



EFFECT OF GRAZING UPON ASPEN REPRODUCTION.

By ARTHUR W. SAMPSON, *Plant Ecologist.*

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PURPOSE.

It is desirable that on lands bearing a stand of aspen (*Populus tremuloides*)¹ a proper balance be maintained between timber production and grazing. In many of the National Forests, particularly those in northern New Mexico and Arizona, in Colorado and Utah, and in portions of Idaho and Nevada, aspen is a tree of considerable commercial value. It is used chiefly for fuel, posts, corral poles, lumber, boxwood, excelsior, and mine props, and the demand for it is steadily increasing. As a protective cover for watersheds, aspen, by reason of its extensive lateral root system, is probably more valuable than any other tree species with which it commonly is found.

¹ Some taxonomists claim that the proper title of the western aspen is *Populus aurea* Tidestrom being distinguished from the more eastern *Populus tremuloides* Michaux by certain technical differences in the flowers and fruit, as well as by the fact that after frost the leaves of the former take on a golden-orange rather than a light-yellow hue. Without entering into the merits of the question, the present usage of the Forest Service is here adhered to.

Beneath the aspen, which ordinarily grows in rather open stands, is usually a luxuriant understory of grasses, weeds, and browse that is grazed with relish by all kinds of live stock. As range land, the aspen type is much more valuable than either the spruce-fir type just above it or the oak-brush type just below it. Unfortunately, however, the stock, especially sheep, do not confine themselves to the forage, no matter how abundant and palatable it may be; they also eat the foliage and tender twigs of the young aspen. This, of course, means that the aspen reproduction is often badly injured or even killed, which makes it very difficult in many cases to secure a second stand of timber.

A study, the results of which are presented in this bulletin, has been made to determine the extent of injury to aspen reproduction by sheep and cattle, the effects of such damage on the development of the young trees, and the best method of protecting the reproduction from injury without unnecessarily restricting the grazing of live stock. Though the results are meant to apply especially to conditions in the National Forests, they may also be of value, possibly with slight modifications, in the case of farm woodlands in the East where the forage under aspen is converted into meat or butter fat.

METHOD.

The study, which covered a period of five years (1902 to 1916 inclusive), was conducted on the Manti National Forest, in central Utah, where the timber and forage are typical of the commercial aspen type in National Forests.

A general study was made on 122 sample plots in virgin and lightly thinned aspen, at elevations between 7,500 and 10,000 feet, in both sheep and cattle ranges and covering all variations in timber and forage.

A detailed study of the extent and growth of aspen reproduction and the extent of its injury by stock and other agencies was made on selected clear-cut areas, four of which were located on sheep range and two on cattle range. Two of the plots on the sheep range and one on the cattle range were securely fenced against stock (Plate I); the others were left open to grazing. The reason for selecting clear-cut areas for the intensive study of reproduction is that aspen reproduces mainly by sprouts from the roots of older trees and the best method of harvesting mature aspen is to cut the timber clear.

On each clear-cut area transect and quadrat sample plots were established so that the sprouts originally observed could be definitely located in future examinations.

In 1913 and 1914 all plots were examined twice—once in June and again in September. In subsequent seasons only the transects and quadrats on the clear-cut areas were examined twice during a

season, the plots in the standing timber being examined only in the autumn.

The reproduction injured or killed was classified according to height, sprouts of from about 6 inches to 1½ feet constituting the youngest class, those from 1½ to 2½ feet the second class, and so on up to sprouts 4½ feet high. Record was also made of the intensity of grazing; that is, whether it was light, medium, or heavy. Plots were classed as "lightly grazed" where 50 per cent or less of the palatable vegetation had been cropped; "moderately grazed" where from 50 to 70 per cent of the forage had been consumed, and "heavily grazed" where more than 75 per cent of the palatable vegetation had been eaten.

INJURY TO ASPEN REPRODUCTION BY LIVE STOCK IN STANDING TIMBER.

EFFECT OF SHEEP BROWSING.

Injurious browsing of aspen reproduction means the removal by stock of terminal or lateral shoots, or both, to a sufficient extent to interfere more or less seriously with the subsequent growth and development of the sprouts. The removal of a single lateral twig or the mere nipping of the terminal bud are disregarded, since the study has shown that to interfere seriously with the food manufacturing power or with the form development of the young trees at least one-fourth of the total number of branches must be destroyed. If browsing is confined to the upper half of the sprout, including the terminal shoot, the damage is more serious, especially so far as concerns the ultimate form of the tree.

Table 1 summarizes the effects of sheep browsing on plots in standing timber, according to seasons and to the intensity of grazing. There is also given the number of sprouts injured by other things than livestock. Of a total of 16,631 sprouts observed during the five years of study; 17.1 per cent were killed and 27.3 per cent were more or less injured by browsing, while 37.5 per cent were uninjured. It is noteworthy that 11.7 per cent of the total number of sprouts were killed and 6.3 per cent injured by causes other than grazing. Unfavorable climatic conditions and the activities of bark-eating rodents were chiefly responsible for these results. It is evident that very few vigorous sprouts remain to perpetuate the stand where sheep grazing is continued.

Considerable variation in extent of injury to the reproduction occurs in different seasons. In the case of the lightly grazed plots, for example, only 3.7 per cent of the aspen reproduction was injured in 1912, but the percentage was 30.8 in 1913. Similar variations occur in the case of moderately grazed and heavily grazed plots.

They are probably due more or less to chance. No appreciable difference was observed in the extent and degree of injury by browsing during different portions of the season so long as the foliage remained intact. When the wood of the stems hardens the stems are browsed practically not at all by cattle and only to a limited extent by sheep.

The effect of the intensity of grazing on the vigor and growth of the reproduction is better shown by figures covering a number of years. These are given in Table 2, which summarizes the data on intensity of grazing presented in Table 1.

The lighter the grazing the greater is the percentage of uninjured sprouts. Thus, on the lightly grazed plots more than half (58.2 per cent) of the total number observed were uninjured; on the moderately grazed plots a little less than half (43.8 per cent); and on the heavily grazed areas only about a fifth of the stand (22.2 per cent) escaped injury.

TABLE 1.—*Injury to aspen sprouts on plots in standing timber.*

Grazing intensity and year of examination.	Total number of sprouts.	Uninjured sprouts.		Killed by grazing.		Injured by grazing.		Sprouts killed by causes other than grazing.		Sprouts injured by causes other than grazing.	
		Num-ber.	Per-cent.	Num-ber.	Per-cent.	Num-ber.	Per-cent.	Num-ber.	Per-cent.	Num-ber.	Per-cent.
Lightly grazed:											
1912.....	108	104	96.3			4	3.7				
1913.....	954	633	66.3	21	2.2	294	30.8				
1914.....	1,169	652	55.7	89	7.6	219	18.7				
1915.....	595	233	39.1	95	15.9	41	6.9				
1916.....	267	176	65.9	36	13.5	40	15.0				
Moderately grazed:											
1912.....	128	117	91.4			5	3.9				
1913.....	880	617	70.1			252	28.6				
1914.....	2,697	1,011	37.5	303	11.2	532	19.7				
1915.....	1,864	571	30.6	327	17.5	227	12.1				
1916.....	1,127	611	54.2	146	12.9	310	27.6				
Heavily grazed:											
1912.....	154	138	89.6	9	5.8	3	1.9				
1913.....	458	234	51.3			223	48.7				
1914.....	2,471	624	25.2	412	16.7	1,192	48.3				
1915.....	2,632	370	14.0	688	26.1	964	36.6				
1916.....	1,127	151	13.4	712	63.2	239	21.2				
Total.....	16,631	6,242		2,838		4,545		1,449		1,057	
Average.....			37.5		17.1		27.3		11.7		6.3

TABLE 2.—*Injured, killed, and uninjured aspen sprouts on plots in standing timber subject to sheep grazing during a five-year period.*

Period of examinations and grazing intensity.	Total number of sprouts examined.	Uninjured sprouts.		Sprouts killed by grazing.		Sprouts injured by grazing.	
		Num-ber.	Per-cent.	Num-ber.	Per-cent.	Num-ber.	Per-cent.
1912-1916:							
Lightly grazed.....	3,093	1,798	58.2	241	7.8	598	19.4
Moderately grazed.....	6,686	2,927	43.8	776	11.6	1,352	20.2
Heavily grazed.....	6,842	1,517	22.2	1,821	26.6	2,621	38.4

RELATION BETWEEN INTENSITY OF GRAZING AND INJURY TO SPROUTS.

The character of injury to sprouts will, of course, largely determine (1) the subsequent density of the aspen stand, (2) the ultimate form of the trees, (3) the subsequent rate of growth, and (4), to a considerable extent at least, the size of the trees and the commercial value of the timber. The removal of the leader or terminal shoots of aspen reproduction, for instance, may destroy the symmetry of the tree, especially if the leader is removed more than once. The injury caused by the destruction of lateral branches is chiefly physiological, the nutriment on which the specimen may build being roughly proportionate to the number of laterals; i. e., to the leaf area.

The extent of browsing of leaders and laterals, or both, the mortality due to excessive browsing, and the number of sprouts uninjured on the plots in standing timber during 1915 and 1916 are summarized in Table 3. The greatest number of specimens were under observation during these two years.

