Great Basin Naturalist

Volume 45 | Number 1 Article 20

1-31-1985

Differential effects of cattle and sheep grazing on high mountain meadows in the Strawberry Valley of central Utah

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DIFFERENTIAL EFFECTS OF CATTLE AND SHEEP GRAZING ON HIGH MOUNTAIN MEADOWS IN THE STRAWBERRY VALLEY OF CENTRAL UTAH

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Abstract.— Species diversity, niche metrics, cover, frequency, and soil relationships were studied on high mountain meadows on adjacent cattle and sheep allotments in Strawberry Valley, Wasatch County, Utah. The cattle allotment vegetation was predominantly Mountain bluebell (*Mertensia ciliata*), and the sheep allotment vegetation was predominantly Smallwing sedge (*Carex microptera*). Other species of importance on both areas included Letterman needlegrass (*Stipa lettermanii*), Mountain bromegrass (*Bromus carinatus*), and Yarrow (*Achillea millefolium*). Tall forbs were most abundant on the cattle allotment, and low forbs, perennial grasses, and sedges were most abundant on the sheep allotment. Vegetation composition on the two allotments was significantly different.

High mountain meadows in Utah have been important to ranchers as forage resources since the pioneers entered the state in 1847. The effects of grazing in Utah have been recorded since 1865 and have shown that vegetation composition and productivity are altered by livestock (Roberts 1930). Recent studies conducted near Elk City, Idaho, show that cattle grazing reduces herbage production, changes species composition, and increases bare ground in dry mountain meadows (Leege et al. 1981). Livestock graze selectively, with sheep being best adapted to browse ranges and cattle showing preference for grass ranges (Stoddart et al. 1975). Depending on levels of grazing, common use by more than one class of livestock can improve the range or accentuate the detrimental effects caused by individual species. Merrill et al. (1968) stated that common use equalized the grazing pressure, and each species benefited from the grazing of the other.

The purpose of this study was to determine the differential effects of 30 years of continuous cattle and sheep grazing upon the vegetative composition of dry mountain meadows. Data from this study are useful for the efficient management of such meadows.

Study Site

The study sites are in the Strawberry Valley west of Strawberry Reservoir approximately 30 km southeast of Heber City, Wasatch County, Utah (Township 3S, Range 12W, Section 8-W¼, Section 17-W½, Section 20-W½, S½, Uintah meridian) (Fig. 1). Elevation of the sites varied from 2789 to 2819 m. The study sites lie at the head of the Mud Creek and Clyde Creek drainages on the lee-

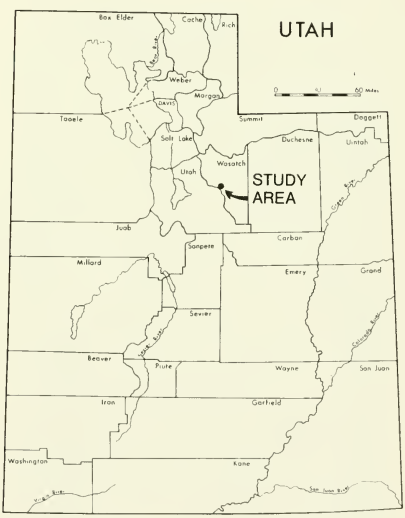

Fig. 1. Map of the study site location in the Strawberry Valley of central Utah.

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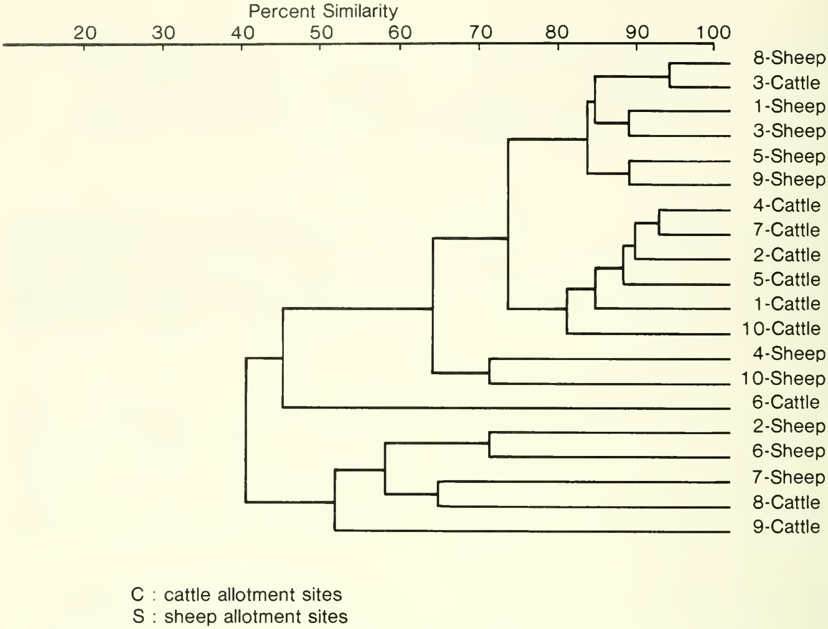

