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The Effect of Cattle, Sheep, and Other Factors on Aspen (Populus Tremuloides) Reproduction After Clear-Cut Logging in Southern Utah

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THE EFFECT OF CATTLE, SHEEP, AND OTHER FACTORS ON ASPEN (*POPULUS TREMULOIDES*) REPRODUCTION AFTER CLEAR-CUT LOGGING IN SOUTHERN UTAH

by

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The Effect of Cattle, Sheep and Other Factors
on Aspen (Populus tremuloides) Reproduction
After Clear-cut Logging in Southern Utah

by

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Aspen is the most widespread deciduous tree of the western United States and the aspen type is important for water, forage, and wood products. Aspen reproduction on cutover areas was thought to be hindered by browsing and other factors, therefore a study was conducted to determine the effects of livestock, pocket gophers, disease, and snowpack damage on aspen reproduction during the first three years after clear-cutting. An enclosure was constructed and divided into nine paddocks. Controlled grazing by cattle and sheep was applied to six different paddocks during three summer periods. Three paddocks were protected from grazing. Results show that sheep utilized more sprouts than cattle, but controlled grazing by sheep or cattle did not prevent adequate aspen regeneration on good sites. Pocket gophers and disease appeared to be the most important decimating factors under controlled grazing. Sheep tended to concentrate on cutover areas so proper herding is needed to prevent misuse, especially the first and second years after initial sprouting.

(77 pages)

INTRODUCTION

Aspen, Populus tremuloides, is the most widespread deciduous tree of the western United States. Vegetation types where aspen is the dominant species cover approximately 2,000,000 acres in Utah, Nevada, southern Idaho, and western Wyoming. The elevation of the aspen type varies from a low of 5,000 feet in southern Idaho to a high of 10,000 feet in southern Utah (Houston, 1954). Grazing, watershed, and timber values make the aspen type one of the most valuable montane types in the Intermountain West.

Forage

The aspen type has a high potential as a summer range for livestock and wildlife because of understory vegetation. Many sites support forbs and grasses that annually produce 1,000 to 2,000 pounds of air-dry forage per acre. Under moderate grazing, the forage cover remains a well balanced mixture of grasses, forbs, and shrubs (Costello, 1944). The production of herbaceous vegetation is greater in openings than under an aspen canopy (Ellison and Houston, 1958).

Grazing values for the aspen type increase during the first few years following clear-cutting, and an average aspen sucker stand in the Lake States provided an additional 100 to 150 deer days of browse per acre for the first three years after logging (Westell, 1954). The nutritive content of aspen sprouts is especially high; samples from a Colorado summer range had a mean protein content of 20 percent which is comparable to good grades of alfalfa hay (Dietz, Udall, and Yeager, 1962).

Watershed

Aspen's extensive lateral root system makes it a valuable protective watershed cover. This is especially important because aspen occurs in high precipitation areas where high intensity rainstorms can cause serious runoff and erosion problems if the soil is not protected. Marston (1952), in a 17-year study on the Davis County Experimental Watershed concluded that about two-thirds of the surface of a watershed should be covered by plants and litter to maintain soil stability.

Timber

Aspen has several commercial timber uses. It is used for posts, poles, lumber, and boxwood. The chief product of aspen logs in Utah between 1917 and 1948 was excelsior (Curtis, 1948).

Reproduction

It is essential that aspen be allowed to reproduce to insure stable watersheds and sustained yields of water, forage, and wood products in the future because of the important role aspen plays in mountainous areas. Aspen stands that have been burned or logged usually produce a large number of sprouts. The success of these sprouts may be influenced by browsing although some sprout browsing may be a valuable aid in thinning stands too dense for rapid healthy growth and to increase the grazing value of the type (Ingram, 1931; Young et al., 1942; DeVos, 1958). Factors which affect the damage caused by browsing are: (1) height of sprouts when browsed, (2) kind of browsing animal, (3) intensity of animal use, and (4) size of area cut. Pocket gophers (Thomomys sp.) also can influence the success of aspen reproduction after clear-cutting (Marston and Julander, 1961).

OBJECTIVES

This study was undertaken because of the importance of the aspen type and observations by field personnel from various agencies that reproduction was being hindered by browsing and other factors. The purpose of the study was to determine the relative magnitude of the effects of livestock, pocket gopher, disease, and snowpack damage on aspen reproduction. From this information management recommendations could be made on obtaining successful aspen regeneration after clear-cutting while still making full allowable use of the increased forage.

Specific objectives were:

1. To determine the effects on aspen reproduction of controlled cattle and sheep use during three grazing periods as compared to grazing protection.
2. To evaluate the effects of pocket gopher, disease, and snowpack damage on aspen reproduction.
3. To determine the relationship of production and utilization of herbaceous forage to the success of aspen reproduction.

REVIEW OF LITERATURE

Silviculture

Although aspen may reproduce by seed, vegetative reproduction is by far the most important means of regenerating cutover stands (Baker, 1925; Ellison, 1943; Larson, 1944). Most sprouts arise from horizontal roots lying near the soil surface, but a few sprouts originate from root collars and still fewer from the stump (Baker, 1918).

The silvicultural treatment that produces the greatest number of sprouts of the highest quality is clear-cutting (Baker, 1918). Farmer (1962) suggested that root sprouting in aspen was related to apical dominance. Removal of the apical bud allowed sprouting from lateral buds. Sprouts in clear-cut areas grow 3 to 4 times faster than those in heavily shaded areas (Stoeckler and Macon, 1956). Baker (1918) found that cutting different ages of parent stands and cutting in different seasons resulted in full regeneration of aspen in the Intermountain Region, though these factors were thought to be important determinants of success in the Lake States (Stoeckler, 1947; Stoeckler and Macon, 1956).

The profuse sprouting of aspen after clear-cutting of good sites provides many more sprouts than are needed to regenerate the stand. Baker (1918) reported that after four years of grazing protection 20,000 to 30,000 sprouts per acre remained on a clear-cut area in Utah. In the Great Lakes region, 6,000 to 12,000 well distributed suckers per acre the second or third year after logging were sufficient to fully regenerate an aspen stand. Greater densities of sprouts resulted in slow growth rates and poor growth forms (Graham, Harrison, and Westell, 1963). The average

density in mature stands in the Intermountain area is 480 trees per acre (Baker, 1918). Some sprout browsing in over-stocked stands was thought to increase the growth rate of surviving sprouts and improve timber quality (DeVos, 1958).

Clear-cutting of aspen not only encourages sprouting, but also results in greater forage production by shrubs, forbs, and grasses than in uncut stands. Ellison and Houston (1958) showed in trenched and untrenched plots that aspen root competition was the chief cause of less herbaceous vegetation within dense aspen stands.

Site

Site has an important influence on the number of aspen sprouts. The most favorable sites for aspen sprouts have soils with fresh moving water within two or three feet of the soil surface (Graham, Harrison, and Westell, 1963). In the Lake States, sites containing a greater number of cords per acre produced more sprouts than sites of fewer cords per acre (Stoeckler and Macon, 1956). Schreiner (1931) believed that site affected the incidence of disease in aspen through its influence on plant vigor.

Browsing

The influence of browsing animals has been found to be an important factor in the ability of a clear-cut aspen stand to regenerate itself. If sprouts are destroyed each year for two or three consecutive years, the roots are no longer able to respond and sprouting entirely ceases (Julander, 1937). Removal of the terminal shoot one or two times does not permanently harm the sprout if enough lateral shoots and photosynthetic material are left to sustain the plant. The Forest Service in southern

Utah believed that cutting areas of 30 or more acres provided a greater chance for stand regeneration than smaller cuts because there was less likelihood of a high percentage of the sprouts being damaged (Olsen, 1968).

Sampson (1919) found sheep in Utah utilized a greater portion of the woody part of a sprout than did cattle. Sheep also fed on the naked stem after leaf fall while cattle did not. Sheep grazing during three successive years after cutting prevented sprout reproduction, but moderate cattle grazing was permissible. Baker (1918) reported that even light use by sheep caused severe damage, thus a three-year sheep grazing deferment after cutting was recommended on Utah ranges. Cattle caused some damage but unless the area was severely overgrazed they did not decrease reproduction below that needed to establish a commercial stand.

Sprouts 45 inches or more in height are out of the reach of destructive sheep browsing, and sprouts 60 inches or more are exempt from harmful cattle use (Sampson, 1919). The growth rate of aspen sprouts after clear-cutting is .5 to 1 foot per year (Baker, 1918; Sampson, 1919; and Larson, 1944), therefore undamaged sprouts become immune to harmful sheep use after three growing seasons and exempt from harmful cattle use after four or five growing seasons.

Pocket Gophers

Previous investigations showed that rodents, primarily pocket gophers, destroy as much as 10 percent of a sprouting stand in one season and are active for the first five years following cutting (Baker, 1918). Other studies have shown that most pocket gopher damage is done under a snowpack in winter and early spring (Aldous, 1945; Julander, Low, and Morris, 1959).

Damage also occurs in summer and fall if rainy weather has softened the ground and made burrowing easier (Ellison and Aldous, 1952). The northern pocket gopher (Thomomys talpoides) is the chief rodent causing damage to aspen sprouts in southern Utah. While tunneling and feeding, gophers clip the lateral root an inch below the ground or the stem two to three inches above the ground (Olsen, 1967). Gopher damage can be differentiated from other damage by the clean, straight cut on the damaged sprouts (Graham, Harrison, and Westell, 1963; Laycock, 1968).

DESCRIPTION OF EXPERIMENTAL AREA

Webster Flat on the Dixie National Forest, approximately 18 miles east of Cedar City, Utah in Section 30, Township 37 South, Range 9 West, was chosen as the study area (Figure 1). This location was selected because aspen was being cut there, it provided a more uniform site than was available elsewhere, and local Forest Service officials were concerned about heavy browsing upon aspen reproduction in the area. Administrative studies conducted by the Forest Service from 1960 to 1962 in clear-cut areas adjacent to the study site had demonstrated the desirability of a detailed research program (Forest Service, 1963).

The soil on the study site developed from a basalt parent material of Quaternary origin which was extruded upon rocks of sedimentary origin. The genetic horizons varied in depth, but consisted of an organic layer, an undifferentiated A horizon, and a textural B_2 horizon. The solum depth was shallower than most aspen soils due to the relatively recent occurrence of the parent lava flow. The slope is about 5 percent, the aspect is east, and the elevation is 9,200 feet. Heavy snowfalls occurred and the average snowpack on April 1, for the years 1965 to 1968 averaged 45 inches. Precipitation from June through September averaged 8.39 inches from 1960 to 1968 (Table 1).

The experimental area was astride a sheep and cattle allotment boundary fence. The area south of the boundary fence was used by sheep until 1961; from 1962-63 it received no grazing, and has been grazed by cattle from 1964 until the time of the study. Sheep grazed the area north of the boundary fence and deer were present over the entire study area.

