa the aspect of silver sagebrush (*Artemisia cana*) is broken here and there by groves of Engelmann spruce (*Picea engelmanni*) and subalpine fir (*Abies lasiocarpa*). At higher elevations timber stands are more extensive, and grassland "parks," hereafter referred to as the grass-forb type, are occupied mainly by herbaceous plants.

Since about 1880 Grand Mesa has been grazed by cattle. Soon after the turn of the century the range was heavily stocked, and dense stands of Thurber fescue (*Festuca thurberi*), photographed by George B. Sudworth in 1889, were replaced or obscured by sagebrush.

When this study was started in 1941, orange sneezeweed (*Helenium hoopesii*) was conspicuous in the grass-forb type. Grass cover was sparse and the range was heavily populated with northern pocket gophers (*Thomomys talpoides*). After snowmelt the ground was cluttered with cores of soil deposited in snow tunnels, and later with mounds of earth excavated by gophers (Fig. 1). By summer's end, cattle had closely grazed most forage plants.

To determine and compare responses of vegetation to different combinations of gopher and grazing control, eight pairs of 1-acre areas on Grand Mesa were located in 1941 for detailed study. The most distant, 7 miles apart, differed in elevation by 600 ft. The two lowest and westernmost pairs supported mainly silver sagebrush; the others supported a mixture of forbs and grasses. One member of each pair was fenced in 1941 to exclude livestock, and the other continued to be grazed. Grazing was much lighter, however, after the number of cattle and length of grazing season were reduced about one-half during the period 1946 to 1950. The lighter grazing continued through 1960.

From 1941 to 1949, pocket gophers were trapped continuously during the snow-free period from every other pair of study areas. On the average, 18 gophers an acre per year were trapped from control areas (Cummings, 1949). Yearly averages ranged from 9 to 35 and those for individual study areas from 14 to 23 an acre. Equal numbers were trapped from grazed and nongrazed range. Although the number of gophers on gopher-present areas was not determined, soil disturbance indicated populations were generally high.

Between 1955 and 1958, the four pairs of study areas on the western part of the Mesa were sprayed with herbicide. An ester of 2,4-D mixed with diesel fuel was applied by airplane at a rate of 3 lb/acre acid-equivalent. Except during the year of treatment, the open range continued to be grazed after it had been sprayed.

Vegetation records were collected from 1941 to 1960. For sampling purposes, each acre was subdivided into nine units of equal size, and two 12.5 ft^2 plots were located at random in each unit each time records were taken.

Herbage production was measured in 1941 by harvesting and weighing vegetation from each plot; thereafter, it was determined by double sampling in which herbage weight was estimated and the estimates adjusted as indicated by records from clipped plots (Pechanec and Pickford, 1937). Weights were converted to an air-dry basis. Production by individual species was estimated in 1942 and 1960; in other years it was determined only for herbage classes, except for sneezeweed, which was measured separately. Sneezeweed was of particular interest because it was very abundant, is nonpalatable to cattle, and poisonous to sheep.

Plant cover was estimated by the square-foot-density method (Stewart and Hutchings, 1936). An index of plant vigor was obtained by measuring maximum heights of flower stalks of 30 nongrazed plants per acre for each of seven species. Measurements were made in July or August when most plants were fully developed.