TABLE 3.—*Character and extent of injury to sprouts according to intensity of grazing, seasons 1915 and 1916. Plots in standing timber.*

Season and grazing intensity.	Total sprouts killed.	Ungrazed sprouts.	Leaders browsed.	Leaders and laterals browsed.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1915:				
Lightly grazed.....	15.9	39.1	4.5	2.3
Moderately grazed.....	17.5	30.6	4.3	7.7
Heavily grazed.....	26.1	14.0	21.5	15.1
1916:				
Lightly grazed.....	13.5	65.9	7.8	7.1
Moderately grazed.....	12.9	54.2	14.6	12.8
Heavily grazed.....	63.2	12.9	4.4	16.7

Both in 1915 and 1916 the mortality was practically the same on lightly grazed and on moderately grazed plots, the average percentage being 14.9 (fig. 1). On the heavily grazed plots, however, the mortality of sprouts was appreciably greater, being 26.1 per cent of the total in 1915 and 63.2 per cent in 1916. The percentage of ungrazed sprouts in 1916 was more than five times as much on the lightly grazed areas and four times as much on the moderately grazed areas as on the heavily grazed plots. The general tendency is the same in the 1916 figures. The averages for 1915 and 1916 on lightly grazed plots was 52.5 per cent, on the moderately grazed areas 42.4 per cent, and on the heavily grazed plots only 13.4 per cent.

The number of terminal shoots or "leaders" removed was practically the same (averaging 4.4 per cent) on lightly and on moderately grazed plots in 1915; but on the heavily grazed areas it was considerably larger, amounting to 21.5 per cent. In 1916 the terminal shoots of 7.8 per cent of the specimens were consumed on lightly

grazed plots, of 14.6 per cent on moderately grazed areas, and of 4.4 per cent on heavily grazed plots. The small percentage on the heavily grazed plots is due to the high mortality of specimens on these plots in previous seasons, which left for observation relatively few specimens having terminal shoots. Table 5 shows that for the whole period from 1912 to 1916, inclusive, the greatest number of

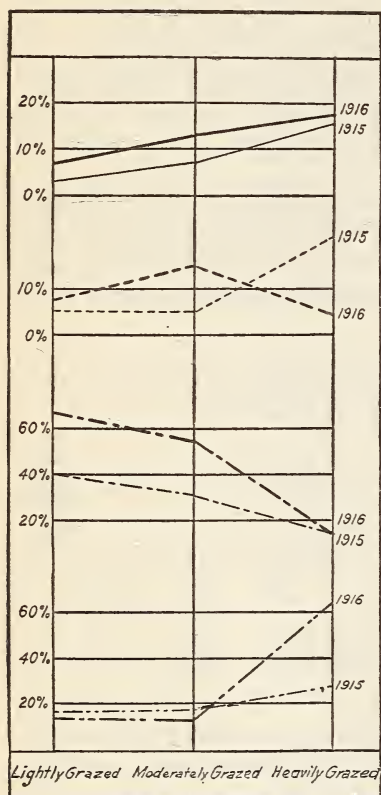


Fig. 1.—Relation of injury of sprouts to intensity of grazing seasons 1915 and 1916.

grazed sprouts, especially those up to a foot or so in height, were in general found on heavily cropped plots, and that the least injuries occurred on the lightly grazed plots. When the total number of sprouts occurring on the plots and the number injured are considered collectively for the five years, regardless of grazing intensity, a little less than half (40 per cent) is found to be injured by browsing. This is considerably lower than on the heavily grazed plots. On most plots the stature of the specimens was appreciably more reduced on the heavily grazed lands than on those where grazing was light or moderate, the portion of the specimens remaining often being mere snags, as is shown in figure 2 of Plate I and figures 1 and 2 of Plate II. In the most extreme cases all the leaves, much of the tender woody growth, some of the buds, and portions of the bark were eaten.

The proportion of specimens with both leaders and laterals browsed is least serious on the lightly grazed plots. On moderately grazed areas the percentage is considerably more,

and on heavily grazed areas it is the highest of all. This holds true both for 1915 and 1916. For the five-year period 1912–1916, Table 4 shows that, regardless of height classes, the average percentage of injured sprouts is least on the lightly grazed plots, intermediate on the moderately grazed areas, and largest on the heavily grazed plots, the figures being 14.1, 24.9, and 53.1, respectively. The results are similar

in the case of the number of killed sprouts, the percentages being 12.3, 14.5, and 16.9 on the corresponding plots. On the lightly grazed areas the average per cent of uninjured sprouts was 46.2, while on the moderately and heavily grazed plots it was 27.1 and 9.1, respectively.

RELATION BETWEEN INTENSITY OF GRAZING AND INJURY TO SPROUTS OF DIFFERENT HEIGHT CLASSES.

The extent of injury to reproduction of different height classes varies considerably. There appears to be no constant relation, however, between the different height classes of reproduction and the percentage of injured or killed sprouts. In Table 4 the sprouts under observation during the 5-year period have been grouped into height classes and assembled according to intensity of grazing.

TABLE 4.—Extent of injury to sprouts in standing timber, according to height classes and grazing intensities.

Grazing intensity.	Height class of reproduction.	Total number of sprouts.	Uninjured.		Sprouts killed by grazing.		Sprouts injured by grazing.	
			Num-ber.	Per-cent.	Num-ber.	Per-cent.	Num-ber.	Per-cent.
	<i>Feet.</i>							
Lightly grazed.....	0.5 to 1.5	891	535	60.1	44	4.9	272	30.3
Do.....	1.5 to 2.5	235	96	40.9	31	13.2	43	18.3
Do.....	2.5 to 3.5	193	68	35.2	36	18.7	10	5.2
Do.....	3.5 to 4.5	173	84	48.6	22	12.7	5	2.9
Average (per cent).....				46.2		12.3		14.1
Moderately grazed.....	.5 to 1.5	1,451	653	45.0	200	13.7	290	20.0
Do.....	1.5 to 2.5	709	217	30.6	123	17.4	206	29.1
Do.....	2.5 to 3.5	416	59	14.2	73	17.5	142	34.1
Do.....	3.5 to 4.5	280	53	18.9	26	9.3	46	16.5
Average (per cent).....				27.1		14.5		24.9
Heavily grazed.....	.5 to 1.5	1,395	246	17.6	318	22.8	665	47.7
Do.....	1.5 to 2.5	628	26	4.1	131	20.8	373	59.4
Do.....	2.5 to 3.5	241	23	9.5	21	8.7	159	66.0
Do.....	3.5 to 4.5	109	6	5.5	17	15.6	43	39.5
Average (per cent).....				9.1		16.9		53.1

The number of specimens remaining on the plots decreases with the increase in height class. Thus in the 3½ to 4½ foot class is found the sparsest stand of reproduction examined, all intensities of grazing considered. This is accounted for by the number of sprouts killed by adverse climatic conditions and by rodents, as well as by the number killed by browsing.

The shoots of the first year's sprouts (6-inch to 1½-foot class) are more succulent than those of sprouts of greater age, but the new twigs and branches produced each season by the older specimens are quite as palatable as are the shoots of younger sprouts. Hence, while the terminal shoot is less liable to injury in the case of the taller and older sprouts than sprouts 1½ feet or less in height, the taller specimens are nevertheless subject to injury of varying serious-

ness so long as the branches are within reach of the sheep. Furthermore, the sprouts listed in Table 5 which have the least height growth, viz, those "less than one season old" and those "below 6 inches, one season old," are undoubtedly protected from grazing by the rather luxuriant cover of herbaceous vegetation which characteristically occurs in the aspen type after about August 1 and hides much of the reproduction from view. The sprouts in these classes show a considerably smaller percentage of grazing than those of greater height. However, the loss chargeable to grazing is considerable, and owing to the succulence of the entire aerial parts during the first season of growth there were numerous individual sample plots representing large areas where on account both of the climatic conditions and of browsing the greatest injury to sprouts was inflicted during the initial season of growth.

In view of the mortality of 1-year-old sprouts due to browsing and causes other than browsing, it may be concluded that even light cropping of the lands is sure to have a determining effect on the ultimate timber stand. The extent to which the land should be grazed when the sprouts are just beginning to appear, therefore, should be determined by the timber stand ultimately desired.

TABLE 5.—*Injuries to sprouts 1½ feet or less in height according to varying intensities of grazing; data grouped by seasons and height classes and according to intensity of grazing. Plots in standing timber.*

Season and height class.	Lightly grazed.			Moderately grazed.			Heavily grazed.			Total number grazed all intensities.	Per cent grazed all intensities.
	Total number.	Number grazed.	Per cent grazed.	Total number.	Number grazed.	Per cent grazed.	Total number.	Number grazed.	Per cent grazed.		
1912.....	98	.....	.....	122	5	4.09	154	16	10.38	21	5.61
1913.....	899	287	31.92	871	262	30.08	458	224	48.90	773	34.69
1914.....	783	299	38.13	1,826	737	40.36	2,150	1,462	68.00	2,498	52.43
1915.....	386	54	13.98	1,405	261	18.56	2,192	1,363	62.15	1,678	42.00
1916.....	216	30	13.90	924	248	26.80	848	88	10.30	366	18.40
Total.....	2,382	670	.....	5,148	1,513	.....	5,802	3,153	.....	5,336	.....
Average.....			28.19			29.38			54.34		40.02
Height class:											
Sprouts less than 1 season old.....	551	107	19.4	1,711	365	21.3	1,861	983	52.8	1,455	35.2
1-year-old sprouts 1 to 1.5 feet.....	315	66	20.9	1,103	202	18.3	1,592	820	51.5	1,088	26.0
Sprouts below 6 inches (1 season old).....	625	146	23.4	991	328	33.0	854	323	37.8	797	32.1
6 inches to 1.5 feet (1 season old).....	891	355	39.9	1,343	486	36.2	1,395	1,026	73.7	1,867	51.4

SUMMARY.