Fig. 2. Cluster diagram of soil factors for the cattle and sheep allotments.

ward side of the ridge top separating Utah and Wasatch counties.

The dry meadows chosen for study occurred in adjacent cattle and sheep allotments located within the aspen-conifer forest. Both allotments have been free of common use grazing since 1952 and are now utilized as summer range by livestock and wildlife. Livestock AUM levels are equivalent on the study sites of both allotments. The area has cool summers and cold winters with heavy snows. Annual precipitation averages 610 mm (24 in), of which 60% falls as winter snow (England 1979). The soils are derived from weathered sandstone and silt-shale. Wind was not measured at the sites but blew continually from the west during the hours we were on the study site.

Methods

Vegetation was sampled by using ($0.25 m^2$) quadrats placed every 3 m along 30 m transects. Twenty transects were randomly selected across the slope, with 10 in the cattle allotment and 10 in the sheep allotment. Monocot plants were identified following Cronquist et al. (1977) and dicots from Welsh and Moore (1973). Cover and frequency of all plant species and plant life form categories were calculated for both cattle and sheep allotments. Cover for each species was estimated as suggested by Daubenmire (1959). Species diversity (Shannon and Weaver 1949, Patton 1962) and prevalent species (Warner and Harper 1972) were determined for the cattle allotment, sheep allotment, and both allotments combined. Vegetative differences between the cattle and sheep allotments were determined by use of cluster analysis (Sneath and Sokal 1973), Spearmans' Rank Correlation (Snedecor and Cochran 1968), and Students t-tests. Niche overlap (based on geographical distribution of individuals) was calculated for each possible pair of species within and between the allotments (Colwell and Futuyma 1971).

Soil samples from the first 20 cm of the soil profile (Ludwig 1969) were taken from each transect and placed in Zip-lock plastic bags to insure water retention. Soil samples were weighed wet, dried in an oven for 20 days at 50 C, and then reweighed. Percentage moisture was determined from the differences in wet and dry weights. Average soil depth was measured with a 1 m penetrometer at the 0-, 15-, and 30-m marks along each transect (Greenwood and Brotherson 1978). Analyses for calcium, copper, iron, magnesium, manganese, nitrogen, phosphorus, potassium, sodium, zinc, organic matter, pH, and texture were conducted by the Soils Analysis Laboratory, Department of Agronomy and Horticulture, Brigham Young University, Provo, Utah. Means, standard deviations, and Students t-tests were used to determine soil differences between cattle and sheep allotments. The study sites were clustered according to the similarity and distribution of soil and vegetation within the allotment meadows (Sneath and Sokal 1973).

Results and Discussion

Soils in the meadows were loams and sandy loams with a minimum of 1.5 inches of available water-holding capacity. This represents the moisture between wilting point and field capacity (USDA 1975). Although not significantly different, soil moisture values taken in late July had means of 10.5% for the cattle allotment and 13.5% for the sheep allotment. These levels are close to the wilting point for most plants and if drying continues will eventually force the plants to become dormant.

Of the soil factors tested, only iron, bare ground, percent sand, and percent silt showed significant differences between cattle and sheep allotments (Table 2). Percentage bare ground and sand were greater and iron concentrations and percentage silt lower in the cattle allotment.

The cluster of all 20 transects in the cattle and sheep allotments were highly similar (41% or greater), and no definite patterns emerged relative to soil difference between the two allotments (Fig. 2).

