AN ABSTRACT OF THE THESIS OF

David Paul Rudeen for the degree of Master of Science

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Title: COMPATIBILITY OF SHEEP AND DEER GRAZING WITH LODGEPOLE PINE REGENERATION IN THE PUMICE REGION OF CENTRAL OREGON

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The objectives of this study were to: 1) assess potential occurrence of browsing by sheep on lodgepole pine seedlings in plantations as affected by time of grazing and existing forage conditions within the plantations; 2) assess the level of lodgepole pine seedling browsing by deer on the plantations prior to grazing of the areas by sheep; 3) attempt to determine whether sheep and deer have a preference for natural or planted seedlings and 4) attempt to determine possible management alternatives which will minimize potential conflicts between sheep grazing and lodgepole pine reforestation projects.

Two sampling areas were studied on logged and subsequently planted areas of the lodgepole pine/bitterbrush/western needlegrass (Pinus contorta/Purshia tridentata/Stipa occidentalis habitat type during the summer grazing seasons of 1975 and 1976 on the Chemult District of the Winema National Forest near Chemult, Oregon.

Shrub density and herbaceous production were determined on each sampling area to enable categorization of the existing forage into the following four forage class sites: 1) high shrub density - high herbaceous production; 2) high shrub density - low herbaceous production; 3) low shrub density - high herbaceous production and 4) low shrub density - low herbaceous production.

Two seedlings were browsed by sheep in 1975. No significant differences were found that year in seedling browsing by sheep by forage class. Thirty-eight seedlings were browsed by sheep in 1976. The data indicated that sheep normally did not browse seedlings in areas of high shrub density but did in areas of low shrub density. In areas of low shrub density, seedling browsing was reduced by high herbaceous production.

A combination of the two years of data indicated that sheep did not browse seedlings under any existing forage conditions studied after approximately the middle of July.

Deer were found to have browsed an average of 13.7 percent of the seedlings on the two sampling areas each year from 1973 through 1976. This ranged from a low of 4.4 percent in 1973 to a high of 35.0 percent in 1974. Available data did not indicate a possible explanation why 1974 was an extremely heavy seedling browsing year by deer. A total of 46.1 percent of the seedlings growing on the two sampling areas had been browsed by deer over the four year period.

In comparing differences in deer browsing of seedlings by forage class, no evident pattern was observed. However, it was observed that progressively more browsing occurred as total forage decreased.

Sheep were found to not have a preference for natural or planted seedlings. Deer, however, exhibited a marked preference for planted over natural seedlings.

Management recommendations made included: 1) allowing the sheep to graze on plantations after the middle of July each year; 2) implementing logging techniques which would reduce damage to the shrub component of the vegetation present and 3) reducing the intensity of slash removal following logging, again to reduce damage to the shrubs present, primarily bitterbrush.

Compatibility of Sheep and Deer Grazing with Lodgepole Pine Regeneration in the Pumice Region of Central Oregon

by

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INTRODUCTION

Due to new technology in the lumber industry and increased demand for lumber products, lodgepole pine (Pinus contorta) timber in the pumice region of central Oregon is now being logged more extensively than in previous years. This increase in rate of logging carries with it an increase in reforestation practices as the U. S. Forest Service attempts to restore lodgepole pine on the logged areas. Subsequent to logging, lodgepole pine sites in the Rocky Mountains have shown an increase in grazing resource potential for approximately 20 years (Basile and Jensen, 1971) through increased production of understory vegetation. A similar reaction following logging could reasonably be expected in central Oregon.

Livestock grazing in this region of Central Oregon has been carried on intermittently since the late 1800's (Brogan, 1965). Due in part to ideological differences of opinion between professional foresters and graziers as well as occasional browsing damage to lodgepole pine seedlings, grazing of this area by sheep appears to have been maintained at a level below its optimal potential.

In 1975, it was concluded that this grazing-reforestation conflict could best be resolved by establishing factual data through research done in the area. Therefore, this project was undertaken at the request of the Chemult District of the Winema National Forest to evaluate the compatibility of sheep (*Ovis aries*) grazing and lodgepole pine reforestation projects.

The objectives of this study were to:

1. assess potential occurrence of browsing by sheep on lodgepole pine seedlings in plantations as affected by time of grazing and existing forage conditions within the plantations.
2. assess the level of browsing of lodgepole pine seedlings by deer on the plantations prior to grazing of the areas by sheep.
3. attempt to determine whether sheep and deer have a preference for planted or natural seedlings.
4. attempt to determine possible management alternatives which will minimize potential conflicts between sheep grazing and lodgepole pine reforestation projects.

STUDY AREA

Location

Both sampling areas were located in Klamath County, Oregon at the eastern edge of the Chemult District of the Winema National Forest. The Bootleg sampling area (Figure 1) was 14.5 air kilometers southeast of Chemult, Oregon. The Jack Creek sampling area (Figure 2) was 25.75 air kilometers southeast of Chemult and 9.25 air miles southeast of the Bootleg area. Figure 3 shows the extent of the central Oregon pumice region and the relative positions of the two sampling areas. The average elevation at both locations is 1,489 meters.

Logging and Planting Dates

The Bootleg sampling area was part of the Dempsey timber sale which was strip clearcut in 1970 and planted in 1973. The area east of Road 2653E (right on Figure 1) was not planted. All the seedlings present there are from natural regeneration.

The Jack Creek sampling area was part of the Syrnix timber sale which was strip clearcut in 1969 and planted in 1974.

Climate

Summers in the Chemult area are generally dry and cool to warm while winters are usually wet and cold. Snow during the

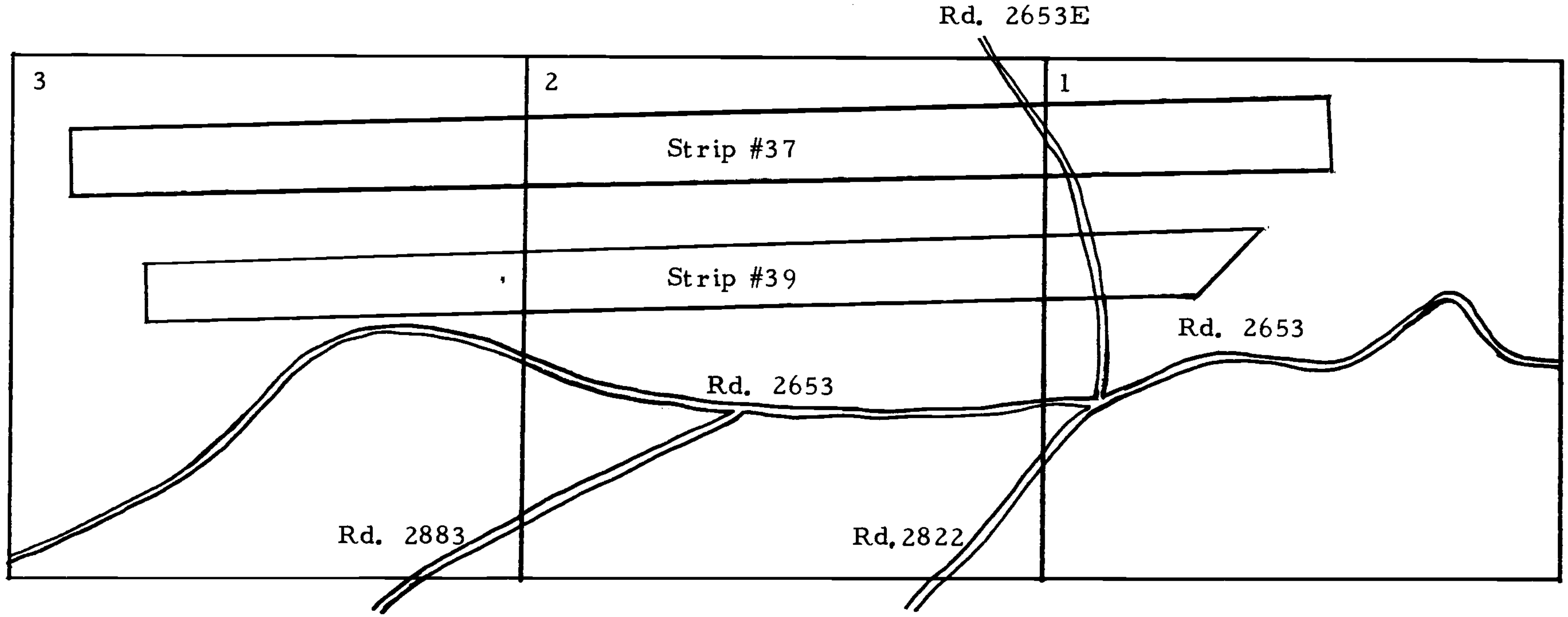

Figure 1. Bootleg sampling area (T28S - R9E).