The effect of sheep browsing in standing aspen timber may be summarized as follows:

(1) Of the total number of sprouts examined during 1912 and 1913, inclusive, the percentage of seriously injured and killed sprouts was



FIG. 1.—CLEAR-CUT PROTECTED ASPEN AREA ON SHEEP RANGE AS IT APPEARED AFTER FENCING IN THE SPRING, 1913.



FIG. 2.—TYPICAL RESULTS FROM BROWSING BY SHEEP OF LEADERS OF ASPEN SPROUTS OF THE FIRST SEASON'S GROWTH ON HEAVILY GRAZED PLOT

Following such browsing the specimens usually die, as was the case in this instance.



FIG. 1.—TWO-YEAR-OLD SPROUTS ON HEAVILY GRAZED PLOT, THE SHOOTS OF WHICH WERE KILLED BY THE BROWSING OF THE TERMINALS DURING THE FIRST SEASON OF GROWTH.

The second set of shoots, produced from adventitious buds, were subsequently seriously browsed. The later sprouts died at the end of the season, after which no more shoots were produced.



FIG. 2.—THREE-YEAR-OLD SPROUTS ON HEAVILY GRAZED PLOT (ON THE READER'S LEFT), SHOWING THE REPLACEMENT OF THE LEADER BY LATERAL SHOOTS SUBSEQUENTLY BROWSED. ON THE READER'S RIGHT, SERIOUS BROWSING OF LEADER AND LATERALS OF ASPEN SPROUT 40 INCHES HIGH.

The specimens were photographed in 1914. In 1915 the specimen to the left died, while the specimen to the right in 1915 and 1916 made very little growth and no terminal bud at that time been produced.

considerably larger than the percentage of the remaining uninjured sprouts. In addition to the mortality and injury due to browsing, 11.7 per cent of the sprouts were killed and 6.3 per cent injured in varying degrees of seriousness by causes other than browsing.

(2) The extent of injury to and mortality of sprouts in standing timber was in direct proportion to the intensity of grazing; also the character of injury, such as the removal of the leader, for example, was notably greater on heavily grazed plots than on moderately and lightly grazed areas. In 1915, for example, an average of 4.4 per cent of the leaders were removed on lightly and moderately grazed plots, while on the heavily grazed areas 21.5 per cent of the leaders were removed.

(3) Considerable variation in the extent of injury and mortality to the reproduction occurred in different seasons, the variation in injured sprouts being over 25 per cent and in killed sprouts over 10 per cent during the five years of study. Within a single season, however, no appreciable variation in degree and number of injured sprouts was observed so long as the leafage remained intact.

EFFECT OF CATTLE BROWSING.

Plots in standing aspen timber grazed exclusively by cattle were selected early in the spring of 1915. In addition to the detailed data on character and extent of injury to aspen reproduction by cattle in 1915 and 1916, data on the extent of injury by browsing prior to the establishment of the sample plots were afforded by the older specimens under observation. Accordingly, injuries covering a great many years were recorded.

The general grazing injuries to the reproduction are summarized in Table 6. The data are grouped according to intensity of grazing, both as to total injury regardless of the height classes of the sprouts and as to injury to the different height classes. Table 6 shows that the extent of injury in 1915 and 1916 varies directly with the closeness to which the range was grazed, being least, indeed practically nominal, on lightly and moderately cropped plots and relatively heavy (17.5 per cent in 1915 and 36.1 per cent in 1916) on heavily grazed areas. While the number of browsed sprouts was fairly large on the closely grazed plots, the injuries were in no instance especially serious, nor was the extent of damage anywhere near as great as that caused by sheep. The damage done by cattle to reproduction of a given height was in no case severe. The average per cent of injury to sprouts above 1½ feet in height was approximately the same as that of sprouts of the 6-inch to 1½-foot class. Thrifty aspen reproduction of varying age and size is found throughout the aspen type in localities where cattle only have been permitted to graze moderately for a number of years. This would indicate that

controlled cattle grazing, such as has been carried out in the vicinity of these plots, and the perpetuation of the aspen stand are not necessarily antagonistic.

The young, tender aspen shoots are browsed more or less by cattle, however, and the damage inflicted may increase in proportion to the density of the reproduction. Hence, where sprouts are produced in sufficient numbers to attract stock and accustom the animals to browse upon aspen, a greater per cent of damage may occur than where the stand of sprouts is sparse, as in standing timber. A maximum number of sprouts invariably follows clear-cutting, and accordingly the extent of injury by grazing to dense stands of reproduction can best be determined on clear-cut plots.

TABLE 6.—*Total number of sprouts the laterals and terminals of which were removed by cattle browsing on plots in standing timber; data grouped according to intensity of grazing and height classes.*

Season and height class.	Lightly grazed.			Moderately grazed.		
	Total number sprouts.	Number browsed.	Per cent browsed.	Total number sprouts.	Number browsed.	Per cent browsed.
1915.....	150	.....	.....	379	3	0.78
1916.....	166	5	3.2	311	13	4.20
Height class:						
6 inches to 1.5 feet.....	31	.....	.....	41	2	4.87
1.5 feet to 2.5 feet.....	99	.....	.....	83	2	2.41
2.5 feet to 3.5 feet.....	40	.....	.....	78	2	2.56
3.5 feet to 4.5 feet.....	31	.....	.....	52	1	1.92

Season and height class.	Heavily grazed.			All intensities of grazing.	
	Total number sprouts.	Number browsed.	Per cent browsed.	Total number sprouts.	Per cent browsed.
1915.....	40	7	17.50	10	1.75
1916.....	36	13	36.10	31	6.20
Height class:					
6 inches to 1.5 feet.....	6	.....	.....	2	2.60
1.5 feet to 2.5 feet.....	15	4	26.60	6	3.20
2.5 feet to 3.5 feet.....	7	.....	.....	2	.....
3.5 feet to 4.5 feet.....	4	.....	.....	1	1.60

INJURY TO ASPEN REPRODUCTION BY GRAZING ON CLEAR-CUT LANDS.

EFFECT OF SHEEP BROWSING.

Because of the high mortality due to natural causes the most authentic data showing the effect of grazing on the stand and the condition of the sprouts can probably be obtained by comparing the stands on similar fenced and unfenced clear-cut plots. Four plots were selected on typical aspen range and clear-cut in the fall of 1912; two of these were fenced against stock and the other two left unfenced.

The data recorded on the two sets of plots are summarized in figures 2 and 3. Figure 2 shows for each season during which the observations were made (1) the rate of sprout production on normal

grazed clear-cut aspen plots, (2) the number of sprouts (a) injured and (b) killed by browsing, (3) the number uninjured, and (4) the number injured, by causes other than grazing. Figure 3 shows seasonally (1) the sprouting ability of clear-cut aspen protected from grazing, (2) the number of sprouts injured (a) by barking by rodents and (b) by frost, and (3) the number killed by (a) barking by rodents and (b) by frost.

In 1913 practically the same number of sprouts per acre were produced on the protected and on the unprotected plots—namely, about 80,000 per acre. In the summer of 1914, when the sprouts were retallied, the number had increased to 105,589 per acre on the unprotected plots and to 90,480 on the protected plots. In the fall of 1914, 103,241 specimens were recorded on the unfenced plots—a slight decline over that of the previous count—while on the fenced areas the number had decreased to 58,324. From that time on there was a sharp but uniform decline on both sets of plots until in the fall of 1916 not one living sprout remained on the grazed plots (Plate III), though 2,646 vigorous sprouts per acre were recorded on the protected plots, most of which had attained a height beyond that at which sheep browse (Plate IV, fig. 1). While this number is ample for the establishment of a full aspen stand, a great many more sprouts have been found on plots established elsewhere.

The number of uninjured sprouts was notably greater on the ungrazed than on the grazed plots (Figs. 2 and 3). On the grazed plots there was a drop in the number of uninjured sprouts in the summer of 1914, due probably to slightly more intensive grazing at that time. This was followed by an increase and then from the fall of 1914 to the summer of 1916 the number of sprouts declined rather uniformly to zero. On the protected plots the number of uninjured sprouts decreased at approximately the same ratio as the total number produced. On the grazed plots there were no uninjured sprouts in the summer of 1916, but on the plots protected from grazing there remained 2,646 sprouts per acre.

The rate of mortality even on the ungrazed plots is surprisingly high. Usually a large proportion of the sprouts are killed, often within a season, by the injuries caused by bark-eating rodents, chiefly field mice, gophers, and rabbits (Plate IV, fig. 2). Besides, a very large proportion of the specimens recorded as merely injured by rodents and by frost died later from such injuries. The reproduction is often completely girdled, and not uncommonly several belts of bark an inch or more in width are removed. While the adverse factors of inclement weather and bark-eating rodents are active in the elimination of reproduction on the fenced and unfenced plots alike, such injury is insignificant compared with the injury chargeable to sheep grazing on the unfenced plots.