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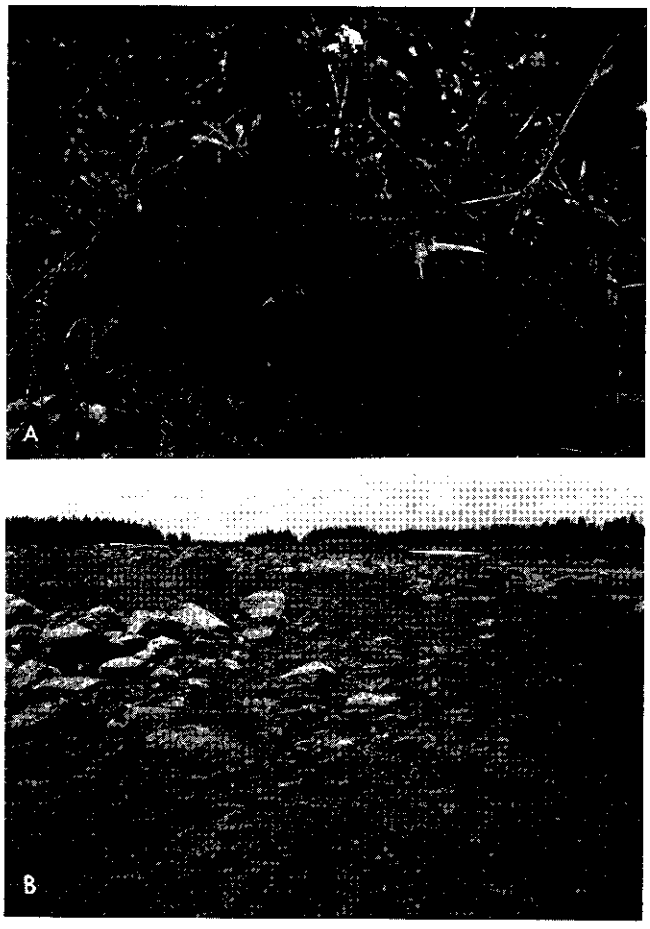

FIG. 1. The mountain pocket gopher commonly buries plants under mounds of soil excavated during summer (A) and under earthen cores deposited in snow tunnels during winter (B).

Terminal records for the pocket gopher study were obtained in 1951, 2 years after gopher control had been discontinued. Responses to livestock exclusion from 1942 to 1960, and to reduced grazing, are reported only for the eight areas not sprayed with herbicide. Responses to herbicide were measured in 1960, 2 to 5 years after the chemical was applied.

Results and Discussion

Responses to Gopher Control.

Herbage available to livestock was increased 195 lb/acre as the result of gopher control the first year (Table 1). Forbs, which produced about three-fourths of the herbage, accounted for nearly three-fourths of the increase. Though average production of grass increased only 30 lb/acre, the increase was nearly in proportion to the amount present. Changes in browse also were small. The initial increase in available herbage apparently resulted mainly from reduced burial and consumption of plant foliage by gophers.

From 1942 to 1951, forbs other than sneezeweed continued to become more productive. By 1951 the increase attributable to gopher control averaged 258 lb/acre. Meanwhile, production of orange sneezeweed declined. On gopher control areas, the decrease averaged 138 lb/acre as compared to 12 lb/acre where gophers were not controlled. The relatively small changes in grass and browse production evidently were not related to gopher control.

Table 1. Herbage yields (lb/acre, air dry) where pocket gophers were controlled from 1941 to 1949, and where not controlled. Each entry is the average of eight 1-acre areas.

Herbage class and year	Gophers controlled	Gophers uncontrolled	Difference
Grasses and sedges			
1941	109	140	− 31
1942	165	166	− 1
1946	204	231	− 27
1947	206	202	4
1951	236	310	− 74
Sneezeweed			
1941	114	57	57
1942	172	48	124
1946	80	46	34
1947	62	58	4
1951	34	36	− 2
Other forbs			
1941	600	524	76
1942	652	504	148
1946	699	504	195
1947	766	498	268
1951	931	597	334
Shrubs			
1941	112	210	− 98
1942	66	138	− 72
1946	66	136	− 70
1947	34	125	− 91
1951	57	170	−113
All herbage			
1941	935	931	4
1942	1055	856	199
1946	1049	917	132
1947	1068	883	185
1951	1258	1113	145

Amount and composition of plant cover also were influenced by gophers. Considered by herbage classes, only forb cover changed significantly between 1941 and 1951. On gopher control areas it increased to 19 from 14%, while on gopher-present areas it remained at 12%.

Changes in crown cover of six individual species were significant. Where gophers were controlled, sedges (*Carex* spp.), lupine (*Lupinus* spp.), and common dandelion (*Taraxacum officinale*) increased, while slender wheatgrass (*Agropyron trachycaulum*), orange sneezeweed, and penstemon (mainly *Penstemon rydbergii*) became relatively

Table 2. Composition (%) of plant cover as influenced by pocket gopher control.