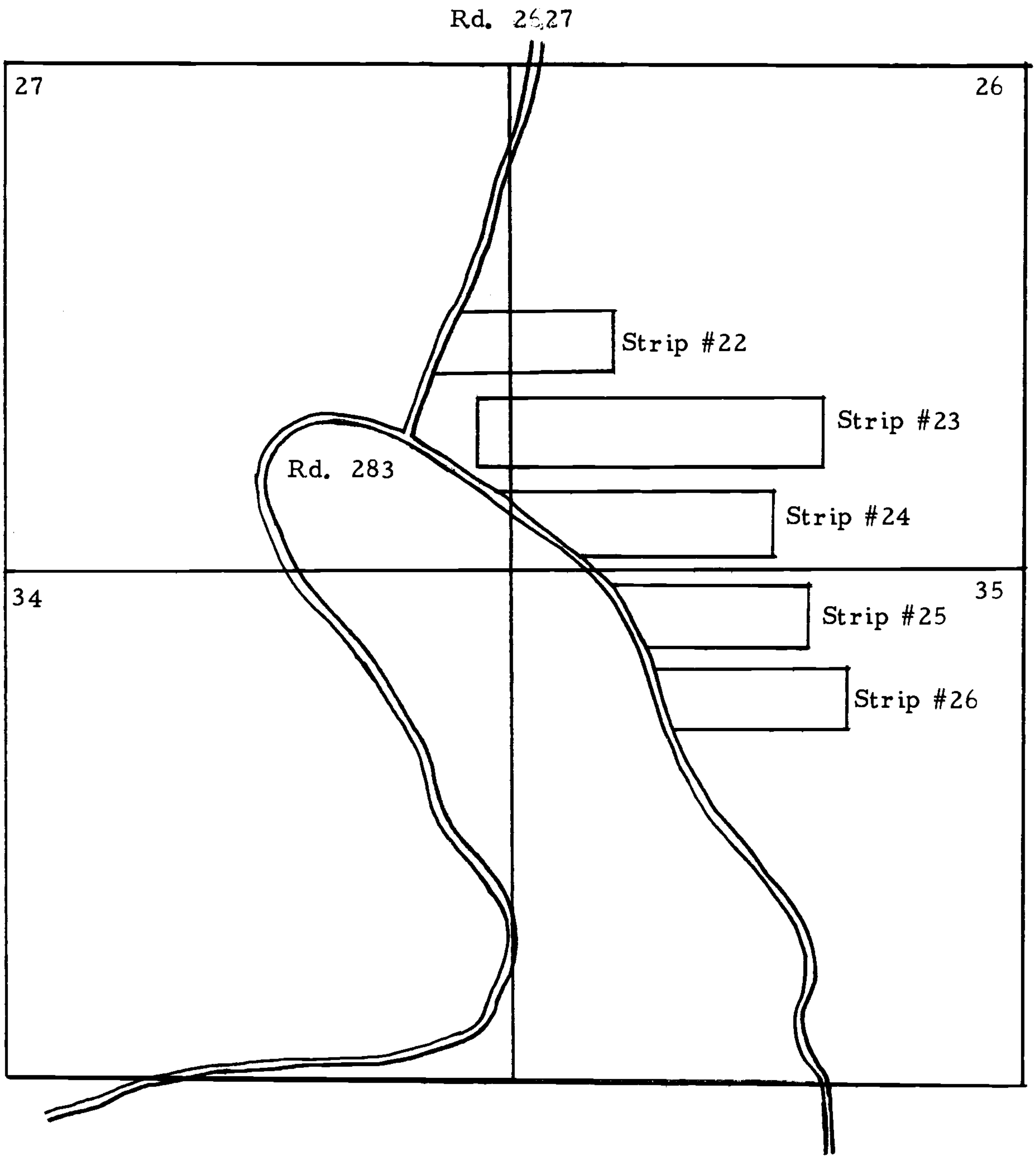

Figure 2. Jack Creek sampling area (T28S - R10E).

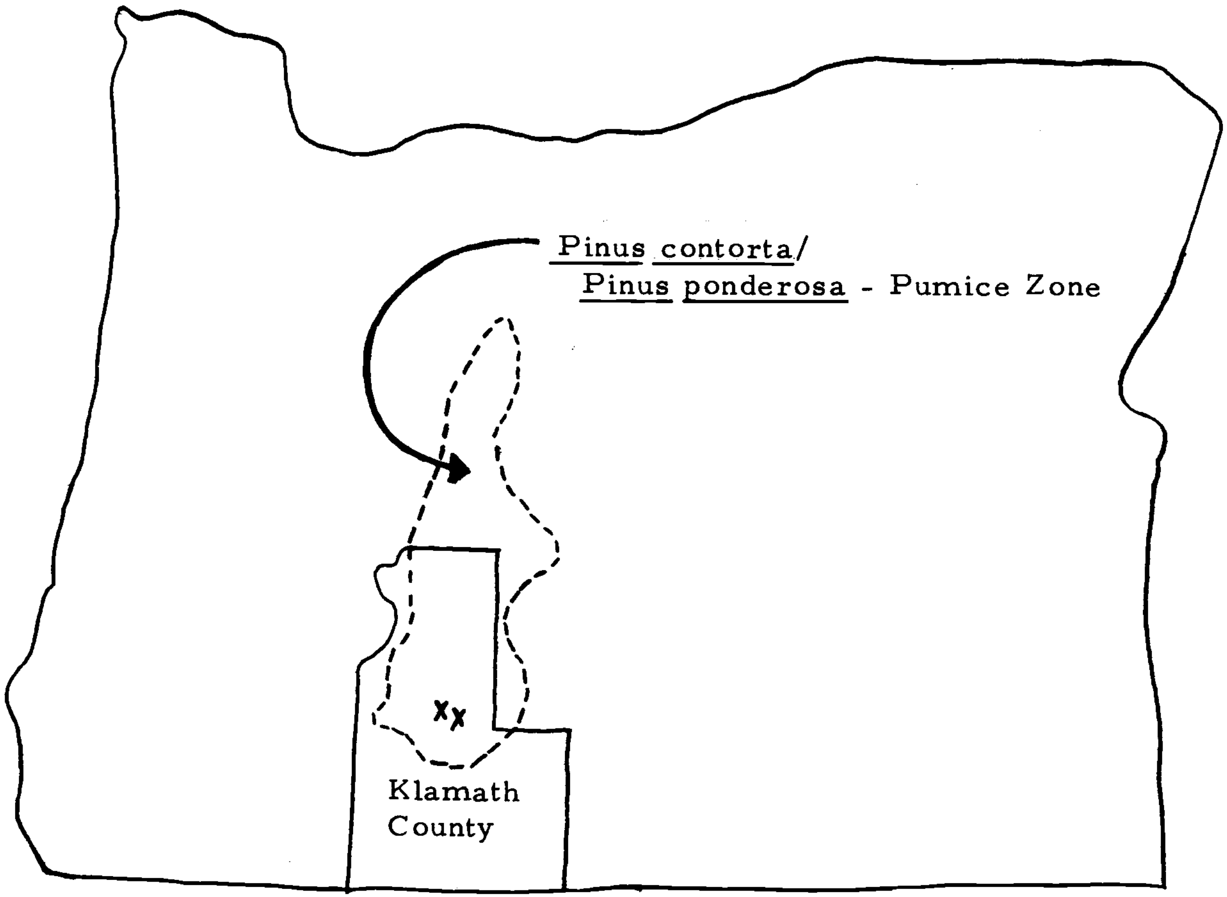

Figure 3. Location of the sampling areas. (Adapted from Stuth, 1975.)

November to March period accounts for approximately 70 percent of annual precipitation (Volland, 1974). However, rain in May and June may account for a significant part of the remaining annual precipitation. Chemult has a mean annual precipitation of 67.5 cm (Johnsgard, 1963). The growing season averages 79 days but frost may occur any month of the year (Herman, 1965).