The differences in concentrations of iron in the allotment soils do not seem important vegetatively. When large amounts of copper, manganese, and zinc occur in acid soils, iron is usually deficient (USDA 1957, Vose 1982). These chemicals have low concentrations in our soils and therefore should not tie up iron.

Textural differences (Table 1) between the two allotments were significant though the differences were small (8% for sand and 5.6% for silt). To understand if these differences influenced vegetation patterns between the two allotments, soil textures for all transects were superimposed on the cluster (Fig. 6) of vegetative data. No distinguishable patterns emerged. Further, when percentages of sand

TABLE 1. Soil characteristics of cattle and sheep allotment meadows with their means, standard deviations, and coefficients of variation. Significance levels were computed using the Students t-test.

Factor	Cattle			Sheep			Significance level
	$\overline{X}$	S_d	CV	$\overline{X}$	S_d	CV	
Bare ground (%)	31.0	12.86	41.4	21.8	7.61	34.9	.05
Soil depth (cm)	47.1	7.0	14.9	45.5	9.2	20.2	N.S.
Clay (%)	12.1	3.2	26.1	14.5	2.9	20.0	N.S.
Sand (%)	52.6	6.1	11.5	44.6	7.3	16.4	.05
Silt (%)	35.3	4.5	12.6	40.9	5.1	12.4	.05
pH	6.1	0.1	1.6	6.2	0.1	1.6	N.S.
Organic matter (%)	2.5	0.8	32.0	3.0	0.7	23.3	N.S.
Soil moisture (%)	10.5	2.9	27.6	13.4	5.1	38.1	N.S.
Calcium (ppm)	881.3	372.0	42.2	1162.7	388.8	33.4	N.S.
Magnesium (ppm)	80.0	22.5	28.1	92.4	33.8	36.6	N.S.
Sodium (ppm)	18.8	11.6	61.7	18.4	7.9	42.9	N.S.
Potassium (ppm)	183.9	118.9	64.7	186.1	48.6	26.1	N.S.
Iron (ppm)	66.4	19.8	29.8	93.8	24.8	26.4	.05
Copper (ppm)	0.9	0.2	22.2	1.0	0.2	20.0	N.S.
Manganese (ppm)	44.7	11.7	26.2	56.7	19.3	34.0	N.S.
Zinc (ppm)	3.8	1.6	42.1	5.2	1.4	26.9	N.S.
Nitrogen (%)	0.1	0.03	30.0	0.1	0.04	40.0	N.S.
Phosphorus (ppm)	33.6	9.8	29.2	38.2	9.2	24.1	N.S.

and silt from the 20 sites were correlated with the prevalent species, no significant relationships developed.

Bare ground affects the amount of moisture that soaks into the ground or runs off. With greater amounts of bare ground, more moisture runs off and can therefore increase erosion on the sites. However, no differences in erosion patterns on the two allotments were observed. The bare ground on the sites has apparently been accentuated by the differential grazing patterns that have occurred over the past 30 years. Cattle tend to select those plants with greater basal areas, thus leaving greater amounts of exposed ground when they are removed from a site.

Twenty-nine of 38 plants species identified within the study area were located on the cattle allotment and 37 on the sheep allotment (Table 2). Percentage cover and frequency for all species are shown in Table 2 and prevalent species in Table 3. The cattle allotment had 13 prevalent species and the sheep allotment 16. The three most prevalent

TABLE 2. Plant species along with their mean cover and frequency values in the cattle and sheep allotment meadows. The species life form and grazing response are noted.