Species	Gophers controlled		Gophers uncontrolled	
	1941	1951	1941	1951
Grass and Sedges	percentage of grass-sedge cover			
Slender wheatgrass	7	9	4	14
Sedges	22	32	21	11
Forbs	percentage of forb cover			
Orange sneezeweed	13	3	7	4
Lupines	8	22	11	12
Penstemons	10	9	8	17
Common dandelion	21	27	14	12

less prominent (Table 2). Branson and Payne (1958) reported similar responses of dandelion and slender wheatgrass to gopher control in Montana. On the Wasatch Mountains in Utah, Richens (1965) found that bulbed plants became more abundant, and annual plants less abundant, following gopher control.

The increases in lupine and dandelion on Grand Mesa are in accordance with earlier findings that those plants commonly are eaten by gophers (Keith, Ward, and Hansen, 1959; Ward, 1960; Ward and Keith, 1962). Lupine increased on all areas on which gopher control was attempted, and dandelion increased on seven of the eight areas. Neither changed appreciably where gophers were not controlled. After gopher control was discontinued, lupine again became relatively inconspicuous.

Gopher-Grazing Relationships.

Vegetation responses to gopher control varied considerably with range use by cattle. For example, forbs other than sneezeweed increased most (373 lb/acre) between 1941 and 1951 on grazed range on which gophers were controlled. The increase was smallest (41 lb/acre) on nongrazed range on which gophers were not controlled. Orange sneezeweed, on the other hand, decreased as much as 106 lb where both cattle and gophers were excluded, and as little as 14 lb where neither was excluded.

The largest increase (181 lb/acre) in grass and sedges resulted from exclusion of cattle only. Slender wheatgrass provided most of the additional forage. Grass increased least (96 lb/acre) on grazed range on which gophers were controlled. Browse responses were relatively small and inconsistent.

Changes in sneezeweed cover were similar to its changes in production. Common dandelion and sedge cover increased most on grazed range on which gophers were controlled, and decreased on nongrazed range on which gophers were present.

Table 3. Average production of herbage (lb/acre, air-dry) on four grazed and four nongrazed areas in a grass-forb type not sprayed with herbicide.

Class of herbage	Grazed		Nongrazed	
	1941	1960	1941	1960
Grass and sedges	124	300	130	353
Forbs	562	433	600	440
Shrubs	20	30	10	8
All herbage	706	763	740	801

Under the latter treatment, slender wheatgrass attained its greatest prominence. Responses of lupine and penstemon to gopher control were not influenced appreciably by grazing.

Comparative changes in vegetation between 1941 and 1951 for the four gopher-grazing treatments are summarized below. Under all treatments, production of grass and forbs other than sneezeweed was higher, and that of sneezeweed and browse lower, in 1951 than in 1941.

Gophers present on grazed range.

1. Average increase in grass production.
2. Below average increase in forbs other than sneezeweed.
3. Least reduction in sneezeweed.

Gophers present on nongrazed range.

1. Largest increase in grass (mainly slender wheatgrass).
2. Least increase in forbs other than sneezeweed.
3. Small reduction in sneezeweed; moderate reduction in dandelion.

Gophers controlled on grazed range.

1. Least increase in grass (no change in wheatgrass).
2. Largest increases in lupine, dandelion, sedges, and forbs (as a group) other than sneezeweed.
3. Average reduction in sneezeweed.

Gophers controlled on nongrazed range.

1. Average increase in grass production.
2. Above average increase in forbs other than sneezeweed.
3. Largest reduction in sneezeweed.

Responses to Reduced Grazing.

Changes in herbage production on areas from which cattle were excluded from 1942 to 1960, and which were not sprayed with herbicide, were not much different from those on adjacent range on which grazing intensity was reduced (Table 3). Under both treatments, grass production increased less than 250 lb/acre, forb production decreased between 100 and 200 lb, and shrub production changed very little. Although total herbage production was somewhat higher in 1960 than in 1941,

the increase was nearly the same on grazed and nongrazed range.

Grasses and sedges in 1941 comprised 18% of the herbage, both on areas to be grazed and nongrazed. In 1960 they comprised 39 and 44%, respectively. Contribution of forbs decreased from 80 to 57% under grazing, and from 81 to 55% under nongrazing. Changes in browse were insignificant.