Geology and Soils

Evidence is plentiful in the Chemult area to support the statement that volcanic activity has been relatively frequent. Volland (1974) stated that much volcanic activity has been present since early Pliocene time.

The soils were derived from pumice or scoria which was deposited over approximately 849,870 hectares (Volland, 1974) of central Oregon when Mt. Mazama, now Crater Lake, erupted almost 7,000 years ago. Due to the cool climate and relatively recent deposition, these soils are as yet poorly developed.

Vegetation

The vegetation of the study area is characterized by conIferous forest with the main tree species being lodgepole pine and ponderosa pine (*Pinus ponderosa*). Interspersed occasionally throughout the forest are meadows which are restricted to flat topography with poorly drained soils. The dominant shrub species is bitterbrush.

The most common plant communities which occur in the general vicinity of the study area are the following (designations from Volland, 1976):

Moist (hairgrass) meadows

Dry meadows

Lodgepole/bearberry

Lodgepole/bitterbrush/forb

Lodgepole/bitterbrush (rhyolite)

Lodgepole/bitterbrush/needlegrass

Lodgepole/bitterbrush/sedge

Ponderosa/bitterbrush/needlegrass

Ponderosa/bitterbrush - manzanita/needlegrass

The *Pinus contorta*/*Purshia tridentata*/*Stipa occidentalis* habitat type comprises approximately 67 percent of the total central Oregon pumice region and 78 percent of the Winema National Forest (Personal communication, William Hopkins, 1976). It is evident from these figures that this habitat type and the seral and climax vegetation which occurs on it is of major importance to Oregon and the Winema National Forest.

Because of its extent and also its economic importance, the study area with its two sampling areas was located on the lodgepole pine/bitterbrush/western needlegrass habitat type.

History of Use

Central Oregon was first explored by white men in the 1840's. Livestock grazing apparently began in the early 1870's when the first settlements were established. Brogan (1965) stated that from the late 1800's to 1909 several bands of sheep grazed the Chemult-Silver Lake area and from that point until 1930 sheep grazing was intermittent due to pressure from cattlemen. From 1930 to the present sheep have grazed on Forest Service lands in the Chemult District. One thousand ewes with their lambs are presently permitted on the allotment.

Timber harvesting began in 1863 with logging of ponderosa pine in the Fort Klamath area. Lodgepole pine harvesting began on a commercial scale in 1956 and, until the recent reduction in the chip market, has continued at an increasingly rapid rate (Stuth, 1975).

For a more detailed description of the study area see Stuth (1975).

LITERATURE REVIEW

Background Information

Many studies have been done over the years to assess the effects of grazing on forest tree regeneration. Although much research has been done, there is still controversy between foresters and graziers. Much of this controversy is based on basic differences in viewpoints and objectives between the two groups. In those forest types which have adequate understory forage to support grazing it is generally economical to allow moderate levels of grazing in conjunction with production of timber. One example was described by Pearson and Whitaker (1973) in which returns on investment for light, moderate and heavy levels of grazing were 13, 10 and 12 percent, respectively. Cloward (1965) gave an example in which a ten percent return on investment was achieved by grazing cattle under longleaf pine (*Pinus palustris*). These types of data should help to lessen the degree of difference between foresters and graziers and help them reach a point where they can work together instead of in opposition to each other.

Substantially more forest grazing work has been related to cattle than to sheep and to tree species other than lodgepole pine. Since no study was found which related sheep grazing to lodgepole pine regeneration, this review of literature will cover similar types of studies with an attempt to relate them to the current study wherever possible.

Cattle-Tree Regeneration Research

Pro-Forest Grazing

Notwithstanding the controversy over forest grazing, the great majority of the studies published supported forest grazing by livestock. A study by Pearson *et al.* (1971) on slash pine (*Pinus caribaea*) regeneration involved various levels of grazing intensity by cattle. They found that light and moderate grazing (33 and 47 percent utilization, respectively) did not affect establishment or survival of seedlings. Heavy grazing (56 percent utilization) on the other hand resulted in 124 fewer trees per acre after five years of use. They also determined that 80 percent of the mortality occurred in the months immediately after planting but that browsing of the pines "virtually" stopped once green herbage became available.

While most of the studies encountered recommended light or moderate grazing intensity, Hedrick (1975) stated that heavy grazing should help rather than hinder growth of trees in mixed conifer forests of northeastern Oregon by reducing competition from shrubs and herbaceous vegetation.

Martin (1954) reported that on properly stocked range, grazing of cattle does not conflict with forest management objectives and that the majority of grazing damage to timber in Ozark forests would be eliminated through good grazing management.

Campbell (1947) observed that cattle do little damage to pine seedlings in the southern coastal plains unless forage is scarce and that, for most economical returns, moderate grazing intensity is best. He also stated that grazing reduces the fire hazard by removing or trampling herbaceous ground cover. Hornkohl and Read (1947) stated that exclusion of grazing from Ozark woodlands in winter and early spring along with even distribution and conservative stocking during summer and fall would eliminate browsing of seedlings. They also stated that reduction of understory vegetation reduced fire hazard as well as vegetative competition.

Reid (1947) observed that although there was little specific data on grazing-reforestation effects in ponderosa pine at that time in the Pacific Northwest, it was "doubtful" that grazing would have any damaging effect on reproduction if the grazing was well managed.

Cloward (1965) stated that for three to five years after planting, grazing pressure should be moderate at most. Hjort (1964) observed that although no uniform rules can be set, with "careful, constant, alert management" grazing and ponderosa pine reproduction can be carried on simultaneously without injury to either. Smith and Stoddart (1947) reported that, in the Intermountain and Central Rocky Mountain regions, grazing removes herbaceous competition and that this balances seedling losses caused by grazing.

In the southern forests, Pearson and Whitaker (1973) reported that with careful management, even heavy cattle grazing does not damage slash pine reproduction "unduly." They also found that annual returns from grazing slash pine forests ranged from $1.82 to $2.67 per acre.

Morris (1947) made the observation that there was little quantitative data at that time to support the widely held opinion that grazing was incompatible with forest regeneration in the Northern Rocky Mountain area. He did state, however, that grazing affects reproduction adversely in some cases but beneficially in others. He also made the observation that overgrazing has been the major problem between forestry and grazing.

Pearson (1974) found that heavy grazing killed 15 to 20 percent of the seedlings in plantations but that deferment of spring grazing would reduce these losses even under continued heavy stocking.

In a study in northeastern Oregon, Erickson (1974) found that, in addition to forestry and grazing being compatible, the combined economic returns would be in excess of either use alone. Also in northeastern Oregon, Edgerton (1971) found that nearly 30 percent of the pine seedlings on his study area had been browsed in 1967 and ten percent in 1969. He stated that this browsing usually consisted of only tips of needles being eaten with an occasional removal of terminal leaders. It was his observation that most of the damage done to terminal leaders was along heavily traveled skid trails. He also found that five consecutive years of grazing did not aid growth of the seedlings through removal of competition. His concluding statement was that summer grazing by cattle was compatible with mixed conifer reforestation in northeastern Oregon and southeastern Washington.

Duvall and Halls (1962) stated that degree of damage to seedlings is almost always closely correlated with grazing intensity and that plantations or areas with young trees should not be grazed heavily or the amount of damage will outweigh the value of the forage utilized.

Campbell (1954) agreed with many of the other researchers. He found that most of the damage to seedlings occurred during the winter and spring when forage was scarce. Therefore, grazing in plantations during those two seasons should be curtailed. At other times of the year, though, grazing can be well integrated with forest regeneration practices. Halls (1958) made an almost identical statement.

Although Heerwagen (1954) did not specify use by cattle or sheep, he agreed in principle with everything already stated. He stated that proper distribution coupled with good management practices decreased browsing damage to the point that there was little or no detrimental effect to pine reproduction. He also stated that seedling browsing which did occur on ponderosa pine in the Rocky Mountains was most pronounced during dry years.

Anti-Forest Grazing

Boyer (1967) reported that cattle grazing was deterimental to longleaf pine seedlings in southwest Alabama and that during the first five years of growth, light grazing (one adult cow per 50 acres yearlong) killed 23 percent of all seedlings in the study area.