	Cattle allotment			Sheep allotment		
Species by life form	Cover	Frequency	GR[1]	Cover	Frequency	GR
LOW FORB						
Achillea millifolium	3.7	59	Ic	51	56	Ic
Agoseris glauca	0	0	Ic	0.1	7	Ic
Allium acuminatum	0	0	Ic	0.1	3	Ic
Artemisia ludoviciana	0	0	Ic	0.4	3	Ic
Castilleja sulphurea	1.2	12	Ic	0.5	11	Ic
Collomia linearis	2.5	46	Iv	4.4	51	Iv
Erigeron speciosus	0.9	11	Ic	0.8	23	Ic
Gayophytum ramosissimum	trace	1	Iv	0	0	Iv
Gilia aggregata	0	0	Ic	0.2	1	Ic
Lupinus argenteus	0.1	3	Ic	0.6	12	Ic
Madia glomerata	0	0	Ic	3.4	10	Ic
Orthocarpus tolmei	4.4	67	Iv	1.2	28	Iv
Potentilla gracilis	1.7	20	Iv	2.7	38	Iv
Ranunculus alismaefolius	trace	1	Iv	0.9	11	Iv
Stellaria jamesiana	0.1	5	Ic	0.5	16	Ic
Vicia americana	0.4	4	Ic	0.7	11	Ic
Viola nuttallii	0	5	Ic	1.8	33	Ic
TALL FORB						
Arabis drummondii	0.5	18	Iv	0.2	8	Iv
Artemisia dracunculus	0.9	17	Iv	1.0	8	Iv
Geranium viscosissimum	1.4	11	Ic	2.1	20	Ic
Hackelia floribunda	0.2	2	Iv	0.7	3	Iv
Helenium hoopseii	0.3	5	Ic	0.8	13	Ic
Hieracium scouleri	0.2	6	Iv	2.9	18	Iv
Ligusticum filicinimum	1.2	24	Iv	0.8	11	Iv
Mertensia ciliata	33.1	91	Ic	7.9	37	Ic
Polemonium foliosissimum	0	0	Ic	0.6	8	D
Rudbeckia occidentalis	0	0	Ic	0.8	2	Ic
SHRUB						
Symphoricarpos orbiculatus	0.3	2	Ic	0.2	2	Ic
PERENNIAL SEDGE						
Carex microptera	3.5	16	Ic	23.0	76	Ic
PERENNIAL GRASS						
Agropyron trachycaulum	2.3	56	D	2.0	40	D
Agrostis variabilis	0	0	Ic	0.4	6	Ic
Bromus carinatus	5.4	73	D	4.4	46	Ic
Deschampsia caespitosa	0.1	4	D	0.3	11	D
Festuca elatior	0	0	Ic	1.9	3	Ic
Melica bulbosa	0.1	3	D	0.1	2	D
Poa pratensis	0.1	3	Ic	0.1	3	Ic
Stipa columbiana	0.2	7	Ic	0.6	12	Ic
Stipa lettermani	8.4	71	Ic	9.4	67	Ic

[1]GR = Grazing response: D = Decreaser, Ic = Increaser, Iv = Invader.

species on the cattle allotment were Mountain bluebell (*Mertensia ciliata*) (33% cover), Letterman needlegrass (*Stipa lettermanii*) (8% cover), and Mountain brome (*Bromus carinatus*) (5% cover). The three most important on the sheep allotment were Smallwing sedge (*Carex microptera*) (23% cover), Letterman needlegrass (9% cover), and Mountain bluebell (8% cover). All other cattle allotment prevalents provided an additional 23% cover, whereas the remaining sheep allotment prevalents provided an additional 32% cover. This corresponds with the species diversity data, since the cattle allotment sites were less diverse (mean DI = 2.5) than the sheep allotment sites (mean DI = 3.0). The diversity differences were not significant.

The major prevalent species for the cattle and sheep allotments (Mountain bluebell and Smallwing sedge, respectively) appear to be dominant because of the differential grazing patterns of the cattle and sheep. Mountain bluebell, which is a tall forb of the montane zone, occurs primarily on loam or sandy loam soils. It has fair forage value for cattle, but it is considered as very good forage for sheep. Sheep will utilize the entire plant before it becomes dormant. Smallwing sedge grows in dense tufts in loamy soils. It is moderately palatable and fairly good forage for sheep but very good forage for cattle and quite sensitive to grazing pressures. Mountain brome is a perennial bunchgrass that is very palatable to all classes of livestock, with sheep usually preferring the seedheads. It usually inhabits deep, moderately moist soils, but it is also found on drier, harsher sites. Letterman needlegrass is a tufted perennial that often grows in large clumps. It is good forage for both cattle and sheep.

Mountain brome and Letterman needlegrass are prevalent species that occur in about equal amounts on both allotments. There should not be much difference in the the use of Mountain brome and Letterman needlegrass in that their forage ratings are somewhat equal for both cattle and sheep. But, with sheep preferring Mountain bluebell more and Smallwing sedge less than cattle, Mountain bluebell should become more abundant on the cattle allotment and Smallwing sedge more abundant on the sheep allotment as time passes. Of the four major prevalent species, only Mountain brome is considered to be a decreaser and the other three species are considered increasers (Table 2).