The proportions of herbage contributed by individual plant species changed substantially during the 19-year period. On areas from which cattle were excluded, Letterman needlegrass (*Stipa lettermani*) produced 35% of the grass in 1942. By 1960 its contribution had declined to 18%. Meanwhile, slender wheatgrass increased to 34% from 8%. Bromegrass (mainly *Bromus anomalus*) and trisetum (mainly *Trisetum spicatum*) each contributed 15% of the grass in 1960 but only 3 to 4% in 1942. Increases in brome and trisetum were countered by similar decreases in sedges and bluegrasses (*Poa* spp.).

Changes in composition of forb herbage on nongrazed range were generally smaller than those for grasses. The largest reduction was in western yarrow (*Achillea lanulosa*), which accounted for 20% of the forb herbage in 1942 and 8% in 1960. The largest increase (6%) was in agoseris (mainly *Agoseris glauca*). Comprising 24 to 30% of forb herbage, sneezeweed was the dominant forb both years.

Of interest is the fact that sneezeweed production declined by 61 lb/acre (significant at 0.05 level) on nongrazed range but retained its original level on grazed range between 1941 and 1947. By 1951, however, after the reduction in range stocking, a significant reduction of 34 lb/acre had occurred on the open range. Thus, abundance of sneezeweed was influenced not only by gophers, but by intensity of range use by cattle (Fig. 2).

On grazed areas, changes in herbage composition were generally similar to, but smaller than, those on nongrazed range. Principal exceptions were that Letterman needlegrass and bluegrasses retained their former prominence, and dandelion became more prominent, under continued grazing. In 1960 slender wheatgrass produced 15% of the grass on grazed range as compared to 34% on areas that had not been grazed for 19 years.

Increased height growth indicated that plants of the seven species observed became more vigorous following discontinuance or reduction in grazing. Flower stalks of Letterman needlegrass, which averaged 16 inches tall in 1941, were 5.2 inches taller on nongrazed range and 1.6 inches taller on grazed range in 1947. Stalks within seven of the eight exclosures attained their tallest recorded height within 6 years after grazing was discontinued. By 1951 average heights differed by only 2.4 inches, and in 1960 they were nearly the same. In 1960, however, plants were 2 to 3 inches taller than in 1941. On nongrazed range, the stalks were 2 inches shorter in 1960 than in 1947, possibly because of increased competition from associated plants.