Hilmon et al. (1962) reported that within nine days after planting longleaf pine and slash pine seedlings in southern Florida, 34 percent of the slash pine and four percent of the longleaf pine seedlings showed severe grazing injury. This was at heavy grazing intensities (15 acres per cow yearlong). However, at light grazing intensities (33 acres per cow yearlong) only 2.7 percent (4 out of 150) of the seedlings were damaged. In addition, they stated that seedling survival under zero, low and medium grazing intensities were comparable. Although they do not make a point of it, this actually means that grazing at pressures up to medium intensity (20 cows per acre yearlong) could be permitted with essentially no damage to seedlings.

Duvall and Halls (1962) further added that they believe the total acreage of slash pine and longleaf pine forests grazed will decline in the future.

Johnson (1952) reported that in the southern Appalachian mountains cattle grazing was incompatible with forest regeneration. However, this was at such an extreme stocking rate for the area (24 acres per cow) that the cattle had to be given supplemental feed in order to "have strength enough to range the area." He also stated that they still lost weight. In reference to Johnson's study, Martin (1954) made the statement that a study in which animals have to be supplemented to keep them from starving or from losing too much weight sheds very little light on the actual relationships which exist between forestry and grazing on areas which are correctly stocked in relation to the forage available.

In 1947, DenUyl stated that the only solution to the problems of forest grazing in the Central States region was to exclude livestock permanently and completely from the woodlands.

Sheep-Tree Regeneration Research

Pro-Forest Grazing

In Oregon, Hedrick and Keniston (1966) determined that browsing of Douglas fir (*Pseudotsuga menziesii*) seedlings by sheep was directly related to the availability of associated vegetation and that grazing which was too heavy (above 50 percent of the palatable forbs) or too early (no specifics given) resulted in excessive levels of browsing on tree seedlings. They also found that for the first three years of the study, heights of seedlings in grazed plantations were less than heights of seedlings in ungrazed plantations. From the fourth year on, however, seedling heights were greater in the grazed plantations.

At the end of ten years the seedlings on the grazed plantations averaged 25 inches taller than the seedlings on the ungrazed control plantations. In conjunction with these results, they found that soil moisture to the 12-inch depth was greater on the grazed plantations than on the ungrazed plantations through the end of the summer. They concluded that, although grazing did result in some damage to seedlings, the benefits of grazing the associated vegetation were seen in accelerating the growth rate of the seedlings and thus helping them get above the height where deer could damage them.

Hall et al. (1959) reported that sheep grazing appeared to be compatible with establishment of Douglas fir when the grazing was correctly managed. Proper timing of use and correct utilization of palatable plant species (proper stocking) assisted in reducing damage to seedlings. They also found that soil moisture to the 12-inch depth was favorably affected by grazing.

In northern Idaho, Tisdale (1960) found that sheep grazing at moderate intensity was not harmful to establishment of coniferous reproduction. From that, he concluded that "reasonable" grazing use was "fully" compatible with good silvicultural practices. Black and Vladimiroff (1963) concluded that sheep grazing did not seriously hinder establishment of Douglas fir seedlings and gave tentative support to controlled grazing by sheep as a management tool.

Sparhawk's (1918) study on reproduction of ponderosa pine in

Central Idaho showed that grazing's most important benefit was to lower the fire hazard by reducing the amount of flammable material on the ground. He also found that the proportion of seedlings killed by browsing was much greater in the earlier part of the season and that damage to seedlings increased "fairly" constantly with increases in grazing intensity. Combining all three of his study areas, he found that five times as many seedlings were damaged and three times as many seedlings killed by other causes than by sheep. Other causes listed were rabbits, porcupines, birds, fungus diseases, tip moths and frost. In addition, he found that heavy sheep grazing on very poor lodgepole pine sites increased subsequent germination but that light or moderate grazing did not.

Anti-Forest Grazing

Campbell (1947) stated that sheep should be excluded from slash pine and longleaf pine seedling stands during winter and spring until the seedlings are four feet tall and are then no longer susceptible to damage. Later (1954) Campbell stated that sheep grazed yearlong on forest range cause serious damage to pine seedlings by browsing terminal leaders and buds that are within their reach.

Maki and Mann (1951) found that 86 percent of the longleaf pine seedlings on their study area in Mississippi were browsed by sheep at a rate of 1, 286 terminal buds per acre per year. The stocking level was 12 acres per sheep yearlong and the study area contained 1,300 acres so there were approximately 108 sheep on two sections of land continuously for the two year duration of the study. They also found that browsing on seedlings was heaviest from October through March.

Deer-Tree Regeneration Research

All literature pertaining to the effect of deer browsing on tree regeneration pointed out situations or conditions in which trees were adversely affected.

Cowan (1945) and Mitchell (1964) both studied the effects of black-tailed deer (*Odocoileus hemionus columbianus*) browsing on Douglas fir seedlings on Vancouver Island. Cowan found that most of the seedling browsing which took place occurred between December and May when there was a shortage of other forage species. Mitchell made the observation that it was unlikely that tree quality or volume at rotation age would be seriously affected despite the fact that over a period of eight to ten years average reduction in seedling height due to browsing amounted to one-half to two feet. He also stated that seedlings which were protected by logging slash or vegetation were browsed less heavily than exposed seedlings.

Crouch (1964) stated that browsing of Douglas fir seedlings by deer (species not specified) in northwest Oregon occurred primarily during the winter months. In a later study he found that the major influence in seedling browsing by deer was related to the number of animals within the area (Crouch, 1969).

Roy (1960) studied the effects of black-tailed deer browsing on Douglas fir seedlings in three separate areas of northwestern California. Browsing damage ranged from extremely light (2.6 percent of the seedlings over the four year study duration) to moderately severe (25 percent of the seedlings browsed) to extremely heavy (essentially 100 percent of the accessible seedlings browsed each year). He concluded that the severity of the browsing appeared to be related to the amount of preferred browse species growing on the area.

METHODS OF STUDY

Selection of Sampling Areas

Both sampling areas were located on the *Pinus contorta/Purshia tridentata/Stipa occidentalis* habitat type since it comprises such a large percentage of the Winema National Forest and of the central Oregon pumice region. The major criterion for selection of specific sampling areas within the habitat type was the presence of all four forage conditions (discussed below) within relatively close proximity to each other in lodgepole pine plantations of either natural or planted seedlings.

Forage Classes

The four forage classes were distinguished as follows:

High shrub - High herbaceous	($>$3500 shrubs/Ha, $>$75 Kg/Ha)
High shrub - Low herbaceous	($>$3500 shrubs/Ha, $<$75 Kg/Ha)
Low shrub - High herbaceous	($<$3500 shrubs/Ha, $>$75 Kg/Ha)
Low shrub - Low herbaceous	($<$3500 shrubs/Ha, $<$75 Kg/Ha)

The values separating forage classes were derived by first observing variation in shrub density and herbaceous production within plantations and then measuring that variation to obtain differentiating values. These values are not concrete, however. They are merely intermediate values which can be employed in the future by Forest Service personnel on the Chemult District for classification of plantations to facilitate management procedures and decisions.

Figures 4 and 5 show the spatial arrangement of the forage class sites within the two sampling areas and Figures 6 and 7 provide examples of the four forage classes. These photographs can be used by Forest Service personnel to categorize plantations without having to sample vegetation to determine density or production.

Due to logging and slash disposal techniques used on the Chemult District in the past, only two sampling areas were found which met the forage class criteria for high shrub density. Therefore, the two sampling areas were used once each in the summer of 1975 and twice each in the summer of 1976.

Shrub Density

As used here, density refers to the total number of plants per unit area. To obtain shrub density and herbaceous production values, 20 transects each 30-meters long were randomly located in two groups of ten within each forage class site. Thus there were 80 transects per sampling area. All 80 transects were established at the beginning of the 1975 summer grazing season and were reused in 1976.