Differential grazing pressures on these meadows has caused secondary succession to occur, since the importance of the dominant species has shifted over time. Both allotments were dominated by increaser and invader plant species, with only five decreaser species being present. Of the decreasers on the cattle

TABLE 3. Prevalent plant species of meadows, along with their cover values for the cattle and sheep allotments combined, the cattle allotment, and the sheep allotment.

Species	Life form	Cattle and sheep	Cattle	Sheep
Mertensia ciliata	TF	18.46	33.13	6.32
Stipa lettermanii	PG	8.88	8.38	9.38
Carex microptera	PGL	8.61	1.38	20.74
Bromus carinatus	PG	4.66	5.43	3.94
Achillea millifolium	LF	4.18	3.70	4.59
Collomia lineatis	LF	2.58	1.75	3.50
Potentilla gracilis	LF	2.30	0.66	4.69
Agropyron trachycaulum	PG	2.05	2.33	1.80
Orthocarpus tolmei	LF	1.97	3.98	0.60
Hieracium scouleri	TF	0.68		1.43
Viola nuttallii	LF	0.48		1.25
Geranium viscossimum	TF	0.52		0.83
Ligusticum filicinimum	TF	0.45	0.61	
Erigeron speciosus	LF	0.43	0.36	0.50
Arabis drummondii	TF	0.38	0.65	
Castilleja sulphurea	LF		0.47	
Helenium hoopseii	TF			0.50
Artemisia dracunculus	TF			0.40
Ranunculus alismaefolius	LF			0.36

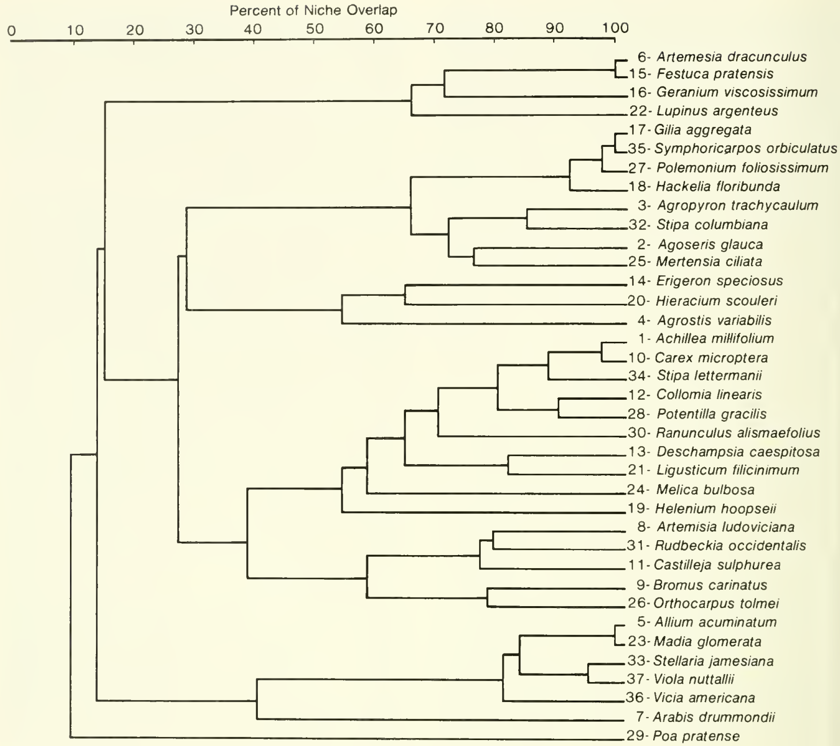

Fig. 3. Cluster diagram of niche overlap, using species of the sheep allotment.

allotment, two were prevalent species and two were not. On the sheep allotment, one was a prevalent species and three were not. All occurred in minimal abundance. This is probably due to the stress of 30 years of grazing pressure. If grazing pressure continues, the plants could decrease in frequency until they disappear from the sites.