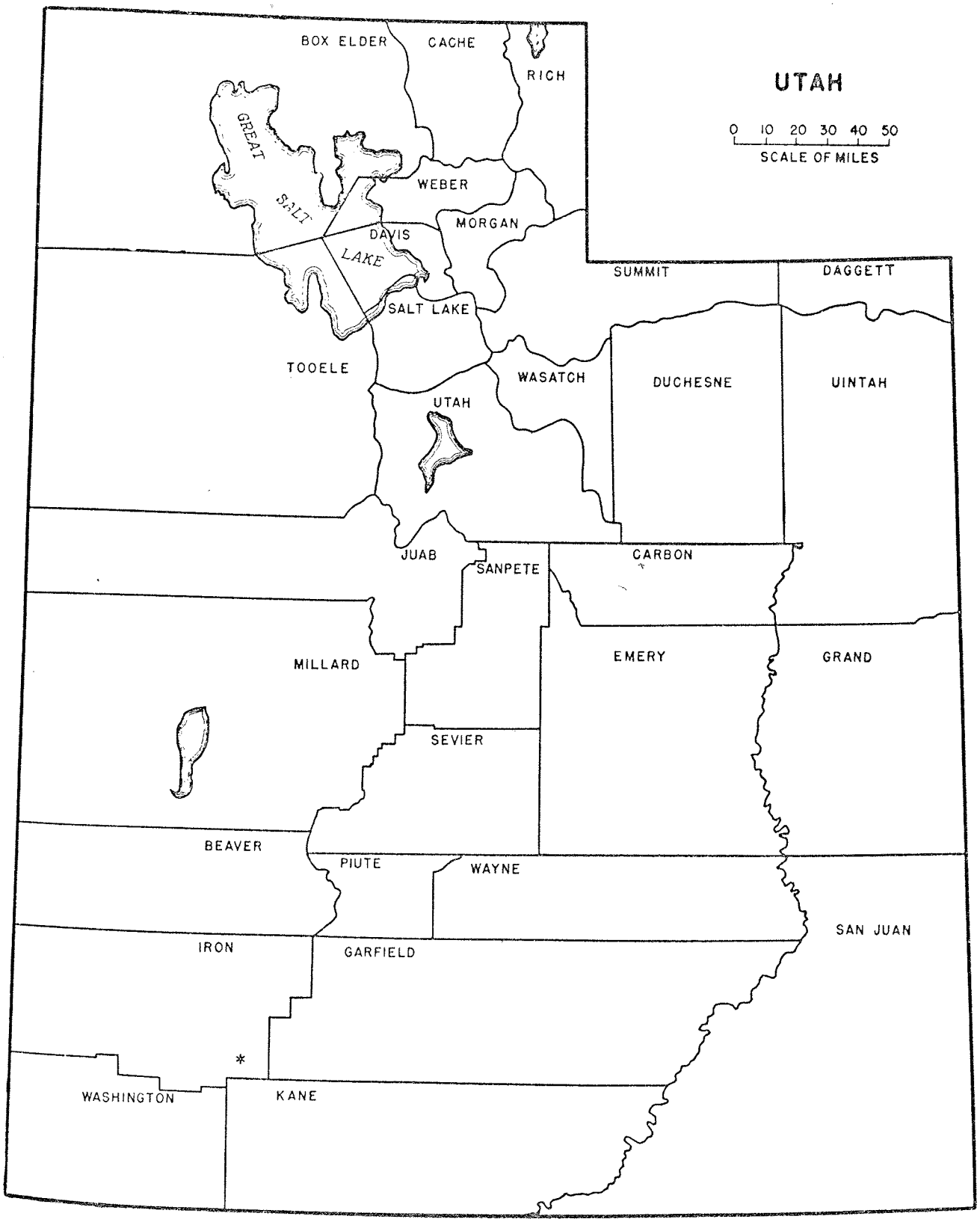


Figure 1. Location of the aspen reproduction study area on the Dixie National Forest in Iron County, Utah.

Table 1. Precipitation for June through September at Webster Flat on the Dixie National Forest (Soil Conservation Service, 1968).

Year	June	July	August	September	Four Month Total
1965	--	4.84[a]	--	4.15	8.99
1966	.13	1.44	2.10	1.63	5.30
1967	3.79	3.07	6.85	5.36	19.07
1968	.93	3.25	2.50	1.72	8.40
Nine year average (1960-1968)					8.39

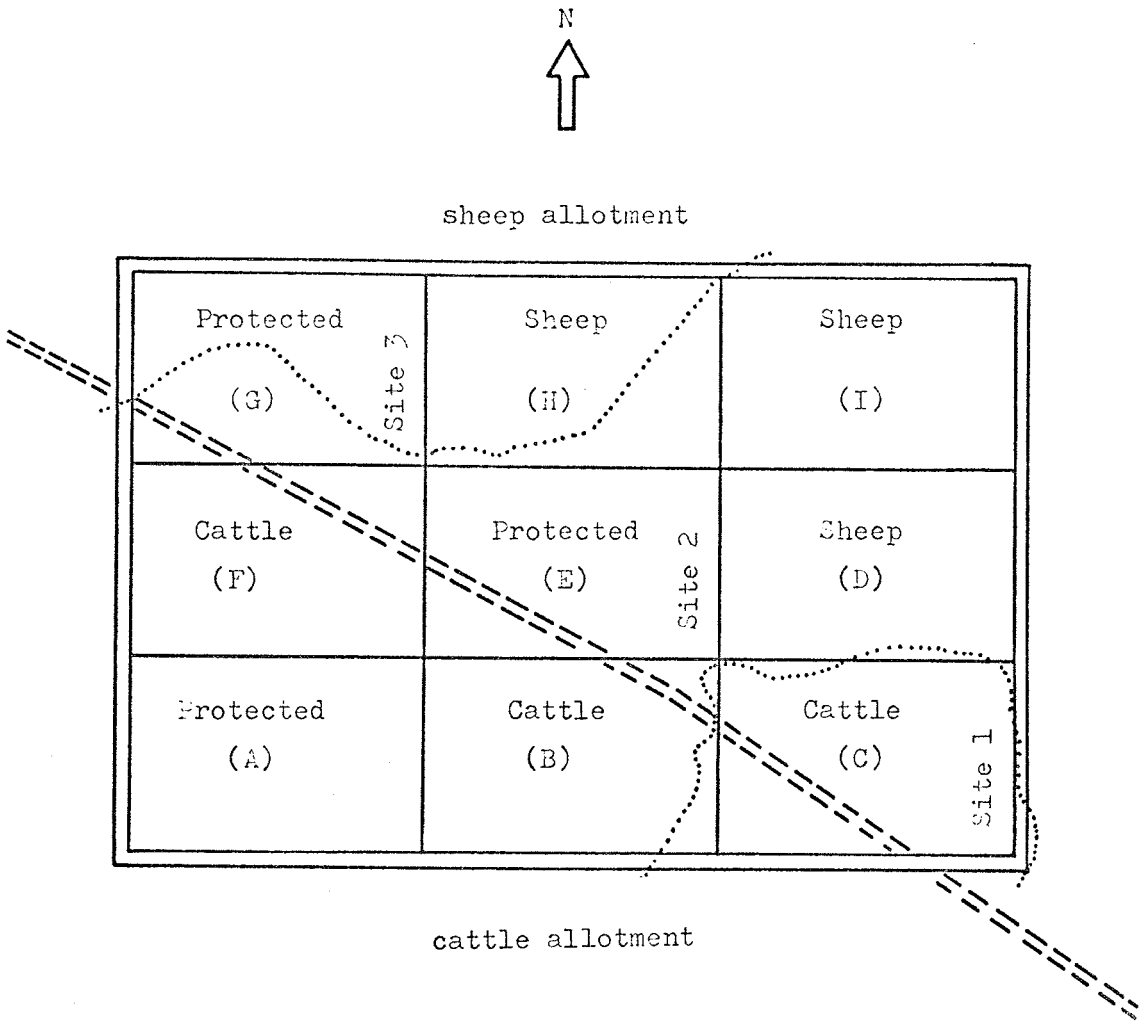
[a]Three month total for June, July, and August.

Table 2. Aspen stand data for three sites at Webster Flat on the Dixie National Forest, 1964 (U. S. Forest Service records, 1964).

	Site 1	Site 2	Site 3
Acres	5.9	12.1	13.8
Basal Area/Acre in Sq. Ft.	55.8	87.5	97.3
Volume/Acre in Bd. Ft.	4,126	7,041	7,313
Cords/Acre/Strata	8.3	14.1	14.6

The timber-sale area was divided into three sites on the basis of cords of wood present before cutting (Table 2 and Figure 2). In terms of wood products, site 1 was the lowest and site 3 was the highest in production (Forest Service, 1964). Site 1 occupied 5.9 acres and was estimated to produce 8.3 cords per acre. Site 2 covered 12.1 acres and contained 14.1 cords per acre, whereas site 3 covered 13.8 acres and provided 14.6 cords per acre. The cord production data suggest that sites 2 and 3 are not actually different in potential.

A 31.8 acre tract of aspen was clear-cut at Webster Flat by Western Wood Excelsior Manufacturing Company from June 20 through August 24 in 1965. All trees with diameters at breast height of six inches or more were removed and smaller trees were left on the ground. Trees showing signs of heartrot could not be used for excelsior so they were left as slash.



Legend

Deer tight fence

Cattle-sheep allotment boundary fence

Site boundaries

Scale 1 inch = 200 feet

Figure 2. The paddock design showing various sites and treatments at Webster Flat on the Dixie National Forest.

METHODS AND PROCEDURES

After commercially valuable aspen trees had been removed a 12.3 acre tract was enclosed with a deer-tight fence by the U. S. Forest Service with materials furnished by the Utah State Division of Fish and Game. The fencing was completed October 20, 1965. Low livestock fences were constructed inside the enclosure to separate the nine paddocks. Cattle, sheep, and deer used the surrounding area before the fence was constructed, but little grazing occurred in 1965 at the study site because of the disturbance caused by the men and equipment working in the area (Olsen, 1967).

Paddocks

The fenced area was divided into nine paddocks of 1.37 acres (200 feet by 300 feet) each to study the effects of controlled cattle grazing, controlled sheep grazing, and grazing protected treatments (Figure 2).

The summer grazing season was divided into three periods. Each kind of animal grazed their respective paddocks concurrently. Each paddock was randomly assigned to cattle grazing, to sheep grazing, or to protection, but the allocation of the three grazing periods was done arbitrarily and remained the same from 1966 through 1968 (Table 3). The three protected paddocks were randomly assigned to each of the three grazing periods so that statistical comparisons could be made.

Prior work

In 1964, an estimate of forage production was obtained from sixty .96 square-foot plots in the uncut aspen forest at Webster Flat (Appendix Table A). In the fall of 1965 each paddock was examined for sprouting

Table 3. Treatments and sequence of grazing periods applied to particular experimental paddocks after clear-cutting at the study area.

	Treatments		
Grazing periods	Cattle paddocks	Sheep paddocks	Protected paddocks
1	B	H	G
2	F	D	E
3	C	I	A

clumps, but few clumps were found (Smith and Doell, 1966). In the summer of 1966, the first year after clear-cutting, information on (1) forage production, (2) forage utilization, (3) number of aspen sprouts, and (4) number of aspen clumps, was collected from the grazed and protected paddocks (Scotter and Doell, 1967). Grazing intensity was determined by using bluebells (Mertensia arizonica) as the key species.

Current Work

Forage Production. Forage production data were collected from fifty 9.6-square-foot plots in each paddock prior to grazing using the weight-estimate method (Pechanec and Pickford, 1937b). The 10 base lines and the first plots on each base line were located randomly, but the rest of the plots on each base line were evenly spaced. The plots were permanently marked by wooden stakes. A 13-foot border on each side of the paddocks was not sampled to minimize fenceline effects.

Forage Utilization. Utilization is defined as "the proportion of the current year's forage production that is consumed or destroyed by grazing animals" (American Society of Range Management, 1964). Utilization data were obtained immediately after grazing by the ocular-estimate method (Pechanec and Pickford, 1937b). Individual utilization estimates for each species were taken from the same plots used to estimate production to provide an unbiased estimate (Smith, 1968).

Grazing was initiated when slender wheatgrass (Agropyron trachycaulum) was still in the boot stage and Kentucky bluegrass (Poa pratensis) was starting to form seed. Cattle were placed in the paddocks on July 19 in 1967 and on July 17 in 1968. Sheep preceded the cattle by one day each year.