Shrub density was obtained by counting all shrubs rooted within a 1x30 meter plot located adjacent and parallel to each transect. Density of bitterbrush (*Purshia tridentata*) was obtained by separating

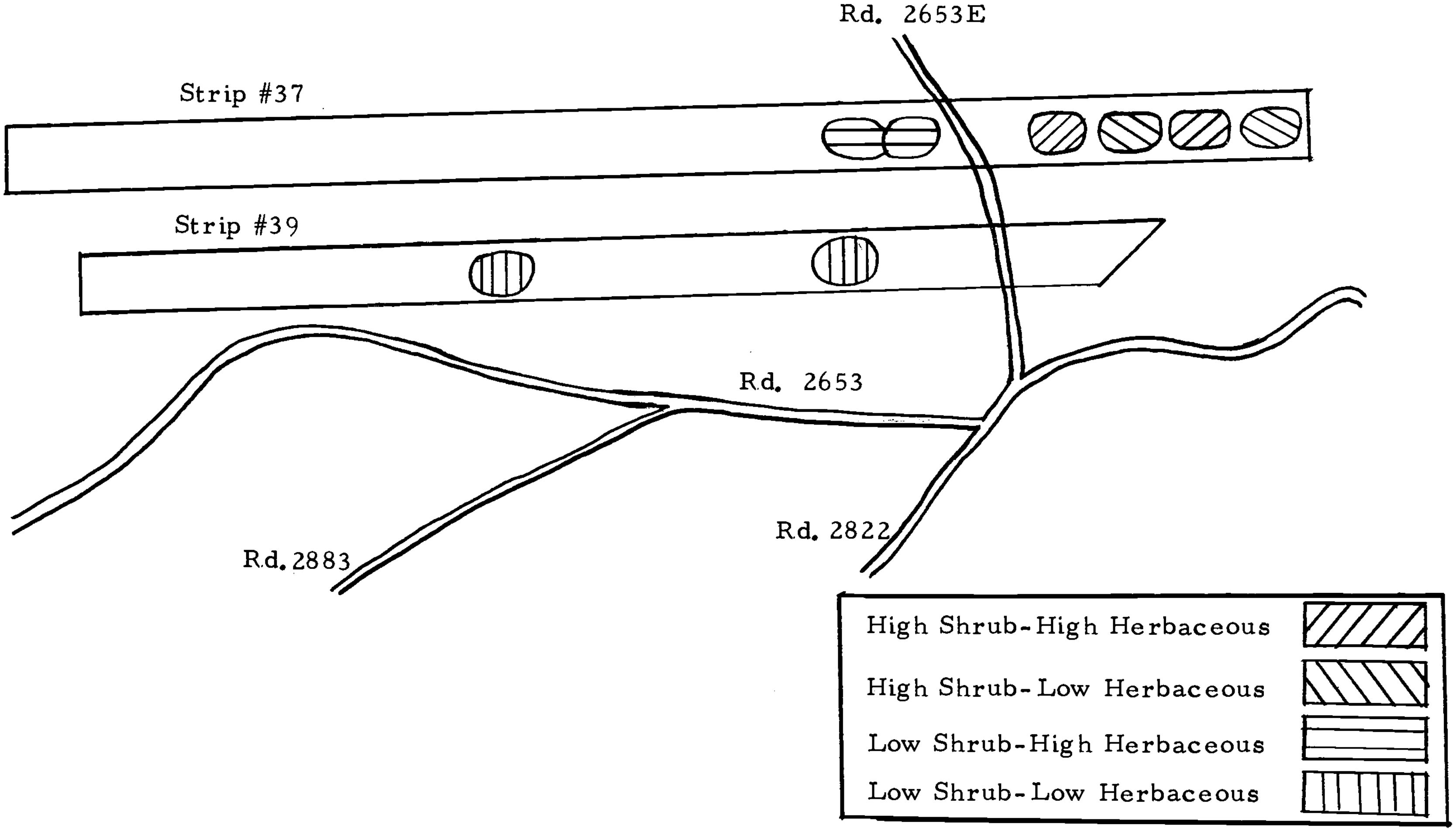

Figure 4. Spatial arrangement of forage class sites within the Bootleg sampling area.

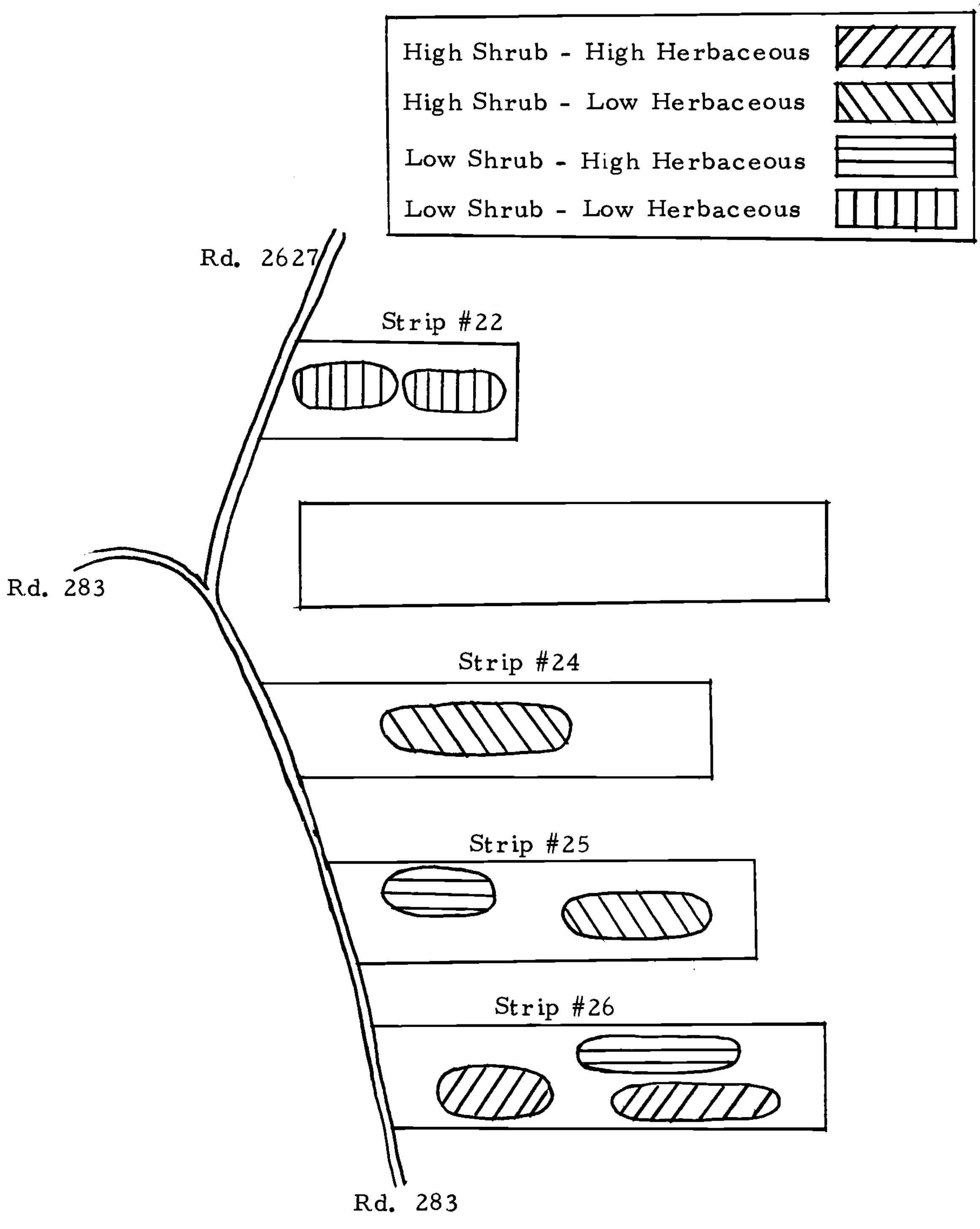

Figure 5. Spatial arrangement of forage class sites within the Jack Creek sampling area.

a)

b)

Figure 6. Photographs of forage classes: a) High shrub density - High herbaceous production; b) High shrub density - Low herbaceous production.

a)

b)

Figure 7. Photographs of forage classes: a) Low shrub density - High herbaceous production; b) Low shrub density - Low herbaceous production.

and counting individual plants based on the following three height groups: 1) <20 cm, 2) 20-40 cm and 3) >40 cm (Stuth and Winward, 1976). This was done to achieve some idea of the relative age structure of the bitterbrush plants in the plantations.

Shrub density was determined on each sampling area at the start of each summer grazing season. It was assumed that density would be essentially the same for the entire summer and would therefore not need to be obtained repeatedly.