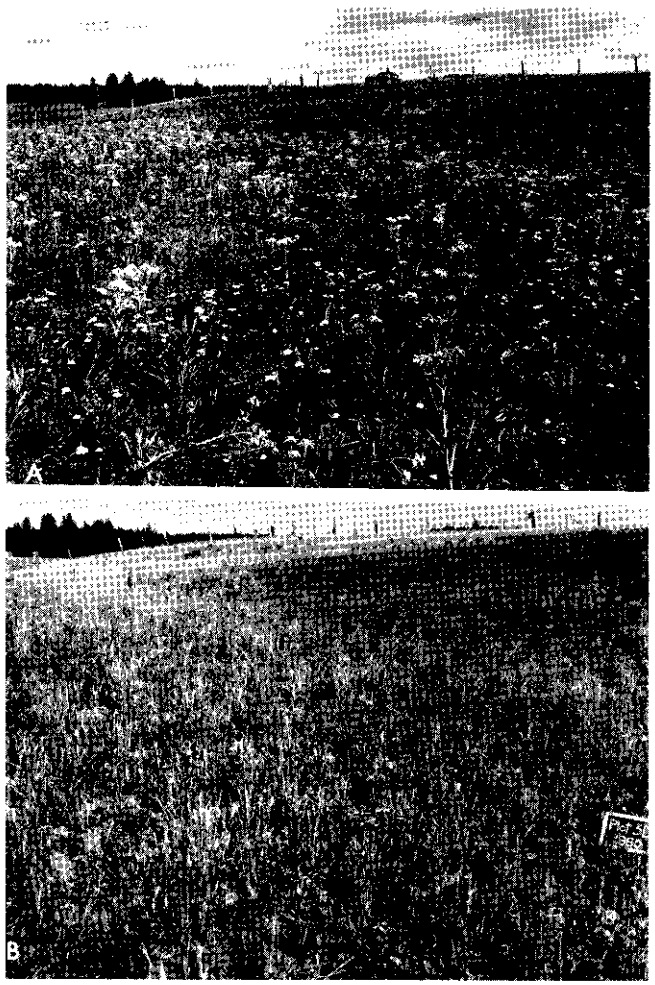

FIG. 2. Orange sneezeweed nearly disappeared from this cattle exclosure between 1941 (A) and 1960 (B) as grass production increased to 576 from 148 pounds an acre. Slender wheatgrass was the dominant grass in 1960. This range was not sprayed with herbicide.

In 1951, flower stalks of slender wheatgrass averaged 3 inches taller, and those of trisetum were 2.4 inches taller, inside than outside the exclosures. Leaves of common dandelion inside the exclosures grew more nearly upright, and in 1951 were 0.6 inch longer than those outside. None of the plants measured had been grazed during the year of measurement.

Heights of western yarrow, orange sneezeweed, and lupine were less influenced by grazing. Although those forbs invariably were shorter on grazed than on nongrazed range after 1941 (pos-

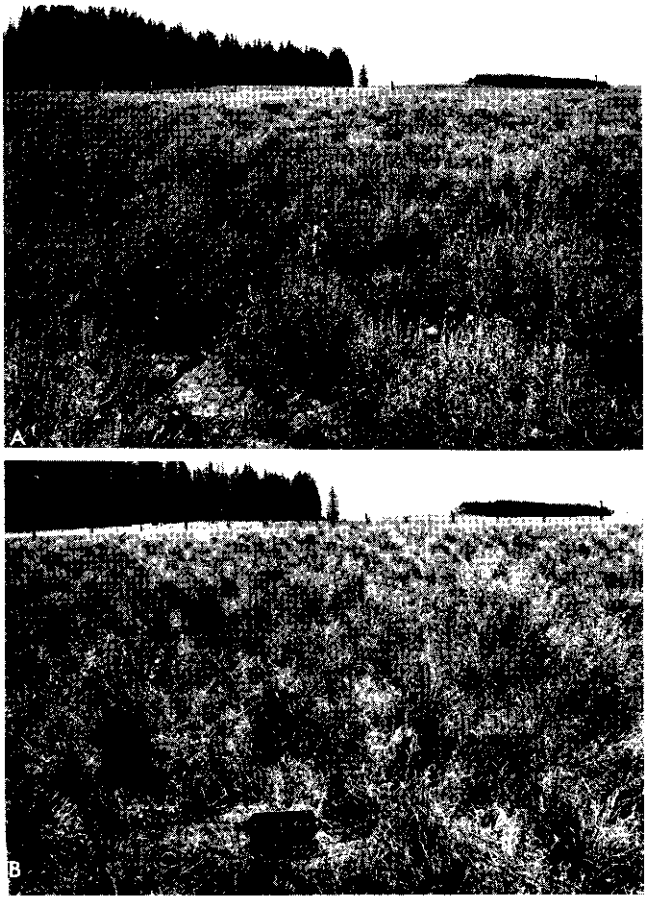

FIG. 3. Sprayed with herbicide in 1958, this site produced 991 pounds of grass an acre in 1960 (B) as compared to 279 pounds in 1941 when silver sagebrush was prominent (A). The increase in grass on sprayed range exceeded that on nonsprayed range by more than 300 pounds an acre.

sibly because of differences in soil tilth), the largest average difference between treatments for any species in any year was 1.7 inches.

Differences in site capability were evidenced by height growth of Letterman needlegrass, orange sneezeweed, and western yarrow. In 1941 their flower stalks were taller on each of the eight lower study areas than at higher elevations. Although differences attributable to site (elevation) averaged only 1.5 to 2.4 inches, they generally persisted throughout the study, or as long as records were taken.

Responses to Herbicide.

Grass production increased substantially more between 1951 and 1960 on areas sprayed with herbicide than on those not sprayed. In the sagebrush type the increase averaged 339 lb/acre (Fig. 3), and in the grass-forb type 255 lb. In comparison, the increase on the eight areas in the grass-forb type that were not sprayed averaged 96 lb (Table 4). During the 19 years of study, grass production on nonsprayed range increased only 200 lb/acre.