Grazing intensity was determined by the key species technique in the first paddock grazed by sheep in 1967. When common dandelion (Taraxacum officinale) received about 75 percent use and bluebells received about 85 percent use, the sheep were removed. All subsequent grazing periods that year were of the same duration as in the first paddocks. Cattle paddocks were stocked with animals such that their gross weights approximated that of the sheep and were grazed for the same number of days as were the sheep. Two sheep died during the grazing season, but 17 to 19 ewes and yearlings used each sheep paddock for 15 days while 3 large Holstein cows grazed each cattle paddock for 15 days (Table 4).

The pregrazing production estimate in the first paddock grazed by sheep in 1968 showed that there was only approximately two-thirds as much forage as had been produced in 1967. Accordingly, the grazing period was reduced to 10 days in order to get the same relative forage removal

Table 4. Animal days use at Webster Flat, 1966-68.

Treatment	Paddock	Animal Days Use Per Acre 1 (1966)[a]	2 (1967)	3 (1968)
Cattle	B	17.5	32.8	29.2
	F	17.5	32.8	29.2
	C	17.5	32.8	29.2
	Mean	17.5	32.8	29.2
Approximate gross weights[c]		--	2700	2400
Sheep	H	72.9	206.6	146
	D	72.9	197.1	146
	I	72.9	194.2	146
	Mean	72.9	199.3[b]	146
Approximate gross weights[c]		--	2200	2200

[a]Data taken from Scotter and Doell (1967).

[b]Different days use for each paddock in year 2 (1967) because of death losses.

[c]Weights not known for year 1 (1966).

as in 1967. Twenty yearling sheep and 4 Hereford heifers were grazed for 10 days in each cattle paddock. Water and salt were positioned to obtain more uniform use of the vegetation during both years.

Aspen Sprouts and Clumps. An aspen sprout was designated as one that had sprouted at any time since the 1965 logging operation. An inventory of aspen sprouts was made on 50 milacre plots immediately after each paddock was grazed. The plots were square, permanently staked, and located in the same manner as the forage production and utilization plots.

The following data were recorded in each plot; (1) number of sprouts, (2) number of sprouting clumps, (3) number of browsed sprouts, (4) number of sprouts with browsed terminal buds, (5) number of sprouts damaged by pocket gophers, (6) number of sprouts damaged by trampling, and (7) number of sprouts damaged by disease. Insect damage was not considered important so information on its effect was not collected. Damage by the 1967-68 winter snowpack was important so its effect on aspen sprouts was evaluated the following summer.

Production of aspen sprouts was recorded as total sprout weight in 1966 and as the weight of leaves and terminal portions in 1967 and 1968. These years are hereafter identified as year 1, 2, and 3 respectively. Leaves and terminal inch of the sprouts were the parts selected by grazing animals and amounted to about 30 percent of the total sprout weight.

Pocket Gophers. In early June of 1968 an additional inventory was made on all aspen plots to determine the amount of pocket gopher damage that occurred under the winter and spring snowpack. A literature review and personal communications indicated that damage from this cause occurred in the winter while the ground underneath the snowpack was soft (Ellison and Aldous, 1952; Welsh, 1968).

Statistical Analysis. Analyses of variance were computed to determine if significant differences existed between years, treatments, and grazing periods. The number of sprouts, clumps, browsed sprouts, browsed terminal buds, pocket gopher-damaged sprouts, and trampled sprouts were analyzed separately. Changes in the number of sprouts and clumps with

time were of chief concern. The F test was used to determine significance. The following model was used in statistical computation.

Source of variation	Degrees of freedom
Years	1
Treatments	2
Periods	2
Y x T	2
Y x P	2
T x P	4
Y x T x P	4
Line/Paddock	162
Plot/Line	720
Total	899

RESULTS AND DISCUSSION

Production and Utilization

Production of herbage was directly related to the amount of summer precipitation (Tables 1 and 5). Year 1 had the lowest four month summer rainfall and produced an average of 570 pounds of herbage (excluding aspen) per acre for all treatments. Year 2 received a heavy summer precipitation and had a high production of herbage which averaged 1,113 pounds per acre. Year 3 received an average rainfall and produced an average of 601 pounds of herbage per acre for all treatments.

Since the manner of recording data differed in Year 1, similar comparisons of aspen production were not possible. Moreover, the rapidly growing sprouts could be expected to show increased production irrespective of precipitation.

Utilization was different in all three years (Table 6 and Appendix Tables B, C, E, F, H, and I). Utilization in year 1 was obtained by grazing a large number of animals for a short period of time and much of the apparent use was due to trampling. Grasses, sedges, forbs, and shrubs received little use even though the key species, bluebells, was used moderately. In year 2, a smaller number of animals were grazed a longer length of time. The key species were used heavily but the average herbage use was light. Sheep made heavier use on the key species than cattle. In year 3, even heavier use was made of the key species and total herbage utilization by both sheep and cattle was also heavy. The utilization of aspen sprouts was light in all three years.

Table 5. Pounds of forage produced per acre (air-dried weight) in cattle, sheep, and protected paddocks for three years after clear-cutting at Webster Flat.

Grazing period	Forage class	Cattle			Sheep			Protected		
		1966	1967	1968	1966	1967	1968	1966	1967	1968
1	Grass and sedges	457	613	216	145	388	201	136	426	374
	Forbs	448	458	195	324	620	279	258	696	289
	Shrubs	11	40	29	2	5	3	T	1	2
	Aspen[a]	217	171	546	125	305	449	149	968	948
	Totals[b]	1133	1282	986	596	1318	932	543	2091	1613
2	Grass and sedges	247	610	325	218	670	320	170	797	529
	Forbs	555	675	363	256	547	201	285	511	239
	Shrubs	7	12	16	1	1	T	1	10	9
	Aspen[a]	204	206	551	57	216	385	198	678	728
	Totals[b]	1013	1503	1255	532	1434	907	653	1996	1505
3	Grass and sedges	387	606	373	126	510	344	165	450	497
	Forbs	365	300	202	190	336	134	371	715	230
	Shrubs	3	3	9	---	2	3	1	14	35
	Aspen[a]	96	134	250	70	206	411	261	506	1004
	Totals[b]	851	1043	834	386	1054	892	798	1689	1766
Mean	Grass and sedges	364	610	305	163	523	288	157	558	467
	Forbs	456	478	253	257	501	205	305	641	253
	Shrubs	7	18	17	1	3	2	1	8	15
	Aspen[a]	172	170	449	84	242	415	203	717	893
	Totals[b]	999	1276	1025	505	1269	910	666	1925	1628

[a]Expressed as total sprout weight in 1966 but thereafter it includes only the leaves and terminal portion of the sprout normally removed by browsing.

[b]Total of grass and sedges, forbs, shrubs, and apical portion of the aspen sprouts.

Table 6. Mean percentage utilization by forage classes in cattle and sheep paddocks for three consecutive years after clear-cutting at Webster Flat.

Grazing period	Forage Class	Cattle			Sheep		
		1966	1967	1968	1966	1967	1968
1	Grass and sedges	43	17	72	16	17	67
	Forbs	45	25	72	38	46	78
	Shrubs	4	8	25	0	41	87
	Aspen	6[a]	1[b]	1	5	6	12
2	Grass and sedges	21	33	69	20	31	77
	Forbs	37	30	65	6	42	85
	Shrubs	1	T[c]	26	0	30	95
	Aspen	4	T	6	6	14	17
3	Grass and sedges	51	44	69	12	49	73
	Forbs	54	38	80	45	52	79
	Shrubs	12	7	9	--	25	90
	Aspen	8	2	3	11	12	17
Mean	Grass and sedges	38	31	70	20	32	72
	Forbs	45	31	72	19	47	81
	Shrubs	6	5	20	0	32	91
	Aspen	6	1	3	7	11	15

[a]Expressed as percentage of total weight utilized.

[b]Expressed as percentage of leaves and the terminal portion of the sprout.

[c]Trace is less than one-half of one percent.

Forage Removal

Except for the cattle treatment in year 2, similar amounts of forage were removed from the cattle and sheep treatments during the second and third years after clear-cutting (Table 7). In year 2 the sheep removed an average of 430.5 pounds of forage per acre and in year 3 they removed an average of 437.5 pounds per acre. The grazing periods were 15 days in 1967 and 10 days in 1968. Although a similar amount of forage was removed between years, it was taken at a slower rate in year 2 and it is believed that the frequent, heavy rainstorms that summer decreased feeding time and forage intake. In year 2 the Holstein cows removed an average of 339.9 pounds of forage per acre and in year 3 the Hereford heifers removed an average of 412.8 pounds per acre. The different rates of forage removal were thought to be due to differences in the kind and number of cows plus adverse weather conditions.

Aspen Sprout and Clump Changes

The number of aspen sprouts and aspen clumps decreased in all treatments during the three years following initial sprouting after clear-cutting (Figure 3 and Table 8). The difference in the number of sprouts and clumps in all treatments between years 2 and 3 was highly significant at the 99 percent confidence level.

An average decrease of 17,103 sprouts and 4,890 clumps per acre occurred during the three year period in the cattle treatment. The greatest decrease in sprout numbers occurred between years 1 and 2, but clump numbers showed the greatest decrease between years 2 and 3. Although a lesser number of sprouts was lost between years 2 and 3, the percentage loss was greater because of the fewer sprouts present in year 2. The

Table 7. Average forage production, percent utilization, and pounds of forage removed by cattle and sheep during the second and third years after clear-cutting at Webster Flat.

Year[a]	Forage class	Production in pounds per acre	Percent of forage utilized (air-dried weight)	Pounds of forage utilized per acre	Production in pounds per acre	Percent of forage utilized (air-dried weight)	Pounds of forage utilized per acre
		Cattle			Sheep		
		3 Holstein Cows			7 Ewes and 10-12 Yearlings[b]		
2	Grass and grasslike	610	31	189.1	523	32	167.4
	Forbs	478	31	148.2	501	47	235.5
	Shrubs	18	5	.9	3	32	1.0
	Aspen	170	1	1.7	242	11	26.6
	Total	1276		339.9	1269		430.5
		4 Hereford Heifers			20 Yearlings		
3	Grass and grasslike	305	70	213.5	288	72	207.4
	Forbs	253	72	182.2	205	81	166.1
	Shrubs	18	20	3.6	2	91	1.8
	Aspen	449	3	13.5	415	15	62.2
	Total	1025		412.8	910		437.5

[a]Years 2 and 3 correspond to 1967 and 1968 respectively.

[b]Two yearlings died during the study period.