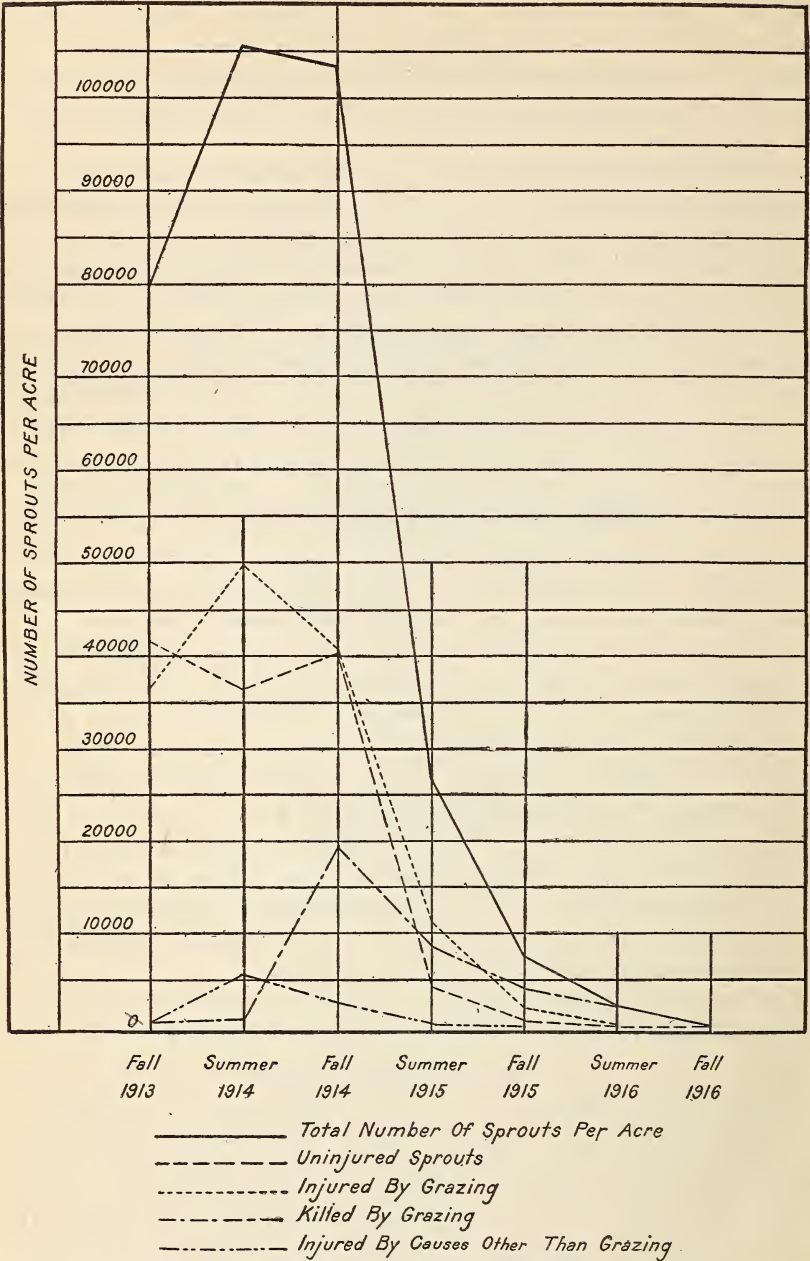


FIG. 2.—Number of sprouts per acre on clear-cut plots and their injury and mortality. (Area unfenced.)



FIG. 1.—CLEAR-CUT ASPEN PLOT NO. 1, UPON WHICH NORMAL SHEEP GRAZING HAS BEEN UNRESTRICTED.

In 1914 there were 103,241 specimens of aspen sprouts per acre; in 1916 not a specimen remained. The shrubby vegetation is mountain elder (*Sambucus microbotrys*).



FIG. 2.—CLEAR-CUT ASPEN PLOT NO. 2, UPON WHICH, LIKE PLOT 1, THE TIMBER WAS REMOVED IN THE FALL OF 1912 AND THE AREA SUBSEQUENTLY GRAZED NORMALLY BY SHEEP.

The density of the reproduction on this plot was practically the same as on plot 1 the first two seasons after the timber was removed, but in the fall of 1916 not a living specimen was to be found. A luxuriant stand of the palatable mountain brome grass (*Bromus marginatus seminudus*), has occupied the soil since clear cutting. The luxuriance of the brome-grass cover is evidence of the fact that the aspen reproduction was not destroyed as a result of overgrazing.



FIG. 1.—FENCED PLOT, COMPLEMENT TO UNFENCED PLOT SHOWN IN PLATE III, FIG. 1.

At the end of the third season following cutting there remained 3,800 vigorous sprouts per acre of an average height of approximately 4 feet. This number three years after cutting is more than ample for the establishment of a full aspen stand.



FIG. 2.—THREE-YEAR-OLD ASPEN SPROUTS ON CLEAR-CUT FENCED PLOT KILLED BY BARK-EATING RODENTS.

Note extent of removal of bark at various places along main stem and at base of large lateral branch.

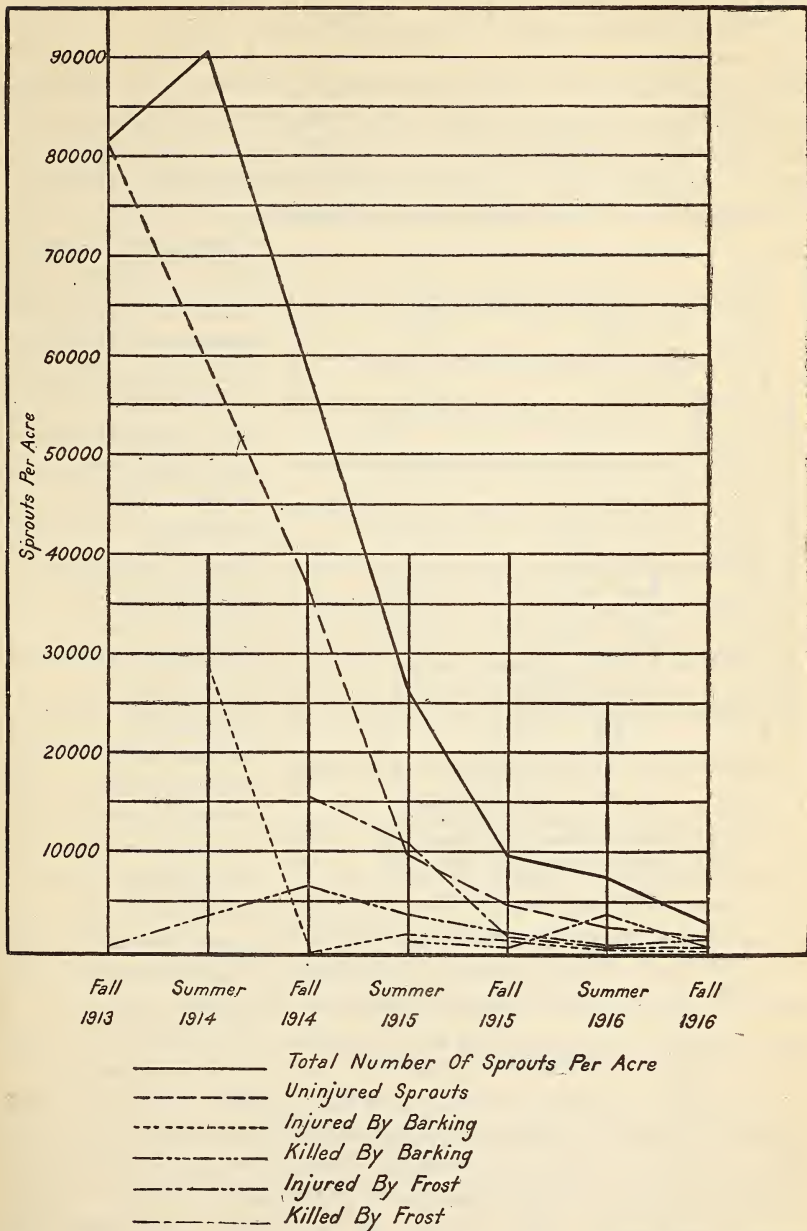
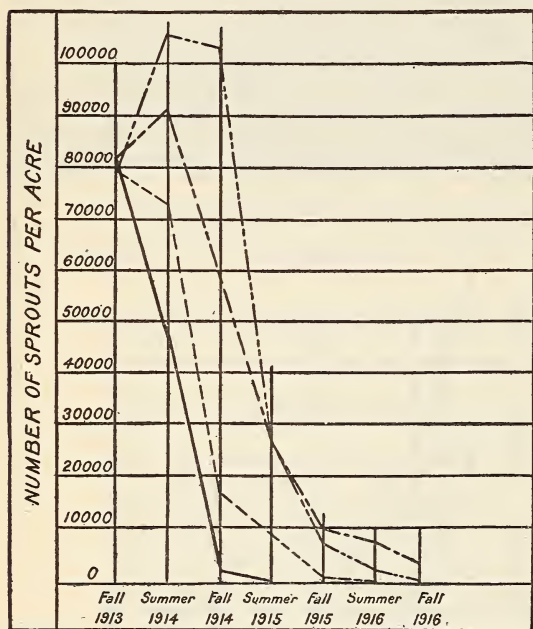


FIG. 3.—Number of sprouts per acre on clear-cut plots and their injury and mortality due to causes other than grazing. (Area fenced.)