Herbaceous Production

Herbaceous production was determined monthly by clipping and weighing and/or ocularly estimating weight by species on two randomly selected meter^2 plots per transect. No individual plot was reused. Approximately two-thirds of the plots were estimated with the designation "Trace" being applied to any weight (estimated or weighed) below one-half gram. All herbaceous production data were determined within not more than three days before the sheep grazed through each sampling area.

Production as well as density data were collected strictly for characterization of the forage classes. Actual density and production numbers have not been used in this thesis in any other way. What was felt to be of most importance was the relationship of high or low shrub density to high or low herbaceous production. This will be discussed at a later point.

Seedling Selection, Tagging and Condition

Seedling Selection

One hundred lodgepole pine seedlings were selected and tagged in each forage class for a total of 400 per sampling area. Criteria for selection were two-fold. First, the seedling had to be the nearest healthy seedling to each sixth meter point along each transect. The requirement that the seedling be healthy implied that no seedling would be selected if it showed obvious signs of sickness or dying. This was an attempt to avoid introducing any negative bias into seedling palatability to the sheep. Evidence of previous browsing on the seedlings was not considered to be reason for non-selection.

The second criterion for seedling selection involved height of the seedlings. To get a cross-section of seedling sizes, the maximum height which was allowed was one meter. It was felt that once a seedling reached one meter in height, there would be very little probability of sheep attempting to browse the terminal leader. No minimum height was set since it was necessary to assess browsing influence on very small seedlings as well as to evaluate the effects of animal trampling.

Seedling Tagging

Each selected seedling was tagged by securing a length of black Dymo labeling tape around its base. The tape was stapled to itself loosely enough that the loop of tape would rest on the ground at the base of the seedling. This method of marking the seedlings was chosen because it provided an inconspicuous tag which presumably would not be an attractant to the sheep.

Seedling Condition

The term "condition" as used here, refers only to whether the tagged seedlings had been browsed at some previous time, either by sheep or by deer.

Each of the four hundred seedlings was checked the day before the sheep were to graze through that sampling area. This was done to establish with some degree of certainty that any new browsing which might occur on the following day was indeed attributable to sheep and not to deer at some previous time.

As each seedling was checked, it was registered on a form which recorded total height of seedling, number of primary (top whorl) limbs and number of secondary (second whorl from top) limbs. Evidence of past browsing was also recorded as well as the year in which that browsing occurred back to 1973. All evidence of browsing which was observed prior to sheep use of the area was attributed exclusively to deer as rabbits (Lepus spp.) are almost non-existent in the Chemult area and porcupines (Erethizon dorsatum) have not been identified as a problem.

The day after the sheep grazed through a sampling area, each seedling was checked again. Any evidence of new browsing which was found was then attributed to sheep.

Sheep Grazing

The day after all shrub density, herbaceous production and evidence of previous browsing information was collected on a sampling area, a band of 2, 250 sheep (ewes and lambs) was grazed through the plantation. The herder was instructed to graze the sheep through the area in the same manner as he would a forested area of comparable size. He was not to push them through the plantation any faster or more slowly than would normally be done. This was intended to ensure "normal" behavior by the sheep. In addition, the sheep were not to be allowed to congregate on the plantations for any length of time other than to graze straight through them as described above.

RESULTS AND DISCUSSION

Shrub Density

Shrub density values determined at the start of each summer were used to characterize the shrub component of the four forage classes. Table 1 presents the total shrub density on a per hectare basis for both years at both sampling areas. Each number represents the average of the two groups of transects in each forage class.

Table 1. Average shrub densities (per hectare) for sampling areas, years and forage classes.

		Forage Classes			
Area	Year	HS-HH[1]	HS-LH	LS-HH	LS-LH
Bootleg	1975	5200	5100	1100	1530
	1976	4400	4650	600	860
Jack Creek	1975	6550	6400	2350	1450
	1976	5650	5665	2300	1165

[1] The four-letter abbreviations designate the following forage classes as explained on page 21.
HS-HH High Shrub - High Herbaceous
HS-LH High Shrub - Low Herbaceous
LS-HH Low Shrub - High Herbaceous
LS-LH Low Shrub - Low Herbaceous

Appendix B provides complete shrub density data for each sampling area each year. (See Appendix A for species list and abbreviations used in Appendices B and C.)

All shrub density values fell within the forage class delineations of greater than or less than 3, 500 shrubs/Ha. However, a comparison of density values shows that data from the two years were generally lower the second summer. An example is the difference shown between 1975 and 1976 data on Group 1 and Group 2 of the high shrub-high herbaceous forage class from the Bootleg sampling area (Appendix B). Group 1 shows a decrease of 400 shrubs per hectare and Group 2 shows a decrease of 1, 200 shrubs per hectare. Comparison of all groups to each other show that shrub density decreased in all groups from 1975 to 1976 except for Group 1 of the Jack Creek sampling area low shrub - high herbaceous forage class.

In an attempt to ascertain the cause for the decline, measurement of shrub density on all 80 transects was repeated a second time early in the summer in 1976. This was done to determine whether or not there had been some discrepancy in technique the first time it had been done. No substantial differences were noted. For some unknown reason(s), there appears to have been a considerable die off of shrubs the past two winters.

Since density values (as well as herbaceous production values) were determined strictly to characterize the forage classes, these decreased density values were used with no further attempt to locate the cause of the decline.

In addition, it was decided that there would be no constructive purpose served in this particular study by doing any more work with the three bitterbrush height groups. For that reason they were broken into the three groups only while density data were being recorded. They may still be statistically analyzed at a later date to see if there is any correlation between age class of bitterbrush and browsing of pine seedlings by sheep and/or deer.

Herbaceous Production

Herbaceous production data were obtained each month two to three days before the sheep grazed through a plantation sampling area. As with shrub density, herbaceous production data were used only to characterize the herbaceous component in the plantations into forage classes.

Table 2 provides average herbaceous production in kilograms/hectare by forage class for each month of both years. Complete herbaceous production data by species for each sampling area for both years is provided in Appendix C.

Table 2. Average herbaceous production (Kg/Ha) by forage class for both sampling areas for both years.

Area	Mo. /Yr.	Forage Classes			
		HS-HH	HS-LH	LS-HH	LS-LH
Bootleg	7/75	77.1	24.6	110.8	16.9
	6/76	80.0	26.5	261.5	29.7
	8/76	133.4	54.6	562.7	30.4
Jack Creek	8/75	71.9[1]	29.2	132.6	34.4
	7/76	142.2	77.6[2]	194.5	69.2
	9/76	130.0	71.9	182.5	89.0[2]

[1] Less than minimum required for "high herbaceous" classification.

[2] Higher than maximum allowed for "low herbaceous" classification.

As evidenced by the footnotes to Table 2, production in three forage classes in the two years did not meet the requirements for those particular classes of greater than or less than 75 Kg/Ha. Those three discrepancies were caused through the process of random selection of plots on which to take production data. It was evident at the time of data collection on those three areas that the herbaceous production would either be too low or too high. However, because the remainder of the area (in each case) was typical for that forage class, no action was taken to change the specific sampling locations.

Seedling Browsing by Sheep

Timing of Browsing

In 1975 the Bootleg sampling area was grazed by the sheep on July 19 and the Jack Creek sampling area was grazed on August 28.

Table 3 shows the number of seedlings browsed (per 400 tagged) in 1975 by month and forage class.

Table 3. Number of lodgepole pine seedlings browsed by sheep in 1975 by month and date.

	July 19	August 28
Seedlings Browsed	2	0

The method for statistical analysis of the data was based on the assumption that the two sampling areas were essentially identical. On this basis, time was used as the replication with each month of the summer grazing season being considered one replicate while the two sampling areas were being used alternately. However, with grazing occurring in only one month each summer, it was decided to analyze the data through use of the Chi-square test.

In 1975 the difference in amount of browsing by month was not significant at the 90% level. Because of the small number of trees browsed, essentially no interpretations could be drawn from the 1975 data. However, when combined with the 1976 data, a pattern began to develop.

In 1976 the Bootleg sampling area was grazed by the sheep on June 30 and again on August 10. The Jack Creek sampling area was grazed by the sheep on July 29 and again on September 16.

Table 4 shows the number of seedlings browsed (per 400 tagged) in 1976 by month and date.