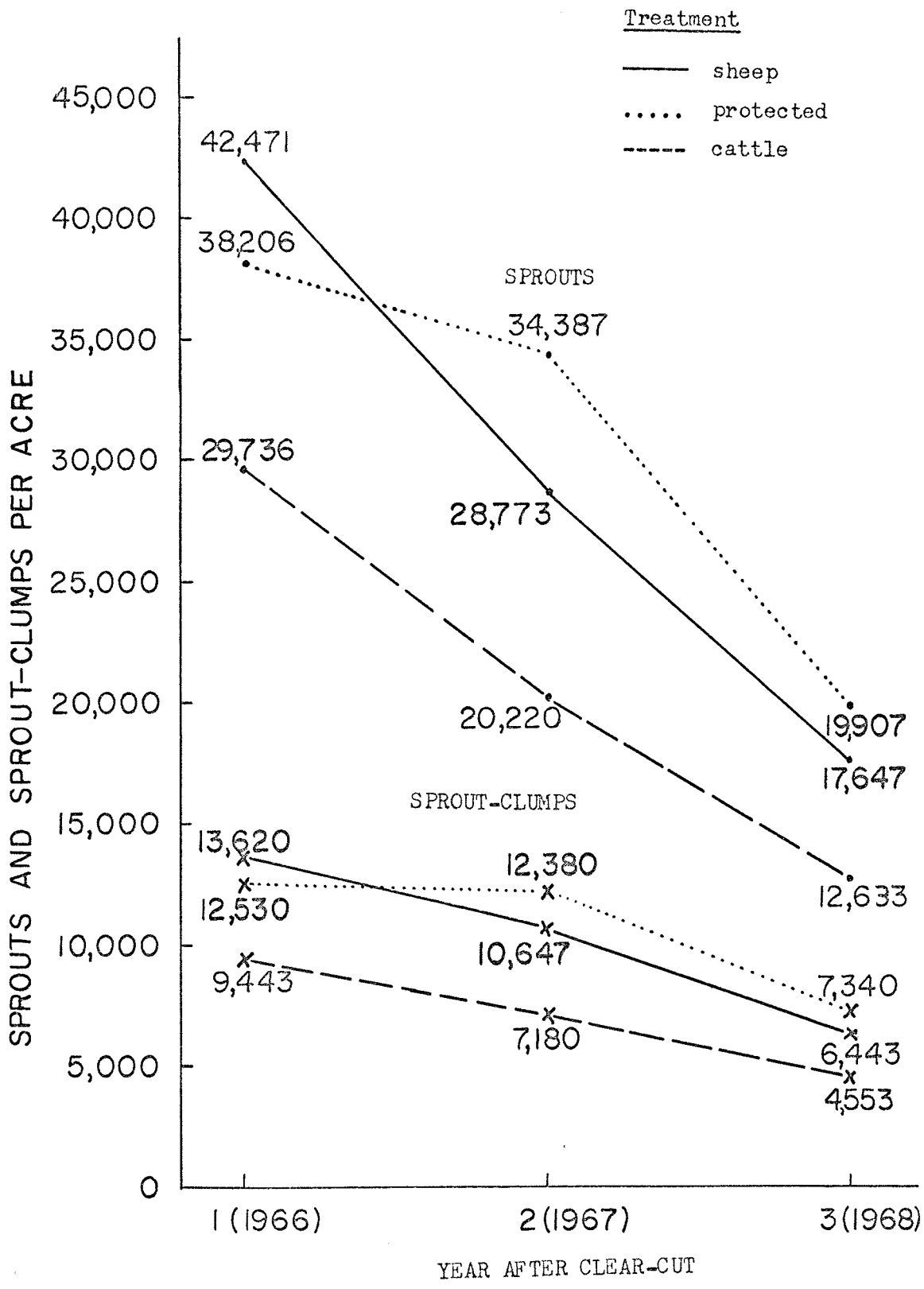


Figure 3. The mean number of aspen sprouts and sprout-clumps per acre for cattle, sheep, and protected treatments during the first three years after clear-cutting at Webster Flat.

Table 8. The number and percentage changes in aspen sprouts and sprout-clumps per acre for the three treatments during three consecutive years following clear-cutting at Webster Flat.

Treatment	Change between years 1 and 2				Change between years 2 and 3				Change between years 1 and 3			
	Sprouts		Clumps		Sprouts		Clumps		Sprouts		Clumps	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
Cattle	9,516	32.0	2,263	24.0	7,587	37.5	2,627	36.6	17,103	57.5	4,890	51.8
Sheep	13,698	32.2	2,973	21.8	11,126	38.7	4,214	39.6	24,824	58.4	7,187	52.8
Protected	3,819	10.0	150	1.2	14,480	42.1	5,040	40.7	18,299	47.9	5,190	41.4

percentage decrease in clumps was slightly smaller than that for sprouts over the three year period, but in both instances the decrease exceeded 50 percent.

The sheep treatment had an average decrease of 24,824 sprouts and 7,187 clumps per acre during the three year period. The yearly pattern of sprout and clump decrease under sheep grazing was similar to the pattern under cattle grazing, although the magnitude of sprout decrease was greater. The percentage decreases were similar to those in the cattle treatment, but because of a greater initial stand, the number of sprouts lost was actually greater. Initially there were 12,735 more sprouts per acre in the sheep paddocks due to a better site, but at the end of year 3 the differential was only 5,014 more sprouts per acre.

In the protected treatments, sprouts per acre decreased by an average of 18,299 and clumps per acre decreased by 5,190 over the three year period. The yearly pattern of sprout and clump decrease was different from the cattle and sheep patterns. Between years 1 and 2 the decrease in the number of sprouts and clumps was very small, whereas the decrease between years 2 and 3 was very large. The relatively high mortality of sprouts after three years suggested that about 50 percent of the shoots sprouting from areas of high site quality will die whether they are grazed or not.

Sprout Mortality Factors

Some of the reasons for the decrease in aspen sprouts include: livestock browsing, livestock trampling, pocket gopher damage, disease damage, and snowpack damage. Analyses of variance were computed to detect changes between years 2 and 3 in browsed sprouts, browsed terminal buds, pocket gopher-damaged sprouts, and trampled sprouts. Highly significant

differences were found in browsed sprouts, browsed terminal buds, and pocket gopher-damaged sprouts, but not in trampled sprouts.

In both the cattle and the sheep treatments there were fewer browsed sprouts and browsed terminal buds in year 3 than in year 2 (Figure 4 and Tables 9 and 10). The decrease in sprout and terminal bud use in both treatments was highly significant. The increase in sprout height and diameter were thought to be the chief reasons for the decreased use. Increased sprout height made terminal buds less available by year 3, while the increase in stem diameter and increase in woodiness is thought to have made the terminal portion of the stem less palatable. Trampling damage in year 3 was slightly less in the cattle treatment and slightly greater in the sheep treatment than in year 2, but neither change was statistically significant (Figure 4). Most of the sprouts damaged by trampling in year 2 were in good condition in year 3.

The number of sprouts damaged by pocket gophers showed a highly significant increase between years 2 and 3 (Figure 5). The sheep treatment had the greatest use in year 2, but the protected treatment received the most use in year 3. With the exception of the protected treatment during year 2, pocket gopher damage seemed to be inversely correlated to sprout abundance (Figures 3 and 5). This suggests that gopher damage may be a more important sprout decimating factor in later years or under low site conditions when there are fewer sprouts per acre. For example, paddock C of low site had 740 sprouts per acre damaged by gophers in year 2 but had 2,240 injured in year 3.

Pocket gopher damage is especially important because gopher damage is likely to kill the sprouts or even entire clumps, whereas a much smaller

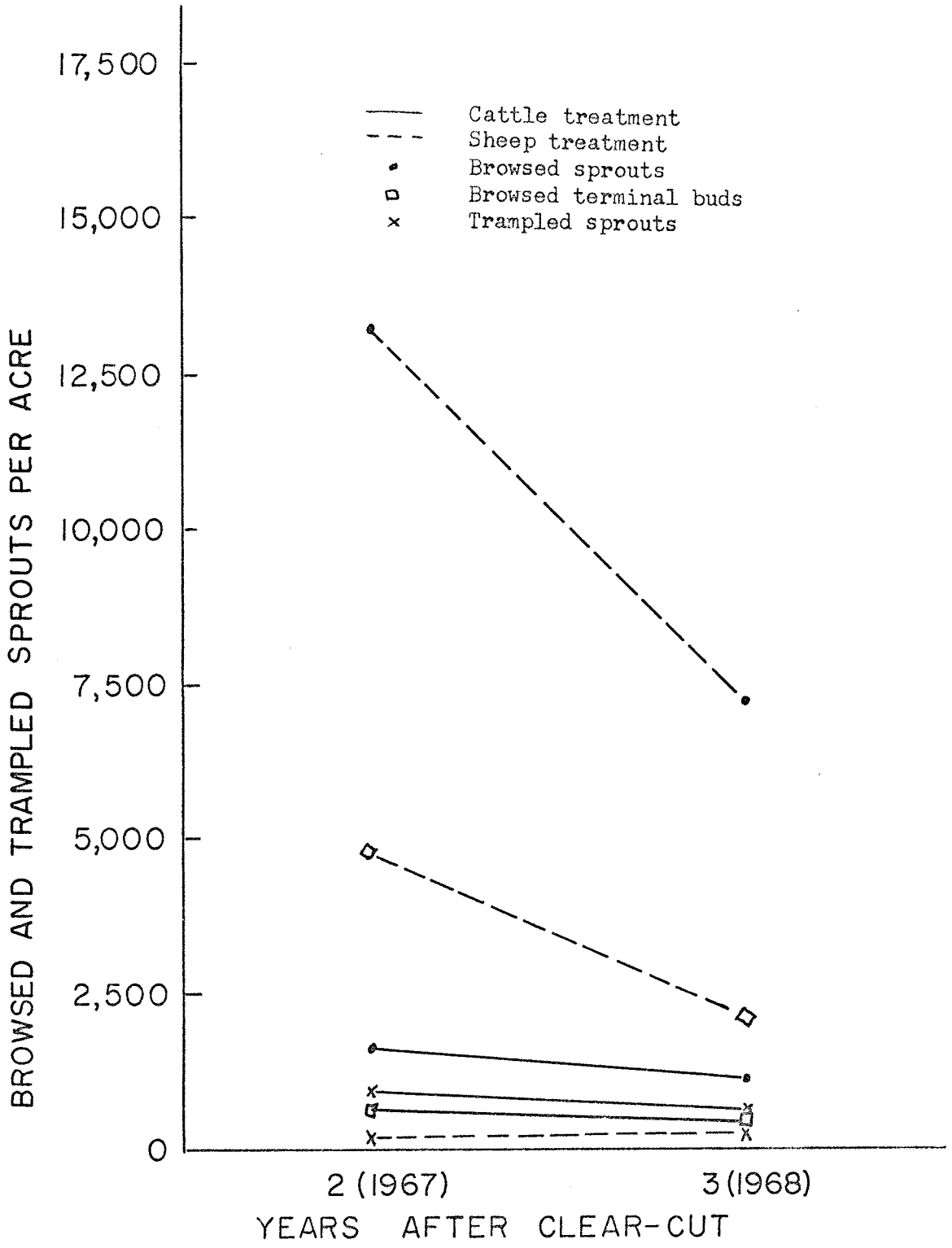


Figure 4. The mean number of browsed and trampled sprouts per acre for cattle and sheep treatments during the second and third years after clear-cutting at Webster Flat.

Table 9. The number of aspen sprouts, sprout-clumps, browsed sprouts, sprouts with terminal bud browsed by cattle or sheep, sprouts damaged by pocket gophers, sprouts damaged by trampling, and sprouts damaged by disease the second year (1967) after clear-cutting at Webster Flat.

Treatment	Grazing period	No. sprouts per acre	No. clumps per acre	Browsed[a] sprouts		Browsed[b] terminal	
				No.	Percent	No.	Percent
Controlled Cattle		23,120	8,560	2,160	9.3	540	2.3
	1						
Controlled Sheep		37,000	13,800	17,300	46.8	6,600	17.8
Controlled Cattle		16,240	6,080	840	5.2	440	2.7
	2						
Controlled Sheep		26,200	10,220	14,220	54.3	5,040	19.2
Controlled Cattle		21,300	6,900	1,860	8.7	980	4.6
	3						
Controlled Sheep		23,120	7,920	8,220	35.6	2,740	11.8
	Mean						
Controlled Cattle		20,220	7,180	1,620	8.0	660	3.3
Controlled Sheep		28,773	10,647	13,240	46.0	4,800	16.7
	Paddock						
Protected	G	36,040	13,080	---	---	---	---
	E	30,500	10,160	---	---	---	---
	A	36,620	13,900	---	---	---	---
Mean		34,387	12,380				

[a]Includes all sprouts that were browsed.

[b]Includes only sprouts which had terminal buds removed.

Table 9. Continued.