On the clear-cut lands protected from grazing and where the mortality of the reproduction was not abnormally heavy, no new sprouts appeared after two years following clear-cutting (fig 4). On the clear-cut unprotected plots, on the other hand, where a large proportion of the sprouts were destroyed by browsing, considerable reproduction was produced not only in the first two seasons but in the third season following cutting, though not subsequently. The removal of practically the entire aerial portion of the sprouts by browsing prevents the transfer and utilization of the large stores of



- Number Of Sprouts Produced Per Season (Protected Area)
 - - - - - Number Of Sprouts Produced Per Season (Unprotected Area)
 - · - · - Total Number Of Sprouts Remaining (Protected Area)
 - - - - - Total Number Of Sprouts Remaining (Unprotected Area)

FIG. 4.—Number of sprouts produced on clear-cut aspen plots computed on acreage basis, 1913 to 1916 inclusive.

plant food deposited in the elaborate root system of the parent plant, and this nutritive material apparently tends to stimulate the production of sprouts in the third season following the removal of the timber. The majority of these third-year sprouts were reproduced between 2 and 5 weeks later than those sent up during the first two seasons after cutting, and instead of individual specimens appearing more or less uniformly over the area, as in the case of sprouts produced during the first two years, they appeared in bunches of from about 3 to 15 specimens.

The sprouts produced during the third season distinctly lacked vigor and were, for the most part, killed by frost or other unfavorable climatic factors. Only a very small percentage, even when not injured by inclement weather, possessed sufficient vitality to become permanently established. Thus only a sparse, uneven, and weak aspen stand may be expected from sprouts originating on grazed lands during the third season after cutting, even though grazing is discontinued the second year after the timber has been removed.

EFFECT OF CATTLE BROWSING.

Injury to reproduction on clear-cut aspen plots chargeable to browsing, trampling, and rubbing by cattle was observed during the seasons of 1915 and 1916 in the same detail as in the case of the plots located on the sheep allotments. Early in the spring of 1915 two representative areas located at an elevation of approximately 8,800 feet were cleared of timber, and sample plots and quadrats were established, by means of which the rate of sprouting and the exact character of damage caused exclusively by cattle were noted. The clear-cut areas were comparable in every way, except that one was subject to normal grazing while the other was fenced against stock.

In recording the damage to the reproduction, account was taken of the injury and mortality due both to the presence of cattle and to causes other than grazing. The data were grouped according to grazing intensity. The results are summarized in Table 7, and for purposes of ready comparison the data recorded in 1915, which are practically the same as for 1916, are shown graphically in figure 5.

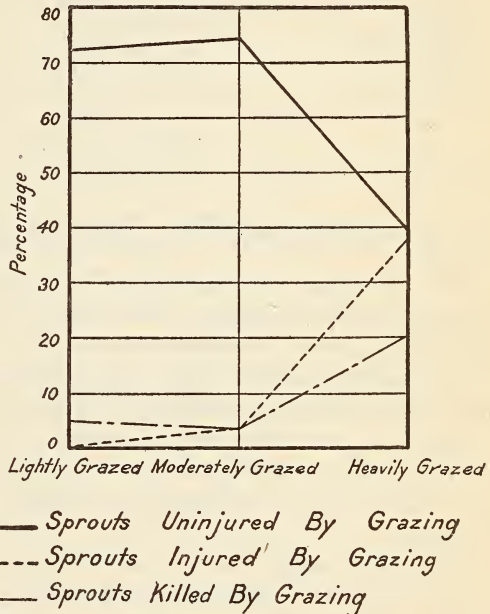


FIG. 5.—Relation of cattle grazing to number of uninjured and killed sprouts, season 1915.

In 1915 the number of uninjured sprouts was highest on the lightly and moderately grazed plots (72.7 and 74.4 per cent, respectively) and notably lower on the heavily grazed areas (40 per cent). In 1916 the relation was similar. There was practically no difference in the per cent of injured and killed sprouts on the lightly grazed and on the moderately grazed plots, while on those heavily grazed there was an appreciable increase in the percentage of both injured and killed sprouts.

A considerable proportion of the sprouts on these plots, as in the case of sprouts on plots previously reported on sheep range, were injured or killed by causes other than grazing. Eight per cent of the sprouts died and 5.9 per cent were injured by causes other than

grazing, while only 2.6 per cent were killed and 5.7 per cent injured by grazing.

TABLE 7.—*Summary of aspen sprouts killed and injured by cattle grazing on clear-cut plots.*

Grazing intensity and year of examination.	Total number sprouts.	Uninjured sprouts.		Killed by grazing.		Injured by grazing.		Total number dead sprouts not killed by grazing.		Injury not due to grazing.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Lightly grazed:											
1915.....	150	109	72.7	7	4.6	.....	.....	20	13.3	14	9.4
1916.....	166	140	84.4	.....	.....	6	3.6	4	2.4	16	9.6
Moderately grazed:											
1915.....	379	282	74.4	12	3.2	15	3.9	46	12.2	24	6.3
1916.....	311	274	88.1	.....	.....	14	4.5	13	4.2	10	3.2
Heavily grazed:											
1915.....	40	16	40.0	8	20.0	15	37.5	1	2.5	.....	.....
1916.....	36	21	58.3	1	2.8	12	33.3	2	5.6	.....	.....
Total.....	1,082	842	.....	28	.....	62	.....	86	.....	64	.....
Mean of all grazing intensities.....	.....	.....	77.8	.....	2.6	.....	5.7	.....	8.0	.....	5.9

COMPARATIVE INJURY TO ASPEN SPROUTS BY SHEEP AND CATTLE.

The damage to reproduction on sheep range, on the plots established both in standing timber and on clear-cut lands, was considerably different in character and extent from that on cattle range. This difference in the degree of damage was evident in all localities where the study was conducted, and especially where plots had been grazed to practically the same degree of intensity.

On plots in standing timber the comparative damage by sheep and by cattle may be summarized as follows (data given in Tables 1, 2, and 6):

(1) The average per cent of reproduction injured by sheep grazing from 1912 to 1916, inclusive, was 27.3, and from 1915 to 1916, inclusive, 19.9. During the latter period the average per cent of injury on cattle range, where the forage had been cropped to practically the same extent, was but 3.97.

(2.) The average per cent of reproduction killed on the plots scattered over the sheep allotments from 1912 to 1916, inclusive, was 17.1, and during 1915 and 1916, 24.8. During 1915 and 1916 less than 0.5 per cent of the reproduction on the plots grazed by cattle was killed by browsing.

On the clear-cut plots the damage to reproduction by sheep as compared with that by cattle is proportionately much more serious than on plots in standing timber. The seriousness of normal sheep grazing on clear-cut aspen lands may be summarized in the statement that in the third year following the removal of the standing timber it may be expected that no sprouts whatsoever will be found on the lands. If any sprouts remain, they are usually so mutilated as either to die after a season or two or so deformed as to produce timber of

questionable value. Reproduction on clear-cut lands located on cattle range, on the other hand, while damaged more or less by browsing, appears to occur in sufficient density over the plots under observation to insure a maximum stand of first quality mature timber.

Practically without exception there are no young aspen sprouts on range grazed annually by sheep during the period that the sprouts are being produced. The few sprouts found are almost invariably lacking in vigor and are often more or less seriously diseased. On the range used exclusively by cattle it is the exception not to find at least a partial stand of sprouts varying in age, most of which are vigorous and healthy. Cattle naturally prefer the leafage of herbs, especially grasses, to shrubs and other woody plants, and while they browse aspen reproduction, the damage they do seldom endangers the permanent establishment of the stand unless the range is stocked with cattle beyond its natural carrying capacity.

An analysis of the character of the injuries showed that the proportion of terminal and lateral shoots browsed was practically the same on cattle and on sheep allotments. It was quite evident, however, that the cattle browsed the foliage more and the woody tissue less than sheep; consequently the complete removal of terminal and lateral shoots was less commonly observed on the cattle ranges than on the sheep ranges. The difference would appear to account for the more rapid and complete recovery of injured sprouts on cattle allotments.

Practically no damage is caused to aspen reproduction by rubbing and trampling by cattle. Rubbing is generally confined to young conifer saplings characteristically scattered through the aspen type, the needles and bark of which afford the friction desired, or to aspen specimens of about pole size. Young aspen sprouts are so limber that stock seldom break the branches or otherwise distort them by rubbing. Sheep, of course, not being addicted to the rubbing habit like cattle, cause virtually no damage in this way. Trampling by either class of stock causes very slight mortality or permanent injury. On sheep ranges the young sprouts are either killed or seriously damaged long before the formation of prominent trails which might otherwise result in trampling out the reproduction. On cattle allotments there is occasionally a small amount of damage to young sprouts by trampling, portions of the bark being removed along the main stem or the specimen being broken; but such injury is negligible on lands stocked according to their actual carrying capacity and on which the animals are properly distributed. Where cattle have a tendency to congregate, however, near watering and salting places, for instance, both browsing and trampling have a telling effect on the density and vigor of the reproduction.

HEIGHT AT WHICH REPRODUCTION IS EXEMPT FROM GRAZING INJURIES.

The factor which chiefly determines the time of exemption of the reproduction from destructive browsing is the height of the sprouts. Observations have shown clearly that as soon as the terminal shoots and some of the lateral branches have attained a growth beyond which stock generally browse, the reproduction is no longer in danger of serious damage. Since sheep are particularly destructive to young aspen reproduction, detailed observations as to the height at which they browse were recorded both on the open range and on controlled plots. The height to which cattle browse was observed under range conditions only.

HEIGHT TO WHICH SHEEP BROWSE.

The height to which sheep browse depends, of course, upon the palatability of the plants that grow within the reach of the animals, as well as upon the particular breed of sheep. Sheep relish woody plants, and they browse the aspen reproduction at as great a height as other highly palatable species. The sheep under observation consisted of about equal numbers of ewes and lambs of the Rambouillet and merino breeds, chiefly the former. The animals of both breeds were of about average size.