Niche overlap values were computed for all species. Our data showed that the distribution patterns of Mountain bluebell and Mountain brome overlapped about 87% and that Mountain bluebell, Mountain brome, and Letterman needlegrass overlapped 57% in general distribution on the cattle allotment. Smallwing sedge and Letterman needlegrass overlapped 89%, and Smallwing sedge, Letterman needlegrass, and Mountain bluebell overlapped 28% on the sheep allotment. When considering all species from both allotments, Smallwing sedge and Letterman needlegrass overlapped 77% and Mountain bluebell and Mountain brome overlapped 77%, yet both pairs overlapped only 37% (Fig. 3–5). This indicates that Smallwing sedge and Mountain bluebell generally had disjunct distribution patterns relative to each other. The disjunct distribution patterns are most likely a result of the differential grazing preferences of cattle and sheep.

Using the cover values of the prevalent species from both the cattle and sheep allotments, Spearmans' rank correlation analysis was used to compare the two allotment meadows as to significant differences in the importance of the dominant species. This analysis showed significant differences in the species rankings on the two allotments

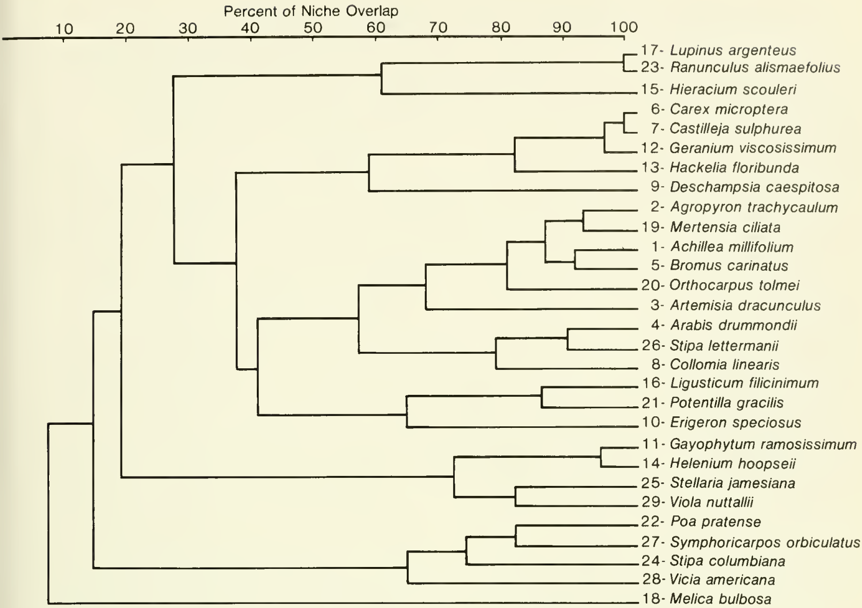

Fig. 4. Cluster diagram of niche overlap, using species of the cattle allotment.

(P<.05), which indicates that, although the two meadows contain many of the same species, the vegetation on the two sites is indeed different. When the 20 transects from the cattle and sheep allotments were clustered on the basis of vegetational characteristics (Fig. 6), all the sheep allotment transects clustered together and 8 of the 10 cattle allotment transects clustered as a unit. The 2 remaining cattle allotment transects clustered with the sheep allotment transects. This also shows the distinct differences in the vegetation of the two allotment meadows.

Since cattle prefer grasses and grasslike plants, and sheep prefer forbs in their diets (Stoddart et al. 1975, Krueger et al. (1974), the plant species were divided into life forms to determine differences existing between allotments (Table 4). The life form classifications used were shrubs, perennial grasses, perennial tall forbs (>12″) and low forbs (<12″). Significant differences (P<.05) appeared relative to low forbs, tall forbs, and perennial sedge life forms. The sheep allotment contained greater amounts of low forbs and perennial sedges, and the cattle allot-

Table 4. Life form types with their average cover and frequency values in the cattle and sheep allotments. Significant differences are based on cover values and Students t-tests.

Plant life form	Cattle allotment Cover	Cattle allotment frequency	Sheep allotment Cover	Sheep allotment frequency	Significance level
Low forbs*	15.0	14	27.4	19	.05
Tall forbs*	37.8	17	17.8	13	.05
Perennial grass	16.6	31	19.2	21	N.S.
Perennial sedge	3.5	16	23.0	76	.05
Shrub	0.3	2	0.2	2	N.S.

*Tall forbs are more than 12 inches tall, and short forbs are 12 inches or less.