Treatment	Grazing period	Pocket gopher damaged		Trampling damaged		Disease damaged	
		No.	Percent	No.	Percent	No.	Percent
Controlled Cattle	1	880	3.8	1,220	5.3	1,160	5.0
Controlled Sheep	1	760	2.0	0	0	1,720	4.6
Controlled Cattle	2	380	2.3	900	5.5	1,600	9.8
Controlled Sheep	2	1,180	4.5	580	2.2	1,040	4.0
Controlled Cattle	3	740	3.5	640	3.0	5,920	27.8
Controlled Sheep	3	1,540	6.7	40	.2	3,940	17.0
Controlled Cattle	Mean	660	3.3	920	4.6	2,900	14.3
Controlled Sheep	Mean	1,160	4.0	200	.7	2,200	7.7
	Paddock						
Protected	G	380	1.0	---	---	4,200	11.7
	E	1,000	3.0	---	---	3,840	12.6
	A	640	1.8	---	---	3,060	8.4
Mean		673	2.0			3,700	10.8

Table 10. The number of aspen sprouts, sprout-clumps, browsed sprouts, sprouts with terminal bud browsed by cattle or sheep, sprouts damaged by pocket gophers, sprouts damaged by trampling, sprouts damaged by disease, and sprouts damaged by snowpack the third year (1968) after clear-cutting at Webster Flat.

Treatment	Grazing period	No. sprouts per acre	No. clumps per acre	Browsed sprouts		Browsed terminal	
				No.	Percent	No.	Percent
Controlled Cattle	1	16,700	6,140	560	3.4	120	.7
Controlled Sheep	1	22,500	8,500	6,140	27.2	2,660	11.8
Controlled Cattle	2	11,340	4,260	360	3.2	160	1.4
Controlled Sheep	2	16,860	6,180	8,940	53.0	2,220	13.2
Controlled Cattle	3	9,860	3,260	2,400	24.3	1,080	11.0
Controlled Sheep	3	13,500	4,620	6,320	46.8	1,380	10.2
Controlled Cattle	Mean	12,633	4,553	1,107	8.8	453	3.6
Controlled Sheep	Mean	17,647	6,433	7,133	40.4	2,087	11.8
	Paddock						
Protected	G	19,800	6,680	---	---	---	---
	E	16,260	6,100	---	---	---	---
	A	23,660	9,240	---	---	---	---
Mean		19,907	7,340				

Table 10. Continued.

Treatment	Grazing period	Pocket gopher damaged		Trampling damaged		Disease damaged		Snowpack damaged	
		No.	Percent	No.	Percent	No.	Percent	No.	Percent
Controlled Cattle		1,480	8.9	1,000	6.0	1,380	8.3	80	.5
	1								
Controlled Sheep		2,420	10.8	240	1.1	1,480	6.6	800	3.5
Controlled Cattle		1,120	9.8	880	7.8	1,140	10.1	620	5.5
	2								
Controlled Sheep		1,860	11.0	440	2.6	1,640	9.7	200	1.2
Controlled Cattle		2,240	22.7	140	1.4	1,320	13.4	80	.8
	3								
Controlled Sheep		2,240	16.6	80	.6	1,920	14.2	340	2.5
	Mean								
Controlled Cattle		1,613	12.8	673	5.3	1,280	10.1	260	2.1
Controlled Sheep		2,173	12.3	253	1.4	1,680	9.5	447	2.5
	Paddock								
Protected	G	3,900	19.7	---	---	1,440	7.3	1,640	8.3
	E	3,120	19.2	---	---	2,460	15.1	1,300	8.0
	A	1,100	4.6	---	---	1,440	6.1	1,300	5.5
Mean		2,707	13.6			1,780	8.9	1,413	7.1

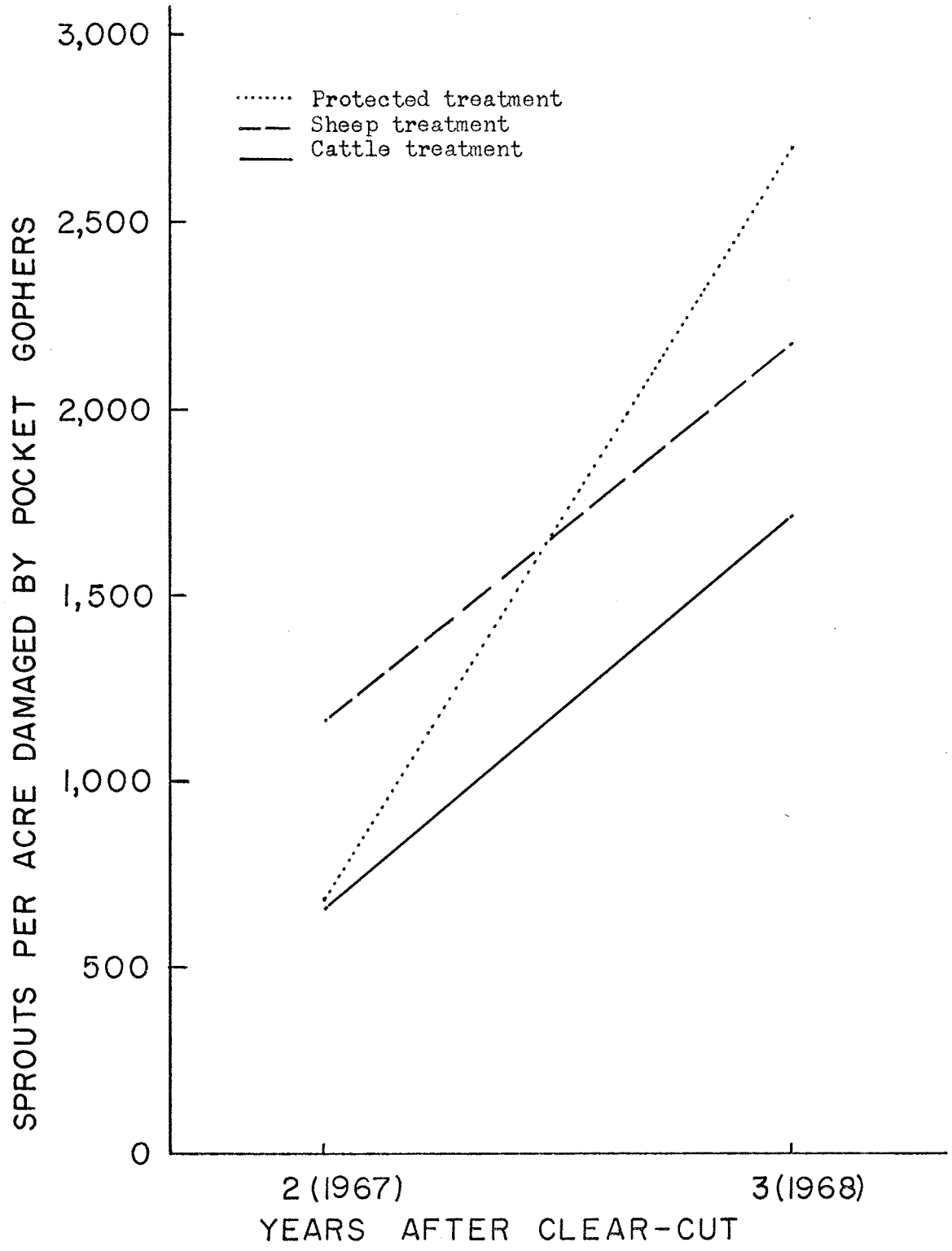


Figure 5. The mean number of sprouts per acre damaged by pocket gophers for cattle, sheep, and protected treatments during the second and third years after clear-cutting at Webster Flat.

proportion of sprouts affected by the other debilitating factors are killed. During the second and third years after clear-cutting pocket gopher damage was carefully observed. From these observations it was thought that pocket gophers may have been the most important causes of sprout mortality.

Examination of sprouts for evidence of pocket gopher damage after snowmelt in early June and at the end of the summer in 1968 showed most of the damage occurred in the winter or spring under the snowpack (Table 11). In all treatments, a total of 1,560 more sprouts per acre were severed at the base of the lateral root during the winter and spring than in the summer. The increased gopher activity in the winter is thought to have resulted from the deep winter snowpack which kept the ground fairly warm and moist thus making tunneling easier. Personal observations also revealed increase in summer tunneling for brief periods following a major rain storm.

Pathogens were important aspen sprout mortality factors. In all treatments the average percent of sprouts affected by disease ranged from 7 to 14 percent for year 2 and 3, but the number of sprouts affected decreased by more than one-half from year 2 to 3 (Tables 9 and 10). This suggests that disease may damage more sprouts in earlier and denser growth stages but, unlike grazing, may damage a similar proportion of sprouts in later years. Disease, like gopher damage, is an important factor because many of the affected sprouts are killed.

Snowpack damage was noticeable following the third winter. By this time the sprouts had reached a height and stem diameter that made them susceptible to bending from the weight of the snow. Several large sprouts

Table 11. The number of aspen sprouts damaged by the northern pocket gopher (Thomomys talpoides) during winter-spring and summer seasons at Webster Flat the third year after clear-cutting.

Treatment	Paddock	Winter - Spring damaged sprouts per acre (1968)[a]		Summer damaged sprouts per acre (1968)[a]	
		No.	Percent	No.	Percent
Cattle	B	1,100	6.6	380	2.3
	F[b]	560	4.9	560	4.9
	C	1,280	13.0	960	9.7
	Mean	980	7.8	633	5.0
Sheep	H	2,220	9.8	200	1.0
	D	1,280	8.0	580	3.0
	I	1,580	11.7	660	4.9
	Mean	1,693	9.6	480	2.7
Protected	G	2,360	11.9	1,540	7.8
	E[b]	980	6.0	2,140	16.2
	A	720	3.0	380	1.6
	Mean	1,353	6.8	1,353	6.8

[a]Sprouts of clipped stems or lateral roots which are killed.

[b]Exceptions to general pattern.

rising from the same clump were affected more than smaller sprouts or large sprouts that were isolated. This observation was supported by the protected treatment in year 3, which had the greatest number of sprouts and clumps per acre and also received the heaviest damage (Table 10). Livestock trampling may have contributed to this problem. The percentage of snowpack-damaged plants that will die or produce poor wood quality in the future is not known.

Effect of Treatment

Differences in site quality and other unknown factors resulted in large initial differences in the number of sprouts between paddocks. After the random assignment of paddocks to treatments the sheep treatment contained the greatest number of sprouts per acre and the cattle treatment had the least (Figure 3). Since an attempt was made to keep livestock stocking rates comparable on a livestock weight basis and the number of initial sprouts were different, a treatment comparison based on the number of sprouts lost was thought to be more accurate than one based on the number of sprouts present at a given time or on a percentage of sprouts lost. Although the sprout mortality in percentage was similar in all treatments, the number of sprouts lost differed greatly.

The protected treatment had a much smaller three-year loss of sprouts than the sheep treatment, but the loss of sprouts in the protected treatment was slightly greater than in the cattle treatment (Table 8). At the end of year 1 the protected treatment averaged 4,265 fewer sprouts per acre than the sheep treatment, but after year 3 the protected area averaged 2,260 more sprouts per acre. A better site and unknown factors resulted in 8,470 more sprouts per acre in the protected treatment than the cattle

treatment in year 1, but after year 3 the protected area had only 7,244 more sprouts per acre. This implies that other factors besides cattle use are responsible for sprout decreases.

The percentage sprout decrease in the protected treatment was about 10 percent less than both sheep and cattle treatments. Because there were great differences in the number of initial sprouts in each paddock and treatment, it was not possible to make statistical tests of the differences. But, a combination of numerical and percentage comparisons imply that protection from grazing only provided a slightly better sprout survival than moderate cattle grazing.

The number of browsed sprouts, browsed terminal buds, and pounds of aspen removed were compared in the cattle and sheep treatments to ascertain if the differential sprout loss could be explained by forage preference of the animals.