In observing the height of grazing on the range it was necessary to adhere almost entirely to reproduction in standing timber, as relatively little aspen timber on the sheep allotments has as yet been clear-cut or heavily thinned. For this reason the height of the sprouts, the stand of which was usually quite sparse and scattered, was uneven and often considerably below the maximum height at which sheep may browse. Accordingly, to determine the height of aspen browsed with unquestionable accuracy, and to secure a basis for future management of grazing in the aspen type, the observations on the range were supplemented by a carefully planned experiment on a clear-cut fenced inclosure where the sprouts varied in height from 20 to 70 inches, the majority having a height of about 45 inches.

The plot was one-fourth of an acre in area. Two 5-year old ewes and three lambs 3 months old were grazed on the plot as long as the feed, consisting of a luxuriant undergrowth of grasses, pea vines, a variety of weeds, and some shrubby growth, was sufficient to sustain the animals at their original weight. Accordingly, the plot was grazed much more closely than would be possible over the range generally where the lands are handled on the basis of a sustained annual yield. The plot in question was clear-cut late in the autumn of 1913 and the sheep were placed on it in August, 1916, so that the major portion of the reproduction was about 3 years of age. At the time the sheep were turned on there was a stand of 30,056 sprouts

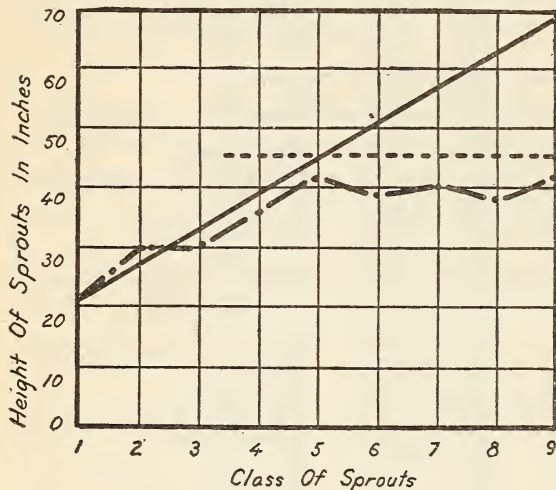
per acre (Plate V, fig. 1). The condition of the sprouts before and after grazing was noted on a transect $2\frac{1}{2}$ feet wide and 40 feet long running across the plot. The results are given in Table 8.

TABLE 8.—Character and extent of sheep browsing on clear-cut aspen plot and height at which injuries were inflicted.

Sprout No.	Height of sprout.	Height browsed.	Condition of sprout. ¹	Character of injuries.
	Inches.	Inches.		
1.....	53.0	43.0	V	Laterals grazed.
2.....	44.5	39.0	V	Do.
3.....	47.5	41.0	V	Do.
4.....	38.0	38.0	V	Laterals and terminal grazed.
5.....	39.0	35.0	V	Laterals grazed.
6.....	36.0	32.0	V	Do.
7.....	42.0	35.0	V	Do.
8.....	55.0	36.0	V	Do.
9.....	47.0	36.0	V	Do.
10.....	33.0	26.0	W	Do.
11.....	29.0	29.0	V	Laterals and terminal grazed.
12.....	37.0	37.0	V	Do.
13.....	59.0	40.0	V	Laterals grazed.
14.....	49.5	37.0	V	Do.
15.....	31.0	31.0	V	Laterals and terminal grazed.
16.....	32.0	32.0	W	Do.
17.....	40.0	40.0	V	Do.
18.....	48.0	36.0	V	Laterals grazed.
19.....	61.0	36.0	V	Do.
20.....	55.5	40.0	V	Do.
21.....	43.5	43.5	V	Laterals and terminal grazed.
22.....	40.5	38.0	V	Laterals grazed.
23.....	54.0	40.0	V	Do.
24.....	50.0	40.0	V	Do.
25.....	55.0	38.0	V	Do.
26.....	36.0	36.0	V	Laterals and terminal grazed.
27.....	32.0	32.0	V	Do.
28.....	50.0	38.0	V	Laterals grazed.
29.....	51.0	41.0	V	Do.
30.....	31.0	31.0	W	Laterals and terminal grazed.
31.....	39.0	33.0	V	Laterals grazed.
32.....	48.0	42.0	V	Do.
33.....	21.0	21.0	W	Laterals and terminal grazed.
34.....	32.0	32.0	V	Do.
35.....	49.0	38.0	V	Laterals grazed.
36.....	39.0	39.0	V	Laterals and terminal grazed.
37.....	69.0	40.0	V	Laterals grazed.
38.....	40.0	40.0	V	Laterals and terminal grazed.
39.....	29.0	29.0	W	Do.
40.....	59.5	45.0	V	Laterals grazed.
41.....	71.0	40.0	V	Do.
42.....	72.0	41.0	V	Do.
43.....	43.0	43.0	W	Laterals and terminal grazed.
44.....	39.5	37.0	V	Laterals grazed.
45.....	45.0	39.0	V	Do.
46.....	62.5	39.0	V	Do.
47.....	43.0	43.0	V	Laterals and terminal grazed.
48.....	69.5	38.0	V	Laterals grazed.
49.....	45.0	45.0	V	Laterals and terminal grazed.
50.....	51.5	40.0	V	Laterals grazed.
51.....	58.0	41.0	V	Do.
52.....	54.0	44.0	V	Do.
53.....	47.0	47.0	W	Laterals and terminal grazed.
54.....	69.0	44.0	V	Laterals grazed.
55.....	58.0	45.0	V	Do.
56.....	70.0	45.0	V	Do.
57.....	73.0	43.0	V	Do.
58.....	61.5	36.0	V	Do.
59.....	70.0	40.0	V	Do.
60.....	54.5	42.0	V	Do.
61.....	66.0	40.0	V	Do.
62.....	39.0	39.0	W	Laterals and terminal grazed.
63.....	61.0	40.0	V	Laterals grazed.
64.....	55.0	38.0	V	Do.
65.....	71.0	42.0	V	Do.
66.....	71.0	45.0	V	Do.
67.....	57.0	32.0	V	Do.
68.....	40.5	34.0	V	Do.
69.....	52.0	35.0	V	Do.

¹ V indicates that the sprout was in vigorous and normal condition after grazing. W signifies that it was weak and likely subsequently to die from the injuries caused by browsing.

Table 8 shows that while the plot was grazed much more closely than would be warranted on the basis of sustained forage yield, only 8 of the 69 sprouts on the transect (11.6 per cent) were seriously grazed and thus likely subsequently either to die or become very deformed. All the other sprouts were in vigorous condition; and though they were browsed slightly, the damage was not such as to manifest itself in the future development of the stand. In most instances the browsing was confined to the lateral branches, only 20 of the 69 sprouts (29 per cent) having both the terminals and the laterals removed. Only 3,483 of the 30,056 sprouts to the acre were



————— Average Height Of Sprouts
 - - - - - { Height Of Sprouts Exempt From
 } Serious Browning
 - · - · - Average Height Browsed

FIG. 6.—Heights at which sprouts are browsed.

sprouts were grouped into 6-inch height classes and the average height of the browsing in the case of each height class recorded. The figures are given in Table 9 and the results are shown graphically in figure 6.

TABLE 9.—Summary of heights at which aspen sprouts are browsed by sheep.

Height class No.	Number of specimens in each height class.	Height class.		Average height grazed.
		Average.	Mean.	
		<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
1	1	18 to 23	21	21.0
2	2	24 to 29	27	29.0
3	6	30 to 35	33	30.7
4	13	36 to 41	39	36.8
5	10	42 to 47	45	41.1
6	10	48 to 53	51	39.0
7	12	54 to 59	57	40.1
8	5	60 to 65	63	38.2
9	10	66 to 71	69	41.8

seriously weakened by browsing, leaving 26,571 vigorous specimens for the establishment of the stand, a number exceeding by more than 24,000 the quantity necessary to restock the land fully.

The most significant fact brought out by the experiment is that the maximum height of sheep browsing was 47 inches, and this occurred only in the case of a single specimen. To show more clearly than in Table 8 the average height at which the browsing occurred, the

The height of browsing increases gradually with the increase in the height classes of the reproduction up to the fifth class; i. e., from 21 to 41.1 inches. From this point on up to the ninth class the height of the browsing varies slightly above or below the 40-inch mark. In the ninth class occurs the maximum average height of 41.8 inches. The average height at which the 69 grazed sprouts in the transect were grazed was 38.1. This is about the height of the top of the heads of mature Rambouillet and merino sheep.

Sprouts the terminal shoots of which have attained a height of 40 inches or so are apt to suffer only slight permanent injury, and extensive observations on the range and on the various check plots have shown that reproduction having an average height of 45 inches is practically exempt from serious injury. Hence lands supporting reproduction averaging 45 inches in height may be grazed with practically no injury to the terminal shoots. Moderate browsing of some of the lateral branches will occur, of course, as long as they are easily within the reach of sheep, but the effect of such browsing is insignificant so far as concerns the development and health of the specimen.

HEIGHT TO WHICH CATTLE BROWSE.

It has been pointed out that reproduction only a few inches or so in height is subject to about the same degree of browsing by cattle as is reproduction of greater heights. Thus, contrary to what might be expected, sprouts two or three feet high which by virtue of their greater conspicuousness might be presumed to afford more convenient browsing than the shorter specimens are nevertheless damaged as little as any of their younger associates.