Forbs on sprayed range produced 490 to 574 lb/acre less in 1960 than in 1951. However, a decrease of 386 lb on nonsprayed range during that period indicates that factors other than herbicide were responsible for much of the reduction. Some forbs undoubtedly reinvaded sprayed areas prior to 1960, particularly in the grass-forb type. Hansen and Ward (1966) recorded the lowest production of forbs the first year, and the highest production of grass the third year, after similar rangeland on Grand Mesa had been sprayed in 1956.

Herbicide killed nearly all silver sagebrush, the only abundant shrub. In 1960, browse production on areas formerly dominated by sagebrush averaged 12 lb/acre, compared with 354 lb/acre prior to spraying. As a result, herbage composition was greatly altered (Table 4).

Responses to herbicide were also revealed through changes in frequency of individual plant species between 1951 and 1960. Not only sagebrush, but most forbs were less common 2 to 5 years after herbicide had been applied (Table 5). Plants most affected were agoseris, aspen fleabane

Table 4. Herbage production (lb/acre, air dry) and composition (%) on areas sprayed with herbicide and not sprayed.

	Sprayed with Herbicide[1]						Not sprayed[2]		
	Sagebrush type			Grass-forb type			Grass-forb type		
Year	Grass	Forbs	Shrubs	Grass	Forbs	Shrubs	Grass	Forbs	Shrubs
Herbage production:									
1951	429	681	354	206	848	44	230	833	28
1960	768	191	12	461	274	10	326	447	20
Diff.	+339	−490	−342	+255	−574	−34	+96	−386	−8
Herbage composition:									
1951	29	47	24	19	77	4	21	76	3
1960	79	20	1	62	37	1	41	56	3

[1] Four areas in the grass-forb type and two in sagebrush were sprayed in 1955; 2 additional areas in sagebrush were sprayed in 1958.
[2] Each entry is the average for 8 areas.

Table 5. Frequency (%) of common plants on sagebrush and grass-forb types treated with herbicide, and on untreated grass-forb type, in 1951 and 1960. Each entry is based on eighteen 12.5 ft² plots/acre.

Species	Sprayed with herbicide				Not sprayed	
	Sagebrush		Grass-forb		Grass-forb	
	1951	1960	1951	1960	1951	1960
Grasses and Sedges						
Slender wheatgrass	80	95	47	80	40	60
Bromegrasses	54	60	19	28	8	26
Sedges	84	72	83	65	96	77
Alpine fescue	0	0	2	4	74	62
Thurber fescue	39	43	0	0	0	0
Prairie Junegrass	24	14	2	0	0	0
Alpine timothy	0	2	9	6	32	24
Bluegrass	29	29	44	28	68	64
Letterman needlegrass	89	79	99	96	98	88
Trisetums	51	44	47	60	58	66
Forbs						
Western yarrow	99	61	96	81	96	93
Agoseris	56	7	97	26	90	57
Pussytoes	20	0	7	6	21	8
Aspen fleabane	58	4	22	4	2	1
Eriogonums	36	4	7	2	2	1
Prairiesmoke sieversia	17	4	11	6	43	40
Orange sneezeweed	28	10	80	17	86	70
Aspen peavine	74	51	46	26	25	25
Lupines	92	24	43	10	87	46
Penstemons	7	6	30	26	78	73
Douglas knotweed	76	85	72	88	22	41
Cinquefoils	93	71	100	74	22	21
Pseudocymopterus	6	4	8	0	72	46
Common dandelion	86	26	100	71	95	91
American vetch	74	4	47	2	22	20
Shrubs						
Silver sagebrush	92	15	10	3	0	0

(*Erigeron macranthus*), eriogonum (*Eriogonum subalpinum* and *E. neglectum*), orange sneezeweed, lupine, and American vetch (*Vicia americana*). Reductions were smaller or less consistent in western yarrow, pussytoes (*Antennaria* spp.), prairiesmoke sieversia (*Geum ciliatum*), aspen peavine (*Lathyrus leucanthus*), common dandelion, Rydberg penstemon, and cinquefoils (*Potentilla anserina* and *P. pulcherrima*). In 1960 these two species of cinquefoil comprised 30 to 40% of the forb herbage on sprayed areas, much more than any other species.