Sheep inflicted heavier use on aspen sprouts than cattle as demonstrated by the greater number of browsed sprouts, browsed terminal buds, and pounds of available aspen per acre consumed during both year 2 and 3 (Figure 4, and Table 7). In year 2, sheep browsed an average of 8 times more sprouts, 7 times more terminal buds, and removed 15 times more pounds of available aspen than cattle (Tables 9 and 7). During year 3 sheep browsed an average of 6 times more sprouts, 4 times more terminal buds, and removed 4 times more pounds of available aspen than cattle (Tables 7 and 10). These large differences in sprout use indicate that sheep prefer aspen sprouts more than do cattle. This difference in sprout preference probably contributed to a loss of 7,721 more sprouts per acre in the sheep treatment than in the cattle treatment.

Sheep use may have also slowed sprout growth. After three years the average sprout heights were 37 inches in the sheep treatment, 45 inches in the cattle treatment, and 45 inches in the protected treatment (Table 12). Sheep browsing may have reduced sprout growth rates enough to make terminal buds susceptible to one more year of browsing in the sheep treatment, whereas at the end of the third year sprouts in the cattle and protected treatments had grown beyond the reach of sheep. The effect of a retarded growth rate on future growth rates and wood quality is not known.

Cattle damaged a greater number of sprouts by trampling than did sheep. The difference was highly significant. However, relatively few sprouts were permanently injured by trampling from either class of livestock in year 2 or year 3.

Effect of Season

In the cattle treatment, the number of terminal buds browsed was largest in the third grazing period during years 2 and 3 (Tables 9 and 10). The difference is highly significant, but was somewhat complicated by a fewer number of shorter and weaker sprouts as a result of a poor site in the paddock assigned the third grazing period. The magnitude of the difference in browsing of the terminal buds between the third period and the first two periods suggests that cattle utilize more terminal buds later in the season.

In the sheep treatment, the number of terminal buds utilized was largest in the first period during years 2 and 3 (Table 9 and 10). The second period had the highest percentage of browsed sprouts during both years. Sprout availability may be more important than period of grazing as is

Table 12. Height of aspen sprouts in cattle, sheep, and protected treatments the first (1966) and third years (1968) after clear-cutting at Webster Flat.

Treatment	Paddock		Height of sprouts in 1966 No.		Height of sprouts in 1966 Average height	Height of sprouts in 1968 No.		Height of sprouts in 1968 Average height
Controlled Cattle	B		497		16.0	141[a]		43
	F		220		19.0	135		49
	C		267		13.4	80		41
		Total	984	Average	16.0	Total 356	Average	45[b]
Controlled Sheep	H		514		16.5	210		37
	D		412		12.4	172[a]		34
	I		476		12.6	202		39
		Total	1,402	Average	14.0	Total 584	Average	37
Protected	G		325		21.5	244[a]		42
	E		461		22.4	105		45
	A		479		20.4	216		49
		Total	1,265	Average	21.4	Total 565	Average	45

[a]Measurements taken in June, while others were taken in August.

[b]Height measurement in inches.

shown in year 2 when sprout browsing was directly proportioned to the numbers of sprouts available. However, the differences between periods were not pronounced. Also, sheep coming off a winter range may have utilized a greater amount of woody material when first reaching the study area due to the time needed to adjust to the increased amount and variety of herbaceous forage present on the summer range.

CONCLUSIONS AND RECOMMENDATIONS

Type of animal use affected aspen sprout survival. Sheep utilized more sprouts, terminal buds, and pounds of available aspen than cattle during the second and third years after cutting. Cattle trampled more sprouts than sheep, but most trampled sprouts were not permanently injured. Differences in site and the number of initial sprouts confounded treatment comparisons. However, large differences between cattle and sheep in sprout utilization and sprout mortality implied that sheep grazing was more detrimental to aspen sprouts than cattle grazing. Sheep use also may have slowed sprout growth, which may effect future wood quality.

The period of grazing affected aspen utilization. Cattle browsed more terminal buds in late summer than in earlier periods. Sheep seemed to utilize more sprouts in earlier periods, which might have been a result of their slow adjustment to the increased herbaceous forage present in the aspen type after a winter spent on the desert.

Protection from grazing influenced aspen sprout success. During the three-year period, sprout numbers decreased about 58 percent in the grazing treatments compared to 48 percent in the protected treatment. The greatest sprout mortality in the protected treatment occurred between years 2 and 3. Pocket gopher damage also increased during this time and was responsible for some of the increased sprout mortality. Plant competition also may have been a factor, but its effects were not measured. Disease and snow-pack damage were other causes of sprout mortality in all treatments.

Pocket gophers and disease may have been the greatest decimating factors, but they are usually impractical or uneconomical to control.

Pocket gopher damage could become extremely important in areas of low reproduction, and some kind of control may be needed under these circumstances although costs generally are prohibitive. Costs of control in Utah averaged $1.13 per acre for initial treatments and $.51 for re-treatment (Richens, 1967).

The production and variety of forbs, grasses, and shrubs probably had an important influence on the use of aspen reproduction by livestock. The relatively high summer precipitation and fertile soil of the study area caused a high production of a variety of forage. Cattle preferred herbaceous forage and did not heavily utilize aspen when other forage types were present. Sheep utilized aspen sprouts more than cattle, but did not eliminate reproduction under the controlled conditions of the study. Grazing made use of many aspen sprouts which would have been lost anyway.

Stage of sprout growth also had an important influence on use and success of aspen reproduction. First year sprouts were short and entirely susceptible to grazing by livestock. Young sprouts were also less woody and more palatable. Thus grazing misuse is most likely to occur at this stage. A well balanced mixture of grass, forbs, and shrubs can divert some grazing, but sheep use can become excessive under careless handling. Many authorities prescribe light grazing by cattle or complete protection of aspen the first year after clear-cutting (Baker, 1918; Sampson, 1919). Second year sprouts were still susceptible to overuse, but moderate grazing did not prevent adequate reproduction. Third year sprouts had attained sufficient height and woodiness to be less susceptible to grazing injury, although they were still within reach of livestock. A larger amount of total forage can be removed at this stage without damaging aspen sprouts.

Most fourth year sprouts probably will be immune to serious livestock injury, because of their height and woodiness.

Site, as measured on the basis of cords of wood present before cutting, was probably an important factor in the number of initial sprouts. Better sites produced more sprouts per acre. Also, according to the literature, better sites may produce sprouts that are more disease-resistant. The quality of a site should be considered when determining the kind of animal and the intensity of use on cutover aspen areas.

After three years of controlled grazing and protection from grazing at clear-cut aspen sites, there were still more aspen shoots remaining than were needed to regenerate the stand. Assuming that about 12,000 sprouts per acre are needed after three years to restock a stand, the protected treatment averaged about 8,000 more sprouts per acre than were needed. The sheep treatment, which contained paddocks of good sites, could have withstood an additional reduction of 1,000 to 10,000 sprouts per acre, depending on the paddock. The retarded growth rate resulting from sheep use may allow for this removal in the fourth year. The cattle treatment, which contained paddocks of low to medium site quality, had about the proper amount of sprouts per acre, with the exception of one low site paddock which was borderline.

The results of this study indicated that controlled grazing by cattle or sheep may be practiced after clear-cutting on sites where there are 14 or more cords of wood per acre. Sites where there are 8 or less cords of wood per acre probably require protection from all grazing for the first year, and protection or light use during the second and third year following clear-cutting to insure adequate aspen regeneration. Recommendations

based on site assume that similar sites will produce an equal number of initial sprouts, but other factors besides prior wood production undoubtedly affect sprouting. Therefore, all factors should be considered in determining proper grazing intensities.

Bed grounds and other livestock concentration areas, especially characteristic of sheep allotments, can severely damage or even eliminate aspen reproduction, thus special care by the livestock operator and land manager should be exercised to obtain proper livestock distribution. The requirement of a 30-acre minimum for each clear-cut area and proper herding can prevent much of this damage.

Rather high use can be made on key forage species, but use must not be so severe as to result in a shortage of herbaceous forage. There must be ample desirable grass and forbs to absorb the grazing pressure. Aspen sprouts cannot withstand heavy use, especially during the initial year of sprouting.

SUMMARY

1. A study was conducted on a clear-cut aspen area in southwestern Utah on the Dixie National Forest to determine the effects of livestock, pocket gophers, disease and snowpack upon the success of aspen reproduction. Nine 1.37-acre paddocks were fenced. Three paddocks each were grazed by cattle and sheep, and three were protected from grazing. Data were collected for three years, 1966 through 1968.

2. Sheep used more sprouts, terminal buds, and pounds of available aspen than cattle, which may have contributed to greater sprout mortality and shorter sprout height observed in the sheep treatment. The period of heaviest aspen use was different for cattle and sheep. Cattle utilized the most terminal buds in the last grazing period, whereas sheep made greater use of the terminal buds in earlier grazing periods.

3. Cattle trampled more sprouts than sheep. However, most trampled sprouts did not appear to be permanently injured, although they may have been more susceptible to snowpack damage.

4. Survival of aspen sprouts was 10 percent greater under protection from grazing than under livestock grazing. Percentage-wise, there was little difference in sprout survival under cattle and sheep use. Assuming about 12,000 sprouts per acre are required the third year after cutting to successfully regenerate an aspen stand, the protected treatment provided 8,000 and sheep about 6,000 more sprouts per acre than were needed. Only in the cattle treatment was the number of sprouts borderline, and this was due to a poor site.

5. Pocket gophers and disease were thought to have been the most important decimating factors in the protected treatment, but plant competition also may have been an important factor. Sources of sprout mortality other than livestock use under controlled grazing were pocket gophers, disease, and snowpack damage. Pocket gophers and disease killed more sprouts than any other factors. Although livestock use decreased with time, disease damage remained constant in the first three years and pocket gopher damage increased. Pocket gopher damage could become very important in areas of low reproduction, but costs of control may be uneconomical.

6. The high production and variety of herbaceous forage in the study area absorbed most of the grazing pressure, thus preventing heavy use of sprouts. A balanced mixture of grass, forbs, and shrubs is probably essential if clear-cut areas are to be grazed without harming aspen reproduction.

7. Year of grazing after clear-cutting was probably the most important factor affecting grazing damage to aspen sprouts. First year sprouts were very susceptible to overgrazing because of their short height and high palatability. Increased height and woodiness of sprouts during the second and third years made sprouts more resistant to livestock damage. Most sprouts will probably be tall enough by the fourth year to be immune from harmful grazing.

8. Site had an important influence on the number of initial sprouting shoots. Better sites produced more sprouts. Controlled grazing by cattle or sheep did not prevent aspen reproduction on sites that produced 14 or more cords of wood per acre. Grazing may need to be prohibited the first year and restricted to cattle the second and third years on sites which produce 8 or less cords. In addition, other factors unique to each specific area should be considered when determining proper grazing intensities.

9. For management purposes, a 30-acre minimum cut-over area and proper herding are needed to prevent livestock from concentrating on logged areas and causing aspen sprout damage. Sheep are especially likely to concentrate, and special care should be exercised to prevent misuse by sheep in early sprout growth stages.

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APPENDIX TABLES

Appendix A. Dry weight of forage production at Webster Flat, 1964 (after Smith and Doell, 1966).