Considerable variation is observed in the height of the browsing by cattle. Isolated instances have been recorded of the removal of leafage to a height of about 70 inches, but browsing at such a height is exceptional and of little economic significance. Damage of greater severity occurs between heights of 55 and 60 inches, the latter figure, however, being about the minimum at which twigs and stems are eaten. Thus in localities where cattle are apt to drift and linger and where it is desired to reforest the lands fully the reproduction should be permitted to attain a growth of not less than 5 feet prior to heavy stocking. Obviously, then, lands which are to be reforested should not be used as salting grounds until a sufficient portion of the reproduction has attained a height beyond which destructive browsing is likely to occur.

RATE OF GROWTH OF ASPEN REPRODUCTION.

In the management of grazing on cut-over lands it is necessary to know, in order to make the most judicious use of the knowledge of the height which aspen reproduction must attain to be exempt from

serious damage by sheep and cattle, (1) the rate of growth of the reproduction and the age at which the major portion of the stand is exempt from serious browsing, and (2) the density of the stand that may be expected, and accordingly the extent of thinning, if any,

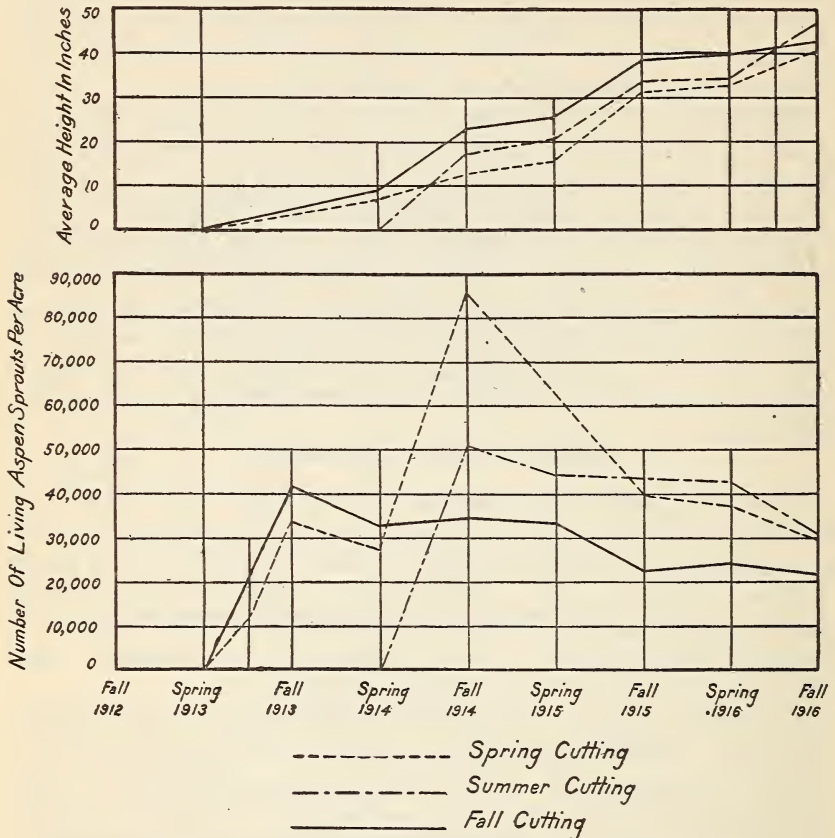


FIG. 7.—Number of sprouts and average height growth according to season of cutting.

that may be permitted by browsing and that will leave enough reproduction to secure the number of trees which the lands will well support.

To determine the sprouting capacity of aspen and the corresponding vigor and rate of growth of the resulting sprouts when the lands are clear-cut in different seasons, the timber was removed on three plots of even-aged aspen, each one-half acre in size. One of the plots was clear-cut in the fall of 1912, another early in the spring of 1913, and the third in midsummer 1913. In Table 10 is summarized the number of living sprouts per acre on these plots and the height growth per season according to the time of cutting. To facilitate comparison of results the data are assembled graphically in figure 7.

TABLE 10.—*Sprouting capacity and height growth of aspen reproduction on clear-cut plots.*

Date of examination.	Fall cutting, 1912.		Spring cutting, 1913.		Summer cutting, 1913.	
	Number of living sprouts per acre.	Average height.	Number of living sprouts per acre.	Average height.	Number of living sprouts per acre.	Average height.
		<i>Inches.</i>		<i>Inches.</i>		<i>Inches.</i>
Summer, 1913.....			11,600			
Fall, 1913.....	41,700		33,800			
Spring, 1914.....	32,670	8.6	27,590	7.3		
Fall, 1914.....	34,700	23.4	85,520	12.5	50,960	16.9
Spring, 1915.....	32,810	25.5	62,580	15.5	44,140	20.3
Fall, 1915.....	22,210	39.2	39,920	31.4	43,850	34.0
Spring, 1916.....	24,100	39.8	37,609	32.5	42,730	34.1
Fall, 1916.....	21,920	43.1	29,910	41.2	31,070	46.6

Table 10 shows that the production of sprouts is heavy on all areas, regardless of season of cutting, and that in general the maximum number of sprouts is in evidence within a season following the removal of the timber. Considering the number of mature, well-developed trees that may occupy the ground, more than enough sprouts are produced on the respective plots regardless of season of timber removal. The most vigorous sprouting occurred on the plot the timber of which was removed in the spring, and the least vigorous on the autumn-cut plot. On the spring-cut plot, however, the death rate of sprouts was greatest. The rate of growth was relatively uniform and approximately the same on each plot, and the annual increment averaged about 15 inches, the height growth being practically the same from season to season.

From the above facts it may be concluded that (a) regardless of season of cutting a sufficient number of aspen sprouts is produced on clear-cut lands to restock the lands fully, provided grazing is properly controlled; and that (b) in general the reproduction will have attained sufficient height by the end of the third year of growth to be exempt from destructive browsing by sheep, and by the end of the fourth, or more certainly the fifth year, to be out of danger from cattle.

SILVICULTURAL MANAGEMENT OF ASPEN.

METHODS OF CUTTING.

Experimental evidence gathered from variously treated plots points to the fact that if the lands are to be devoted permanently to the production of aspen, clear-cutting or repeated heavy thinnings are the best means by which to secure vigorous sprouting and an evenly distributed stand.

As is shown by the sparse stand of sprouts on the plots established in the standing timber, aspen is practically unable to reproduce

under its own shade. Light thinnings are of some value, but a very large percentage of the sprouts soon succumb because of insufficient sunlight. The surviving sprouts are forced into intensive competition with various shade-enduring, aggressive, shrubby, and herbaceous species. This, coupled with inadequate light, renders the sprouts weak and not uncommonly diseased. If the slender specimens are not killed outright by fungous attacks, sooner or later they fall easy victims to the wind.

The average stand of pop timber, the diameter breast-high of which does not exceed 10 inches, consists of about 480 trees per acre. To insure a stand of this number of trees at the average rate of mortality of the sprouts, a stand of 2,500 specimens per acre the third year after cutting is sufficient, even though the lands are moderately grazed by cattle or sheep after the terminal shoots are no longer subject to browsing. In practically any type of aspen properly protected from stock, the stand following clear-cutting will generally be 2,500 specimens per acre. Thus in the case of the plot pictured in figure 2 of Plate V, representing the sprouting capacity following the clear-cutting of an 80-year old stand, there are more than 30,000 specimens at the end of the third year. The sprouting appears to be quite as vigorous when younger stands are clear-cut.

METHODS OF BRUSH DISPOSAL.

Various methods of disposing of the brush are in practice, some of which tend to expose the sprouts unduly and others to protect them. Piling and burning the brush is the most popular; but this method, owing to the complete opening up of the lands, is responsible for highly destructive browsing, especially by sheep, the result being that the stand is materially thinned and correspondingly mutilated. The method appears to endanger the establishment of the stand approximately in proportion to the number of spaces burned.

Experiments have been made in scattering the brush over the cutting without lopping the nonmerchantable parts. The method which has given the best results, and which at the same time lends itself to general field practice, is that of scattering the unlopped ones about the stumps, the butts of the discarded portions being placed next to the stumps in such a manner as to have the branches extend out in all directions from the stump. Since the major portion of the reproduction originates from superficial roots near the parent plant, the tops are located where they will afford the greatest possible protection to the new sprouts.

This light screen of unlopped branches, arranged as described, is surprisingly effective against repeated visitations by sheep during the first three seasons after the cutting, which is the most critical period. While, to be sure, there is usually not a sufficient supply of



FIG. 1.—VIEW SHOWING STAND AND HEIGHT OF ASPEN SPROUTS ON CLEAR-CUT PLOT ADJACENT TO AREA FENCED OFF AND GRAZED BY SHEEP.

Photographed three years after clear cutting and one month after the completion of the grazing experiment on control plot.



FIG. 2.—LUXURIANT STAND OF ASPEN REPRODUCTION AS IT APPEARS ON FENCED PLOT THREE YEARS AFTER CLEAR CUTTING.

Over 30,000 specimens, approximately 75 per cent of the terminal shoots of which are beyond the height of sheep browsing, are growing on the area. At this stage of growth there is very little danger of sheep thinning the stand beyond the maximum timber-carrying capacity of the lands. The removal of part of such a luxuriant stand by browsing would be a distinct benefit. The understory of herbaceous vegetation is luxuriant and consists of the choicest of forage species.

tops to cover effectively the entire ground surface and thus prevent the entrance of stock, the method permits the establishment of a fairly good stand of vigorous, well-formed trees.

Observations covering a five-year period have made it evident that the tops of aspen scattered over a clear-cutting in such a manner as to protect the sprouts are well along in decay in the third year after scattering; and usually by the end of the fifth year only the central axis of the top remains, this portion often being pretty thoroughly decayed. The absence of turpentine and other volatile and highly inflammable oils, coupled with the relatively high precipitation in the aspen type and the tendency of the species to absorb and retain a large percentage of moisture when lying on the ground, makes the fire risk due to the scattering of the brush practically negligible.