Changes in frequency of individual grass species were relatively small and generally similar on sprayed and nonsprayed range. This would indicate that causes other than herbicide were mainly responsible, and that increased production of grass on sprayed range resulted not from establishment of new plants but from improved vigor of plants present when the range was sprayed.

Responses to herbicide were influenced by site characteristics and nature of the vegetation prior to spraying. In 1951 frequencies of several plant species within the sagebrush type differed considerably from those for the grass-forb type. Thurber fescue and prairie Junegrass (*Koeleria cristata*), for example, were nearly restricted to the sagebrush type before and after treatment (Table 5). Within the grass-forb type, alpine fescue (*Festuca ovina brachyphylla*), alpine timothy (*Phleum alpinum*) and bluegrasses were much more common in 1951 on areas not to be sprayed than on those subsequently sprayed. By 1960, 2 to 5 years after herbicide was applied, the relative abundance and distribution of these plants had changed very little.

Summary and Conclusions

Vegetation responses to pocket gopher control, exclusion of livestock, reduced grazing, and herbicide were observed on 16 1-acre study areas on Grand Mesa in western Colorado from 1941 to 1960. The sites were paired, one fenced to exclude livestock and the other left open to grazing by cattle. From 1941 to 1949 pocket gophers were controlled during summer months on every other pair of study areas. Livestock were excluded from eight sites from 1942 to 1960, and stocking of the open range was sharply reduced during the period 1946 to 1950. Thereafter, grazed sites received light to moderate use. The western part of the Mesa on which half the study areas were located was sprayed with herbicide during the period 1955 to 1958.

Because control of pocket gophers by poisoning and trapping was feasible only during snow-free periods, some gophers reinvaded gopher-control areas during winter. Consequently, the responses reported are from intensive, but incomplete, control of gophers.

Principal conclusions are:

1. Gopher control resulted primarily in increased production of perennial forbs, particularly lupine and dandelion which commonly are eaten by gophers. Forbs other than sneezeweed increased by 258 lb/acre between 1941 and 1951, the increase on grazed range being considerably larger than on nongrazed range. Orange sneezeweed became less productive as the result of gopher control. Grasses and shrubs were little affected. Responses to gopher control, however, varied considerably with grazing use by cattle.

2. Exclusion of livestock from a grass-forb range for 19 years resulted in an increase in grass of 223 lb/acre, and a decrease in forbs of 160 lb. The proportion of herbage contributed by grasses and sedges increased to 44 from 18%, and that by forbs decreased to 55 from 81%. Slender wheatgrass,

bromegrasses, and trisetum became more prominent, while Letterman needlegrass, bluegrasses, and sedges became less prominent. Composition of forb herbage was generally stable, the largest change being a 12% reduction in western yarrow. Competition from forbs apparently was mainly responsible for the slow and relatively small increase in grass production.

3. Vegetation changes on range grazed lightly to moderately for 10 years after stocking rate and length of grazing season had been reduced were generally similar to those on rangeland not grazed for 19 years. Principal exceptions were that Letterman needlegrass and bluegrasses retained their former prominence, and dandelion became more prominent, under continued grazing. The findings indicate that deteriorated mountain grassland range may improve almost as rapidly under light grazing as under nonuse.

4. Grass production increased considerably more on range sprayed with herbicide than on range not sprayed. Much of the increase evidently resulted from more vigorous growth of grasses present when the range was sprayed. Kind and frequency of grasses on individual sites 2 to 5 years after the range was sprayed were not much different from those prior to spraying. Although many forbs were killed by herbicide, some were almost as abundant a few years after the range was sprayed as before. Apparently the latter were resistant to herbicide or quickly became reestablished.

Although plant cover responded differently to each treatment, the vegetation on each site tended to retain its individuality throughout the study. The nature of existing plant cover and other site characteristics should be considered, therefore, when predicting responses of mountain grassland to specific management practices.

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