Species	Mean forage production, lbs./acre 20, .96 sq. ft. plots Strata 1	20, .96 sq. ft. plots Strata 2	20, .96 sq. ft. plots Strata 3
Grasses			
Agropyron trachycaulum	11	17	7
Bromus carinatus	172	30	68
Poa spp.	34	123	187
Stipa lettermani	41	41	37
Lazula spp.	21	--	--
Carex spp.	--	14	7
	279	225	306
Forbs			
Achillea millefolium	7	17	18
Delphinium nelsonii	15	5	5
Erigeron spp.	--	2	--
Mertensia spp.	26	--	9
Ranunculus spp.	5	--	5
Stellaria jamesiana	20	25	4
Taraxacum officinale	142	134	161
Thlaspi spp.	56	6	--
Thalictrum fendleri	--	4	--
Trifolium pratense	--	2	--
Vicia americana	46	29	32
Misc. forbs	35	18	2
	352	242	236
Browse			
Populus tremuloides	--	5	--
Symphoricarpos oreophilus	--	2	--
		7	
Total	631	474	542

Appendix B. Forage production and utilization of forage species in cattle paddocks on Webster Flat, 1966 (after Scotter and Doell, 1967).

Species	Paddock B		Paddock F		Paddock C	
	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)
Grass and grasslike:						
Agropyron trachycaulum	111	34	69	4	29	21
Agrostis scabra	--	--	3	75	10	64
Bromus carinatus	100	20	72	8	56	18
Carex chalciolepis	2	10	--	--	--	--
C. occidentalis	11	45	6	34	5	60
Koeleria cristata	--	--	1	0	2	10
Melica bulbosa	--	--	--	--	1	0
Poa pratensis	207	61	84	46	271	62
Stipa columbiana	14	29	6	1	2	0
S. lettermani	12	36	6	20	11	27
Sub-total	457		247		387	
Forbs:						
Achillea millefolium	4	25	1	1	29	54
Agoseris glauca	1	60	--	--	--	--
Arabis glabra	7	0	3	0	1	0
Chenopodium album	6	8	4	0	4	0
Delphinium sp.	--	--	1	0	--	--
Descurainia sophia	30	0	42	0	4	1
Erigeron speciosus	--	--	1	0	19	55
E. ursinus	1	0	--	--	1	0

Appendix B. Continued.

Species	Paddock B Production in pounds/acre (air-dried weight)	Paddock B Utilization (%)	Paddock F Production in pounds/acre (air-dried weight)	Paddock F Utilization (%)	Paddock C Production in pounds/acre (air-dried weight)	Paddock C Utilization (%)
Forbs: (Continued)						
Mertensia arizonica	7	70	283	52	35	68
Phacelia heterophylla	2	50	3	0	3	1
Polygonum aviculare	6	0	2	0	2	0
Ranunculus inamoenus	6	0	1	40	--	--
Senecio multilobatus	65	0	71	0	18	0
Stellaria jamesiana	8	1	7	4	12	11
Taraxacum officinale	285	65	118	48	230	62
Thalictrum fendleri	1	50	5	18	--	--
Trifolium longipes	1	0	--	--	--	--
Vicia americana	17	31	14	6	3	23
Viguiera multiflora	1	55	--	--	--	--
Sub-total	448		555		365	
Shrub and sprout:						
Populus tremuloides[a]	217	6	204	5	96	8
Symphoricarpos oreophilus	11	4	7	T[b]	3	12
Sub-total	228		211		99	
TOTAL	1,133		1,013		851	

[a]Total sprout weight.

[b]Trace, less than one-half of one percent utilization.

Appendix C. Forage production and utilization of forage species in sheep paddocks on Webster Flat, 1966 (after Scotter and Doell, 1967).

Species	Paddock H		Paddock D		Paddock I	
	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)
Grass and grasslike:						
Agropyron trachycaulum	28	3	43	2	27	1
Agrostis scabra	--	--	1	10	5	18
Bromus carinatus	29	9	31	5	29	5
Carex occidentalis	3	34	1	18	4	20
C. praegracilis	--	--	16	30	1	0
Koeleria cristata	1	0	2	0	2	0
Melica bulbosa	5	0	1	10	1	0
Poa pratensis	72	26	106	33	42	26
Stipa columbiana	1	1	3	0	2	1
S. lettermani	6	9	14	2	13	3
Sub-total	145		218		126	
Forbs:						
Achillea millefolium	2	8	12	11	1	1
Arabis glabra	1	0	3	0	2	0
Calochortus nuttallii	--	--	--	--	1	0
Chenopodium album	T	0	1	50	--	75
Delphinium sp.	43	7	10	34	--	--
Descurainia sophia	4	0	9	2	2	0
Erigeron speciosus	5	35	3	50	--	0
Mertensia arizonica	92	57	75	50	34	56
Phacelia heterophylla	16	11	9	16	1	5

Appendix C. Continued.

Species	Paddock H Production in pounds/acre (air-dried weight)	Paddock H Utilization (%)	Paddock D Production in pounds/acre (air-dried weight)	Paddock D Utilization (%)	Paddock I Production in pounds/acre (air-dried weight)	Paddock I Utilization (%)
Forbs: (Continued)						
Ranunculus inamoenus	--	--	2	30	1	43
Senecio multilobatus	50	1	6	3	23	0
Stellaria jamesiana	6	0	17	1	20	0
Taraxacum officinale	103	60	102	75	102	63
Tragopogon porrifolius	--	--	--	--	1	75
Vicia americana	2	5	6	10	2	1
Trifolium longipes	--	--	1	0	--	--
Sub-total	324		256		190	
Shrub and sprout:						
Populus tremuloides[a]	125	5	57	6	70	11
Symphoricarpos oreophilus	2	0	1	0	--	--
Sub-total	127		58		70	
TOTAL	596		532		386	

[a]Total sprout weight.

Appendix D. Forage production of all forage species in protected paddocks on Webster Flat, 1966 (after Scotter and Doell, 1967).

Species	Production in pounds per acre (air-dried weight) Paddocks G	E	A
Grass and grasslike:			
Agropyron trachycaulum	52	44	51
Agrostis scabra	--	1	2
Bromus carinatus	25	47	42
Carex occidentalis	3	1	12
C. praegracilis	1	--	--
Koeleria cristata	1	T	--
Melica bulbosa	1	3	1
Poa pratensis	43	63	25
Stipa columbiana	3	--	2
S. lettermani	7	11	30
Sub-total	136	170	165
Forbs:			
Achillea millefolium	1	5	--
Agastache urticifolia	--	--	1
Agoseris glauca	1	--	--
Arabis glabra	2	1	9
Chenopodium album	T[a]	--	3
Descurainia sophia	18	3	67
Erigeron speciosus	14	2	--
E. ursinus	T	--	--
Hydrophyllum capitatum	4	--	--
Mertensia arizonica	49	159	27
Osmorhiza chilensis	--	1	--
Phacelia heterophylla	13	--	--
Ranunculus inamoenus	T	1	--
Senecio multilobatus	22	33	187
Stellaria jamesiana	16	16	17
Taraxacum officinale	105	59	46
Thalictrum fendleri	1	--	1
Vicia americana	12	--	13
Viguiera multiflora	--	5	--
Sub-total	258	285	371
Shrub and sprout:			
Populus tremuloides[b]	149	197	261
Symphoricarpos oreophilus	T	1	1
Sub-total	149	198	262
TOTAL	543	653	798

[a]Trace, less than 1 pound per acre.

[b]Total sprout weight.

Appendix E. Forage production and utilization of forage species in cattle paddocks on Webster Flat, 1967.

Species	Paddock B		Paddock F		Paddock C	
	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)
Grass and grasslike:						
Agropyron trachycaulum	78	2	99	22	80	25
Agrostis scabra	1	5	--	--	11	38
Bromus carinatus	70	16	137	37	43	32
B. tectorum	--	--	--	--	T	50
Carex occidentalis	4	33	2	53	--	--
C. praegracilis	3	14	--	--	1	80
Melica bulbosa	3	48	2	42	1	33
Phleum alpinum	1	3	T	0	--	--
Poa pratensis	441	28	349	40	452	57
Stipa columbiana	4	T	15	37	7	42
S. lettermani	6	17	5	54	4	42
Trisetum spicatum	2	0	1	15	7	38
Sub-total	613		610		606	
Forbs:						
Achillea millefolium	7	10	3	13	2	54
Agoseris glauca	1	1	--	--	--	--
Allium acuminatum	1	0	1	0	T	50
Androsace septentrionalis	T	0	2	0	T	0
Arabis glabra	19	8	11	44	6	17
Calochortus nuttallii	--	--	1	0	--	--
Claytonia lanceolata	T	0	--	--	--	--
Chenopodium album	1	22	1	44	4	37
Delphinium barbeyi	10	5	6	62	--	--
D. nelsoni	9	64	10	3	--	--

Appendix E. Continued.

Species	Paddock B Production in pounds/acre (air-dried weight)	Paddock B Utilization (%)	Paddock F Production in pounds/acre (air-dried weight)	Paddock F Utilization (%)	Paddock C Production in pounds/acre (air-dried weight)	Paddock C Utilization (%)
Forbs: (Continued)						
Descurainia pinnata	10	10	17	6	4	30
Erigeron flagellaris	1	0	--	--	--	--
E. speciosus	9	5	10	44	--	--
E. ursinus	5	32	T	100	--	--
Fritillaria atropurpurea	1	0	--	--	--	--
Mertensia arizonica	67	43	243	64	155	78
Microsteris gracilis	1	0	1	12	--	--
Phacelia leucophylla	1	22	3	32	10	42
Polygonum aviculare	--	--	2	22	2	26
Ranunculus inamoenus	8	12	15	43	3	42
Senecio eremophilus	41	6	174	11	38	36
Stellaria jamesiana	33	38	38	38	8	33
Taraxacum officinale	172	44	55	53	40	69
Thalictrum fendleri	15	54	--	--	--	--
Thlaspi glaucum	--	--	--	--	T	17
Tragopogon porrifolius	--	--	T	0	2	68
Trifolium longipes	4	49	--	--	7	71
Urtica angustifolia	9	10	--	--	--	--
Vicia americana	32	32	82	64	19	73
Viguiera multiflora	1	0	--	--	--	--
Sub-total	458		675		300	
Shrubs and Sprout:						
Populus tremuloides[a]	171	1	206	1	134	2
Symphoricarpos oreophilus	40	8	12	T	3	7
Sub-total	210		218		137	
TOTAL	1,282		1,503		1,043	

[a]Buds and leaves.

Appendix F. Forage production and utilization of forage species in sheep paddocks on Webster Flat, 1967.

Species	Paddock H		Paddock D		Paddock I	
	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)
Grasses and grasslike:						
Agropyron trachycaulum	70	19	89	12	200	40
Agrostis scabra	4	1	32	12	30	37
Bromus carinatus	86	21	68	17	101	40
Carex occidentalis	3	25	2	73	1	88
C. praegracilis	--	--	T	90	--	--
Melica bulbosa	14	25	2	22	3	52
Phleum alpinum	--	--	T	15	--	--
Poa pratensis	196	14	458	21	146	61
Stipa columbiana	3	11	5	8	15	35
S. lettermani	8	21	4	34	6	42
Trisetum spicatum	4	19	10	7	8	50
Sub-total	388		670		510	
Forbs:						
Achillea millefolium	17	40	28	50	9	30
Allium acuminatum	3	71	2	1	T	14
Androsace septentrionalis	--	--	T	17	--	--
Arabis glabra	19	22	9	34	6	26
Claytonia lanceolata	T	0	--	--	--	--
Chenopodium album	2	29	2	52	2	78
Delphinium barbeyi	112	13	18	78	--	--
D. nelsoni	20	79	4	28	--	--
Descurainia pinnata	23	35	11	31	20	35
Erigeron flagellaris	--	--	4	12	T	0
E. speciosus	T	80	12	74	--	--
E. ursinus	T	0	T	34	T	0

Appendix F. Continued.