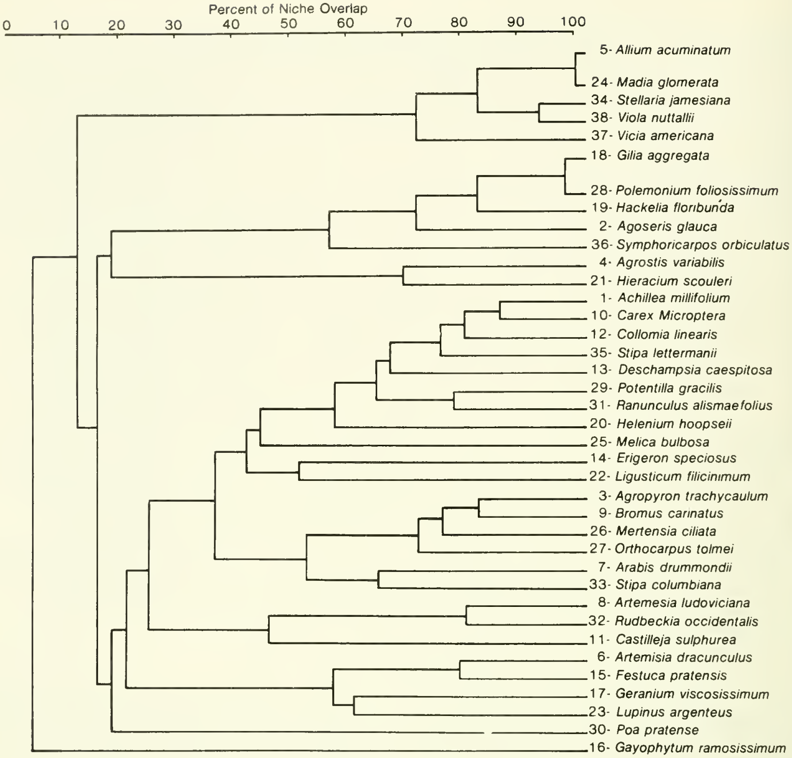

Fig. 5. Cluster diagram of niche overlap, using a combination of the species of the sheep and cattle allotments.

ment had greater amounts of tall forbs. Perennial grasses were more prominent on the sheep allotment, but differences were not significant.

With the soil factors showing little or no differences between allotments, the differences in vegetative composition in the allotment meadows appear to have been caused by grazing pressures. Perennial sedges are preferred by cattle and thus appeared more abundantly on the sheep allotment. Conversely, sheep prefer forbs that were more abundant on the cattle allotment. As grazing pressures increase, preferred vegetative life forms decrease and may disappear from the allotments used by a specific type of livestock.

To more efficiently manage these meadows, plant species and life forms should be grazed evenly. This would reduce the effects of preferential grazing (which tends to favor one species over another), which changes competitive relationships among species. This can be achieved by grazing at the proper time of year and with the proper mix of livestock species and numbers. An appropriate mix or rotation of livestock onto the allotment meadows would allow for a more uniform use of life forms and species to occur without losing any preferred species from the grazing area.

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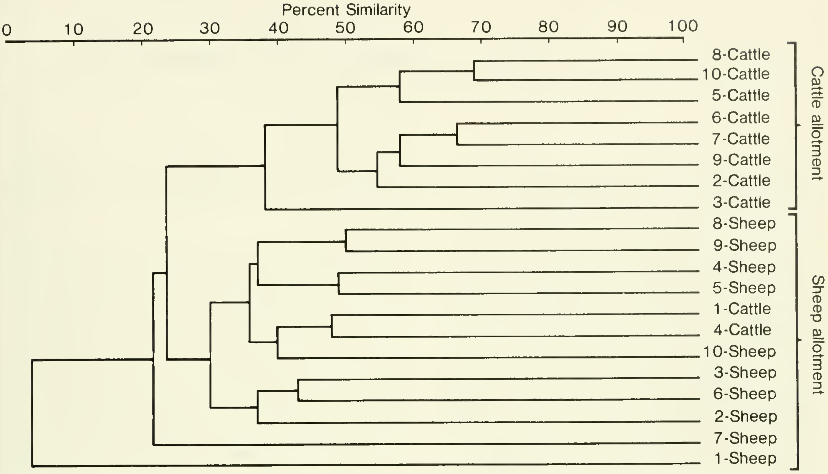

Fig. 6. Cluster diagram of the percentage similarity of vegetation on study sites from both allotments.

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