Table 4. Number of lodgepole pine seedlings browsed by sheep in 1976 by month and date.

	June 30	July 29	August 10	September 16
Seedlings Browsed	38	0	0	0

During this year the difference in amount of browsing by month was highly significant (at the 99% level). When considering the 1976 browsing data alone, it appears that the sheep can safely be allowed to graze through lodgepole pine plantations in Chemult beginning sometime in July. When 1975 data are included, it can be safely concluded that sheep grazing in lodgepole pine plantations after approximately July 15 will cause essentially no damage to the seedlings.

With the present state of knowledge, an attempt to provide a reason for the decline or cessation of browsing in early July would be mere speculation. However, various researchers have studied the question of plant palatability. Some of the proposed causes of differential palatability are thirst (Heerwagen, 1954), succulence or free water content (Hall et al., 1959; Heady, 1964; Radwan, 1972; Radwan and Crouch, 1974) or essential oils (von Rudloff, 1971; Radwan and Ellis, 1975). Although changing palatability of the young trees may be an important factor, additional research is needed in this area to determine the cause of the decrease in browsing by sheep as the summer season advanced. If it were known why the sheep stop browsing seedlings after this period, it could allow reforestation people and range managers on the Winema National Forest to predict more closely the time at which the sheep could be allowed to graze plantations.

Browsing by Forage Classes

Total number of lodgepole pine seedlings browsed in 1975 by forage class is presented in Table 5.

Table 5. Number of lodgepole pine seedlings browsed in 1975 by sheep by forage class.

	Forage Classes			
	HS-HH	HS-LH	LS-HH	LS-LH
Seedlings Browsed	0	0	2	0

Again, with only two seedlings browsed during the summer of 1975, no statistical significance was found. However, the 1975 data did fall into the pattern when observed with the 1976 data.

Table 6 shows the number of lodgepole pine seedlings browsed by the sheep in 1976 by forage class and Table 7 gives Chi-square values for all combinations of the four forage classes as well as level of significance.

Table 6. Number of lodgepole pine seedlings browsed in 1976 by sheep by forage class.

	Forage Classes			
	HS-HH	HS-LH	LS-HH	LS-LH
Seedlings Browsed	3	0	9	26

Table 7. Combinations, Chi-square values and significance of all possible combinations of forage classes (sheep).

Combinations	χ^2	Significance
HS-HH/HS-LH	3.05	NS
HS-HH/LS-HH	3.19	NS
HS-HH/LS-LH	21.33	**
HS-LH/LS-HH	9.42	*
HS-LH/LS-LH	29.89	**
LS-HH/LS-LH	10.01	*

**Significantly different at the 99% level.

*Significantly different at the 95% level.

It should be explained that the three seedlings which were browsed in 1976 (Table 6) in the high shrub-high herbaceous forage class were all on the same transect. And that transect, through the action of random placement of transects, happened to run through a micro-area (within the forage class site) which had very few shrubs and practically no herbaceous vegetation. Other non-tagged seedlings within the same micro-area were also browsed. Adjacent and just outside the micro-area, however, the seedlings were not browsed.

The level of seedling browsing on the HS-HH area was not significantly different from that on the HS-LH area. The implication is that high or low levels of herbaceous production within an area of high shrub density do not have any significant effect on the levels of sheep browsing on the lodgepole pine seedlings. It should also be stated here that "shrubs" is in reference to bitterbrush which is an extremely palatable shrub to sheep. It is also by far the dominant shrub on the area.

The next comparison, HS-HH to LS-HH, included the three browsed seedlings which occurred in the micro-area within the typical high shrub-high herbaceous forage class vegetation. If the micro-area feature is not considered, the difference in browsing levels was non-significant. This would be in direct opposition to the implications of the first comparison. It would, in effect, imply that high or low shrub densities made no difference as long as herbaceous production was high. In actuality it was felt that the three seedlings browsed were abnormalities within the norm for high shrub areas. If these three browsed seedlings are not included on the statistical test the differences in browsing between HS-HH and LS-HH areas are indeed significant. The Chi-square value would then be 9.42 rather than 3.19.

The third comparison was of HS-HH to LS-LH, the two extremes in vegetation classes. On the one hand was an area of high shrub density and high herbaceous production and on the other was an area practically barren of anything but tree seedlings. The difference in browsing of young trees on these two areas was highly significant. Sheep browsed 26 of the trees in the LS-LH area compared to only three trees in the HS-HH area. The high Chi-square value (21.334) shows the degree of significance (Table 7).

The fourth comparison, that of HS-LH to LS-HH, also was significant. This comparison shows that the sheep are more likely to browse seedlings in an area of low shrubs and high herbaceous production than in an area of high shrubs and low herbaceous production.

Of extremely high significance was the comparison of HS-LH to LS-LH. This firmly reinforces the very strong importance of high versus low levels of shrub density. Clearly, sheep would be more apt to browse seedlings in the latter type area.

The last comparison which was of LS-HH to LS-LH also was significant. It indicated that in two areas with very few shrubs, the amount of herbaceous forage available does make a difference, in that less seedling browsing would tend to occur on the area with high herbaceous production.

Synthesized, the presence or absence of bitterbrush is of vastly more importance to the safety of seedlings on plantations which are grazed by sheep than is the presence or absence of herbaceous forage (in this case mostly grasses and sedges).

Degree of Damage to Seedlings

In a short term research study such as this one, few if any valid long-range conclusions can be drawn regarding the possible height or vigor losses to browsed tree seedlings as a group. In addition, since the apical meristem is in the tip of the terminal leader, it was decided that recording the degree of damage in centimeters, for example, would be superfluous. Browsing of lower branches and/or needles was also not recorded. General observations were made, however. It was observed that the sheep generally ate the terminal leader back almost to the base of the first whorl of lateral branches. In addition to eating the terminal leader, they also ate at least part of the first whorl of lateral branches back to the same level. From these observations it appeared that the sheep did not merely browse a seedling quickly as they went by, but actually tended to stop and eat at least several bites.

Natural vs. Planted Seedling Preference by Sheep

Of the two seedlings browsed by sheep in 1975, one was planted and the other was natural. No statistical significance could be established on that data base.

Of the 38 seedlings browsed in 1976, three were in an area of strictly natural regeneration and therefore, also could not be included in testing to determine significance. The remaining 35 browsed seedlings were used for statistical testing of sheep preference for planted versus natural tree seedlings. Table 8 shows the total number of natural and planted seedlings browsed and Table 9 presents the Chi-square value obtained from the 35 seedlings which could be tested.

Table 8. Number of natural and planted lodgepole seedlings browsed by sheep in 1975 and 1976.

Year	Natural	Planted
1975	1	1
1976	15	23

Table 9. Number of natural and planted lodgepole pine seedlings browsed and the Chi-square value derived.

	Natural	Planted	χ^2	Significance
Seedlings Browsed	12	23	0.98	NS

There was no significant preference by sheep for planted over natural seedlings (Table 9) and it can then be said that planted seedlings apparently are not more palatable than natural seedlings.

Based on intuition only, however, it is this researcher's opinion that first year (just planted) seedlings are more palatable than two or more year old seedlings. This opinion is based on personal observation of various Chemult plantations during the two summers and on information obtained from Chemult reforestation personnel. Possibly the fertilizers used in the seedling nurseries or some other undetermined factors make the seedlings more palatable. There were no first year seedlings in the plantations sampled. Therefore, the data did not provide evidence in support of higher palatability of first year seedlings. More research needs to be done along the lines of seedling palatability and on natural vs. planted preference to enable land managers to more confidently and knowledgeably manage both grazing and pine reproduction.

Trampling Effects

Although not mentioned anywhere else in the thesis, it should be noted that there was not one instance of a seedling being injured by being stepped on. Not one seedling, tagged or untagged, in any of the plantations both summers was found to have been stepped on, much less damaged.

Seedling Browsing by Deer

Browsing by Year

The entire Chemult District lies within the summer range of the mule deer (*Odocoileus hemionus hemionus*) herd which winters in the Silver Lake area.

Stuth (1975) stated that the deer generally leave their winter range in mid-April. He did not state when they generally reach the Chemult area but it would be reasonable to assume that they would have arrived by late April or early May. It is at about this same time that lodgepole pine seedlings are beginning to start leader growth.