Species	Paddock H Production in pounds/acre (air-dried weight)	Paddock H Utilization (%)	Paddock D Production in pounds/acre (air-dried weight)	Paddock D Utilization (%)	Paddock I Production in pounds/acre (air-dried weight)	Paddock I Utilization (%)
Forbs: (Continued)						
Hydrophyllum capitatum	11	80	--	--	--	--
Mertensia arizonica	65	79	138	82	6	89
Microsteris gracilis	3	42	2	19	--	--
Osmorhiza chilensis	1	0	--	--	--	--
Phacelia leucophylla	8	64	3	22	17	57
Polygonum aviculare	T	0	1	23	4	84
Ranunculus inameonus	9	66	14	47	1	85
Senecio eremophilus	76	11	106	11	180	10
Stellaria jamesiana	34	50	43	35	22	38
Taraxacum officinale	183	73	122	78	40	82
Thalictrum fendleri	8	82	2	90	T	90
Thlaspi glaucum	--	--	1	42	--	--
Trifolium longipes	--	--	--	--	1	86
Vicia americana	26	60	25	78	28	85
Sub-total	620		547		336	
Shrubs and sprout:						
Populus tremuloides[a]	305	6	216	14	242	11
Symphoricarpos oreophilus	5	41	1	30	2	25
Sub-total	310		217		244	
TOTAL	1,318		1,434		1,269	

[a]Buds and leaves.

Appendix G. Production of all forage species in protected paddocks on Webster Flat, 1967.

Species	Production in pounds per acre (air-dried weight) Paddocks G	E	A
Grasses and grasslike:			
Agropyron trachycaulum	228	201	177
Agrostis scabra	4	25	3
Bromus carinatus	90	92	141
Carex occidentalis	--	--	2
C. praegracilis	--	--	T
Melica bulbosa	3	1	4
Phleum alpinum	4	--	1
Poa pratensis	82	467	102
Stipa columbiana	12	4	17
S. lettermani	1	T	3
Trisetum spicatum	2	7	T
Sub-total	426	797	450
Forbs:			
Achillea millefolium	19	13	7
Allium acuminatum	T	T	--
Androsace septentrionalis	T	--	--
Arabis glabra	10	3	6
Chenopodium album	8	32	1
Delphinium nelsoni	T	T	T
Descurainia pinnata	17	11	6
Erigeron flagellaris	1	--	--
E. speciosus	13	--	3
Mertensia arizonica	280	307	117
Microsteris gracilis	--	T	--
Osmorhiza chilensis	--	1	1
Phacelia leucophylla	10	10	8
Polygonum aviculare	5	3	1
Ranunculus inamoenus	26	2	1
Senecio eremophilus	270	88	494
Stellaria jamesiana	6	3	11
Taraxacum officinale	6	5	15
Thalictrum fendleri	--	4	10
Thlaspi glaucum	1	--	T
Tragopogon porrifolius	T	--	1

Appendix G. Continued.

Species	Production in pounds per acre (air-dried weight) Paddocks G	E	A
Forbs: (Continued)			
Trifolium longipes	T	--	--
Vicia americana	22	29	32
Viquiera multiflora	2	--	1
Sub-total	696	511	715
Shrub and sprout:			
Populus tremuloides[a]	968	678	506
Symphoricarpos oreophilus	1	10	14
Sub-total	969	688	520
TOTAL	2,091	1,996	1,685

[a]Buds and leaves.

Appendix H. Forage production and utilization of forage species in cattle paddocks on Webster Flat, 1968.

Species	Paddock B		Paddock F		Paddock C	
	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)
Grass and grasslike:						
Agropyron trachycaulum	19	43	42	40	74	55
Agrostis scabra	--	--	--	--	10	71
Bromus carinatus	62	67	135	76	59	72
B. tectorum	--	--	--	--	--	--
Carex occidentalis	1	81	1	92	--	--
C. praegracilis	1	90	--	--	2	89
Melica bulbosa	2	94	1	95	2	79
Phleum alpinum	1	70	4	60	--	--
Poa pratensis	126	86	139	82	216	85
Stipa columbiana	1	8	1	50	5	69
S. lettermani	1	86	1	69	4	83
Trisetum spicatum	2	93	1	60	1	20
Sub-total	216		325		373	
Forbs:						
Achillea millefolium	3	64	1	40	8	74
Agoseris glauca	2	78	--	--	--	--
Allium acuminatum	T	0	T	0	T	0
Androsace septentrionalis	1	38	--	--	T	95
Arabis glabra	T	48	T	48	T	95
Calochortus nuttallii	--	--	--	--	T	95
Chenopodium album	1	64	3	70	5	85
Delphinium barbeyi	17	50	3	65	--	--
D. nelsonii	1	95	1	68	T	71
Descurainia pinnata	5	35	16	23	11	68
Erigeron flagellaris	1	95	--	--	1	84

Appendix H. Continued.

Species	Paddock B		Paddock F		Paddock C	
	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	
Forbs: (Continued)						
Erigeron speciosus	4	55	3	88	4	84
E. ursinus	T	95	--	--	1	94
Lathyrus leucanthus	7	74	21	74	6	81
Mertensia arizonica	77	91	253	87	105	91
Microsteris gracilis	T	95	5	95	T	95
Osmorhiza chilensis	--	--	T	60	T	95
Phacelia leucophylla	3	62	4	54	3	55
Polygonum aviculare	1	63	2	59	5	79
Ranunculus inamoenus	5	94	5	73	T	60
Stellaria jamesiana	14	86	15	76	9	87
Taraxacum officinale	29	79	21	73	28	78
Thalictrum fendleri	17	95	--	--	--	--
Thlaspi glaucum	--	--	--	--	2	95
Tragopogon porrifolius	--	--	1	95	1	95
Trifolium longipes	1	95	--	--	4	69
Urtica angustifolia	2	90	--	--	T	--
Vicia americana	2	81	7	87	5	95
Sub-total	195		363		202	
Shrub and sprout:						
Populus tremuloides[a]	546	1	551	6	250	3
Symphoricarpos oreophilus	29	25	16	26	9	35
Sub-total	575		567		259	
TOTAL	986		1,255		834	

[a]Buds and leaves.

Appendix I. Forage production and utilization of forage species in sheep paddocks on Webster Flat, 1968.

Species	Paddock H		Paddock D		Paddock I	
	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)
Grasses and grasslike:						
Agropyron trachycaulum	36	49	51	35	98	40
Agrostis scabra	T	65	17	70	30	82
Bromus carinatus	45	62	71	64	124	73
B. tectorum	T	48	--	--	--	--
Carex occidentalis	2	93	1	95	2	95
C. praegracilis	--	--	T	95	--	--
Melica bulbosa	5	81	1	95	2	91
Phleum alpinum	5	85	T	95	--	--
Poa pratensis	104	84	168	85	74	85
Stipa columbiana	1	40	3	53	11	53
S. lettermani	1	79	5	75	1	85
Trisetum spicatum	1	48	2	80	2	50
Sub-total	201		320		344	
Forbs:						
Achillea millefolium	3	88	5	61	8	82
Allium acuminatum	T	0	--	--	T	0
Androsace septentrionalis	--	--	T	63	T	95
Arabis glabra	2	73	T	95	T	63
Chenopodium album	5	92	2	83	1	91
Claytonia lanceolata	--	--	T	95	--	--
Delphinium barbeyi	103	38	9	75	--	--
D. nelsonii	2	82	T	95	T	95
Descurainia pinnata	11	67	12	58	17	61
Erigeron flagellaris	--	--	T	85	--	--
E. speciosus	1	95	2	80	--	--
E. ursinus	--	--	--	--	T	95

Appendix I. Continued.

Species	Paddock H		Paddock D		Paddock I	
	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)	Production in pounds/acre (air-dried weight)	Utilization (%)
Forbs: (Continued)						
Hydrophyllum capitatum	2	95	8	95	--	--
Lathyrus leucanthus	6	94	3	95	9	89
Mertensia arizonica	44	91	90	92	18	96
Microsteris gracilis	2	83	T	95	--	--
Phacelia leucophylla	7	9	3	89	8	70
Polygonum aviculare	10	91	1	73	4	84
Ranunculus inamoenus	15	93	5	88	1	58
Senecio eremophilus	1	90	--	--	T	48
Stellaria jamesiana	19	94	9	95	14	94
Taraxacum officinale	39	92	47	88	46	90
Thalictrum fendleri	2	95	--	--	T	95
Thlaspi glaucum	--	--	T	95	--	--
Trifolium longipes	--	--	T	95	1	95
Urtica angustifolia	T	90	--	--	--	--
Vicia americana	4	93	1	89	5	92
Sub-total	279		201		134	
Shrub and sprout:						
Populus tremuloides[a]	449	12	385	17	411	17
Symphoricarpos oreophilus	3	87	T	95	3	90
Sub-total	552		386		414	
TOTAL	932		907		892	

[a]Buds and leaves.

Appendix J. Production of all forage species in protected paddocks on Webster Flat, 1968.

Species	Production in pounds per acre (air-dried weight) Paddocks G	E	A
Grasses and grasslike:			
Agropyron trachycaulum	126	62	114
Agrostis scabra	1	5	4
Bromus carinatus	135	114	275
Carex occidentalis	T	--	3
C. praegracilis	--	T	4
Melica bulbosa	2	2	2
Phleum alpinum	16	2	3
Poa pratensis	88	340	61
Stipa columbiana	2	1	28
S. lettermani	2	1	T
Trisetum spicatum	1	1	2
Sub-total	374	529	497
Forbs:			
Achillea millefolium	5	5	T
Agoseris glauca	T	--	--
Allium acuminatum	--	--	T
Androsace septentrionalis	T	T	--
Arabis glabra	--	--	1
Chenopodium album	20	20	3
Claytonia lanceolata	--	T	--
Descurainia pinnata	7	5	12
Erigeron flagellaris	1	--	--
E. speciosus	5	--	2
E. ursinus	--	--	1
Hydrophyllum capitatum	--	--	T
Lathyrus leucanthus	15	7	33
Mertensia arizonica	190	161	98
Osmorhiza chilensis	--	T	T
Phacelia leucophylla	14	11	9
Polygonum aviculare	9	3	5
Ranunculus inamoenus	6	1	2
Stellaria jamesiana	11	5	16
Taraxacum officinale	13	10	26
Thalictrum fendleri	1	5	5
Tragopogon porrifolius	1	T	1
Vicia americana	5	4	10
Viquiera multiflora	--	--	4
Sub-total	289	239	230
Shrubs:			
Populus tremuloides[a]	948	728	1,004
Symphoricarpos oreophilus	2	9	35
Sub-total	950	737	1,039
TOTAL	1,613	1,505	1,766

[a]

Appendix K. Analyses of variance for years, treatments, and periods. The number of sprouts, clumps, browsed sprouts, browsed terminal buds, pocket gopher damaged sprouts, and trampled sprouts in each plot between years 2 and 3 were analysed.

Source of variation	Degrees of freedom	Mean squares					
		Sprouts	Clumps	Browsed sprouts	Browsed terminal bud	Pocket gopher damaged sprouts	Trampled sprouts
Years	1	26885.1**	3640.1**	1078.0**	200.7**	60.3**	1.4
Treatments	2	8891.8**	1290.6**	1030.7**	1030.7**	29.8**	52.0**
Periods	2	2966.2**	476.7**	129.2*	32.7**	12.0*	7.6**
Y x T	2	782.5	128.3*	867.3**	175.0**	2.0	1.6
Y x P	2	176.3	47.8	286.5**	22.9*	27.5**	.5
T x P	4	1260.1**	295.5**	281.4**	73.8**	6.7	5.1
Y x T x P	4	184.5	28.5	147.9**	11.2	10.4*	1.1
Experimental error	162	317.2	31.3	27.5	5.8	4.1	.9
Sampling error	720	331.7	35.2	32.1	7.0	3.4	.9
TOTAL	899						

* Significant at .05 level.

** Significant at .01 level.

VITA

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