Another means of protecting the sprouts from browsing is to pile the tops in windrows, as it were, thereby fencing out the stock during the period required for partial decay of the nonmerchable parts. This method, however, is not particularly applicable to field operations, and instead of fostering the sprouts by protecting them from frost, the sun's excessive heat, evaporation, and other adverse factors, exposes the reproduction to the elements in much the same way as when the brush is piled and burned.

SUMMARY.

(1) Aspen, a tree of high commercial value on many National Forests in the West and on some of the farm woodlots and lands adjacent thereto in northeastern United States, is often reproduced with difficulty where the lands are made to serve the double purpose of timber and meat production.

(2) The leafage, young twigs, and branches of the reproduction are browsed with varying degrees of relish by both cattle and sheep. Over 90 per cent of the damage inflicted by stock is chargeable to browsing, the injury due to trampling, rubbing, and similar causes being negligible.

(3) Sheep are responsible for severe damage to the reproduction, both as it occurs in standing timber and on clear cuttings, regardless of the variety and supply of choice forage. Cattle cause some damage, but the extent of injury is usually slight, except where the lands are overgrazed or where the animals are inclined to congregate for more or less lengthy periods.

(4) The injury and mortality chargeable to the presence of live stock is roughly proportional to the closeness to which the lands are grazed. Observations covering a 5-year period in standing timber on sheep range showed that 27.2 per cent of the reproduction was either injured or killed on lightly grazed plots, 31.8 per cent on moderately grazed areas, and 65 per cent on heavily grazed plots. A

large proportion of the nonbrowsed sprouts are killed by causes other than grazing. In standing timber on cattle range also the injury varied according to grazing intensity, but was less than on the sheep range. During 1915 and 1916 the average percentage of injured and killed sprouts by cattle browsing was 1.6, 2.4, and 26.8 on lightly, moderately, and heavily grazed plots, respectively.

(5) On clear-cut lands, where the reproduction is conspicuous and the stand even, the annual mortality due to sheep grazing is exceedingly heavy. As a rule three years of successive sheep grazing on such lands results in the destruction of the entire stand. Some injury is also caused by cattle on clear-cut areas, but unless the range is stocked with cattle beyond its normal carrying capacity there is little danger of the reproduction being destroyed beyond the requirements necessary for the establishment of a full commercial stand.

(6) Only slight difference is recorded in extent and character of browsing either by sheep or by cattle on different height classes of reproduction, so long as the total height growth of the sprouts has not passed the limit at which stock find the food accessible.

(7) A comparison of the character and intensity of browsing shows that a notably greater proportion of the woody stems is consumed by sheep than by cattle. Even in the autumn after the leaves have dropped sheep devour a considerable quantity of the stems of a single season's growth regardless of the presence of an abundance of choice forage. In the case of cattle, however, the naked stems are practically untouched.

(8) Aspen sprouts are not necessarily permanently injured, nor will the mature tree be lacking in form or symmetry as a result of the removal once or twice of the terminal shoot. Nearly any one of the lateral branches which grow near the terminal shoot appears to be a potential terminal and may readily assume the function of the terminal itself. The destroyed leader is very commonly and promptly replaced by shoots originating from adventitious buds near the terminal. On the other hand, the removal of both the lateral branches and the terminal shoot to such an extent as to interfere appreciably with photosynthesis and the nutrition of the specimen readily weakens and decreases its subsequent rate of growth materially. If the normal leaf surface is not readily replaced and then maintained, death is the inevitable result.

(9) On lands protected from grazing aspen sprouts are produced only during the first two seasons after cutting. On grazed lands a considerable number of sprouts are sent up for three successive seasons following the removal of the timber. The third year's reproduction, however, appears from two to five weeks later than that produced in the two previous seasons and is, for the most part,

eliminated shortly after its appearance by adverse climatic factors, chiefly frost.

(10) A surprisingly large proportion of the reproduction produced even on the most favorable sites is killed during the first three years of its growth by causes other than grazing. Frost and bark-eating mammals, notably gophers, field mice, and rabbits, are mainly responsible for such mortality. Much of the damage caused by gophers and mice is done under the snow during winter or early spring.

(11) The factor that chiefly determines the time of exemption of the reproduction from destruction by sheep and cattle is the height of the sprout. The average maximum height at which sheep browse is approximately 42 inches. Sprouts averaging 45 inches in height are found to be exempt from destructive browsing by sheep. In the case of cattle there is some damage to sprouts between 55 and 60 inches in height, but seldom to those of any greater height. Reproduction averaging 5 feet in height, therefore, is practically free from damage by cattle browsing.

(12) The annual rate of height increment of the aspen reproduction averages about 15 inches. Hence sprouts 3 years of age are exempt from serious injury by sheep, and those from 4 to 5 years of age are free from serious injury by cattle.

(13) Aspen is practically unable to reproduce under its own shade, and the best means of obtaining vigorous and dense reproduction, and at the same time of harvesting the timber economically, is to clear-cut the lands or to thin the stand heavily.

(14) In the logging operations various methods are used in disposing of the branches and tops, the most common practice being to pile and burn them. This method of brush disposal is not conducive to the best results on typical aspen lands, as it exposes the reproduction unduly both to grazing and to unfavorable climatic conditions. Protection from live stock and from frost, excessive insolation, evaporation, and other adverse factors is obtained by arranging the unlopped tops about the stumps so as to protect the on-coming sprouts. In three or four years, when the reproduction is practically exempt from serious browsing, the brush is for the most part decayed and out of the way. Furthermore, such a disposition of the brush does not make the danger from fire any greater.

RECOMMENDATIONS.

From the results given in the preceding pages certain recommendations may be made for managing grazing in the aspen type so as to secure the highest possible economic use of the lands, both in the way of timber output and meat production. If properly handled, live stock will not prove antagonistic to the establishment of the reproduction, the understory of palatable forage will not be wasted, and

by the consumption of the herbage the fire risk to the timber may be greatly minimized.

Being unable to reproduce in its own shade, aspen must be well opened up either by heavy thinnings or by clear-cutting, preferably the latter, if the lands are to be fully restocked.

When the logging is done on sheep range, or on a combination sheep and cattle range, the forthcoming reproduction will be destroyed almost to the last sprout if the areas are even moderately grazed by sheep during the first three years following the cutting. To avoid destruction of the young aspen cover, then, only three courses are open: (1) Entire exclusion of grazing for three successive seasons following logging, (2) exceedingly light grazing by sheep, and (3) moderate grazing by cattle.

Obviously, the first of these possibilities does not appeal either to the timberman or the stockman. The entire exclusion of grazing animals means increased fire risk and additional fire patrol, the cost of which must be met by the timberman. For the stockman whose farm operations generally, including to a large extent the marketing of the crops produced, are dependent upon the grazing afforded in the aspen type, entire exclusion of stock may spell ruin.

The second possibility, very light grazing by sheep, would upon first thought appear to meet the requirements, and guarantee establishment of the reproduction. But the sheepman who will graze his sheep *very lightly over the choicest of forage*, such as invariably becomes established on clear-cut or heavily thinned aspen lands, has not yet been discovered. Naturally the sheepman's interests lie in the production of the maximum mutton and wool consistent with sustained forage yield; he has little interest in the production of timber. Since the standards of grazing intensity vary with the individual, what may be declared as very-light cropping by the average stockman might be classed as moderately heavy by the grazing expert or the silviculturist. Furthermore, the intensity of the grazing, at least so far as the stockman is concerned, would, of course, be judged by the extent of cropping of the herbaceous cover rather than by the seriousness of the browsing of the aspen reproduction, whereas, owing to the tendency of sheep to browse rather than graze, the aspen would probably be badly damaged before much of the herbage would be consumed. Accordingly only the very lightest grazing, coupled with the most expert handling of the flocks during the first three seasons, could be expected adequately to protect the reproduction, and exceedingly few herders would be qualified to assume such responsible management.

This brings us to the third course open to avoid the destruction of the young aspen cover; viz, moderate grazing by cattle. The aspen type occupies lands of moderate elevation usually characterized by

gentle topography, and the forage is made up quite as much of herbaceous as of woody species, so that this type is fully as well suited to the grazing of cattle as of sheep. Moderate cattle grazing during the first three or four seasons following cutting would insure a satisfactory stand of timber, while at the same time the forage crop could be utilized to its full capacity and the profits from grazing left unimpaired. Furthermore, it is well known that a temporary change in the class of stock generally grazed on the lands materially increases and improves the forage, as the species relished by cattle may be quite different from those relished by sheep. This reverse of close cropping by cattle of species grazed lightly by sheep for many years and light cropping of the species previously weakened by continued close grazing would permit the species especially relished by sheep not only to regain their full vigor, but to reproduce abundantly, and thus maintain themselves against competition with other species. Shifting from sheep to cattle for a three-year period, then, would accomplish two important things: (1) It would guarantee the establishment of a full aspen stand, and (2) it would improve the carrying capacity of the range for sheep grazing.

Obviously on cattle range no change in grazing is required, provided the lands are not too heavily stocked. Care should be taken, however, to have the stock properly distributed over the range at all times. This may best be accomplished by the proper location of salting grounds and watering places. Where the animals are inclined to drift on the lands so early in the season as to be forced to subsist on browse of second choice, such as aspen reproduction, in the absence of more choice feed, drift and division fences should be built to facilitate judicious distribution of the stock.

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