Table 10 shows the number of seedlings browsed by deer each year from 1973 through 1976 for both sampling areas as well as the combined totals. The percentages shown are based on 400 seedlings each year for the sampling areas and on 800 for the combined data. Individual seedlings browsed in more than one year are included in each respective year.

Averaging the data in Table 10 showed that 13.7 percent of the seedlings on the two sampling areas were browsed by deer each year from 1973 through 1976. Deer browsing was extremely heavy on both sampling areas in 1974 (Table 10). With the data available at this time, no hypothesis can be suggested to explain the extremely heavy 1974 browsing.

Table 10. Number of seedlings browsed each year by deer for both sampling areas and combined totals. (Seedlings browsed more than once were included in each respective year's data.)

Year	Bootleg		Jack Creek		Combined	
	Seedlings Browsed	% by Year	Seedlings Browsed	% by Year	Seedlings Browsed	% by Year
1973	18a[1]	4.50	17a	4.25	35a	4.38
1974	121	30.25	159	39.75	280	35.00
1975	15a	3.75	44	11.00	59ab	7.38
1976	41	10.25	24a	6.00	65b	8.13

[1]Within columns, numbers followed by the same letter are not significantly different at the 95% level.

Table 11 presents the total number of seedlings browsed by deer on both sampling areas in the four-year span as well as the combined totals and all percentages.

Table 11. Total number of seedlings browsed by deer between 1973 and 1976 by sampling area and combined totals.

Sampling Area	Seedlings Browsed	%
Bootleg	160[1]	40.0
Jack Creek	209	52.3
Combined Total	369	46.1

[1]Differences in levels of seedling browsing on each sampling area were highly significant.

Differences in seedling browsing by deer between the two sampling areas were highly significant (Table 11). Since both areas were located on the same habitat type and both had similar forage class values, the difference in seedling browsing is likely not related to available alternate forage. One possible explanation for the higher level of seedling browsing on the Jack Creek sampling area is the presence of Jack Creek itself. Jack Creek runs no more than one-quarter mile from any of the Jack Creek sampling area plantations. This longer distance from free water may have been the reason for the lower overall seedling browsing by deer on the Bootleg sampling area.

Deer Browsing by Forage Class

Table 12 shows the total number of tagged seedlings browsed by deer from 1973 through 1976 by forage class and Table 13 shows significance values by forage class combinations.

Table 12. Total number of lodgepole pine seedlings browsed by deer by forage class from 1973 through 1976.

	Forage Class			
	HS-HH	HS-LH	LS-HH	LS-LH
Seedlings Browsed	92	102	104	141

Table 13. Combinations, Chi-square values and significance of all possible combinations of forage classes (deer).

Combinations	χ^2	Significance
HS-HH/HS-LH	0.59	NS
HS-HH/LS-HH	0.84	NS
HS-HH/LS-LH	12.06	**
HS-LH/LS-HH	0.02	NS
HS-LH/LS-LH	7.38	**
LS-HH/LS-LH	6.60	*

**Significantly different at the 99% level.
*Significantly different at the 95% level.

Progressively more browsing occurred as total forage decreased. Seedling browsing was significantly higher in the LS-LH areas than in any of the other forage classes. These data point out the importance of minimizing loss of understory vegetation during logging and slash disposal operations.

Natural vs. Planted Seedling Preference by Deer

In contrast to what was found for sheep, deer did exhibit a preference for planted seedlings (Table 14).

The conclusion which can be drawn here is that deer will browse planted seedlings more readily than natural seedlings in the Chemult area.

One theory which has been advanced to explain this type of situation is that the seed source for the seedling stock is from a different area than where the seedlings are planted. This is not a possiblity here, however, since the seeds were collected from the same general area of the Chemult District as where the seedlings were eventually planted (Personal communication, William Mann, 1976). Until planting age, the seedlings were grown in nurseries in the Bend area. Again, more research is needed which is aimed at understanding the factor(s) responsible for this differential use so that management can be directed toward decreasing the currently high level of seedling browsing by deer.

Table 14. Number of natural vs. planted seedlings browsed by deer by sampling area combined with Chi-square values and significance.

Sampling Area	Natural	Planted	χ^2	Significance[a]
Bootleg	19	87	11.36	**
Jack Creek	59	144	20.60	**
Combined Total	78	231	31.65	**

[a]All values in rows are significantly different at the 99% level.

Seedling Tagging Problem

An unforeseen problem with the tagging system used was discovered at the beginning of the second summer of field work. It was noted that some of the labeling tape loops which had been used to tag the seedlings had worked their way up a few of the smaller seedlings and had killed some of the lower branches. These branches had been pulled up parallel to the main stem of the seedling by the tape loops. The means by which this occurred was unclear but it appeared to have happened during the winter. It is possible that hard-crusted snow pushed the loop up around the lower limbs which were then killed when water collected and froze inside the loop and around the stem and limbs. General vigor of these seedlings did not appear to be significantly reduced in that they were observed to continue good growth throughout the entire growing season. Even so, it would probably be advisable to develop a different method for tagging the seedlings if this type of study were to be done again.

It was also observed in some of the larger seedlings that diameter growth was so rapid that the tape loops which were stapled to themselves around the stem were "stretched" loose and fell off.

Everything considered, the tagging system used was a good one for single summer research studies but it would probably be advisable to devise a different method for longer term studies.

MANAGEMENT RECOMMENDATIONS

Sheep Grazing Changes

At the present time sheep are not allowed to graze any plantations on the Chemult District at any time other than for research purposes. The data which were collected over the two summers of the study clearly indicated that sheep do not cause excessive damage to either natural or planted lodgepole pine seedlings in plantations with high levels of shrub (bitterbrush) density. It would be logical, then, to recommend that the sheep be allowed to graze the high shrub plantations at any time of the summer grazing season except possibly during the first year after planting. There are two problems, however, which preclude this recommendation being implemented. The first is that, on the whole district, there are only four plantations which have high shrub densities. The second problem is that of communication with the herders. The majority of the herders either do not speak English or speak it poorly and most U. S. Forest Service personnel do not speak Spanish. This also precludes clarity in giving instructions to the herders to graze only four certain plantations but not all the others.

A better answer to the problem of sheep grazing the plantations is to delay the season of use. Since the sheep did not browse the seedlings in any of the forage classes after July 19, it is recommended that the herders be allowed to graze all plantations within the allotment each year after approximately July 15. An exception possibly would be first year plantations.

It is this researcher's personal feelings that the owners, camp tenders and herders are almost as interested in not damaging the seedlings as the reforestation officers for the Forest Service. For this reason it is felt that such a change in present grazing policy would be welcomed and adhered to.

One stipulation which would be an integral part of this recommendation is that the sheep be allowed to graze over a given plantation one time only each summer. It is felt that, due to reduced availability of forage, probability of browsing damage to seedlings on a second trip through a plantation would be higher. It should be noted here that the herders probably would be quite willing to accept this stipulation since they seldom, if ever, graze their sheep over a given piece of ground more than once. The pumice dust gets unacceptably thick after once over and chokes the sheep. In addition, the forage which is easily available has been reduced and the herders do not like to make their sheep work to find forage.

Logging Techniques and Slash Treatment Changes

Considering the fact that 46.1 percent of all tagged seedlings on the two sampling areas have been browsed by deer at one time or another, it appears that protecting the seedlings from the deer is of vital importance.

One way in which the seedlings can be protected is to do a less thorough job of slash clean-up after logging. According to the Fire Control Officer on the Chemult District, the three southern plantations on the Jack Creek sampling area (see Figure 5) were experiments in minimum slash removal (Personal communication, Maurice Kelley, 1976). Kelley also stated that these areas still met Forest Service Fire Control standards for slash left after logging operations. For the most part, this reduced intensity of slash removal resulted in much higher levels of bitterbrush density since piling slash by caterpillar tractor as it is done on the Chemult District destroys much of the remaining bitterbrush plants not killed by the logging operation. As seen by the lower degree of seedling browsing on high shrub density areas by both sheep and deer, it is the presence of alternate forage species (primarily bitterbrush) which tends to reduce seedling browsing. The value of slash in protecting seedlings from browsing and trampling damage also may be important (Edgerton, 1971). Grisez (1960) stated that slash has a "definite protective effect" and should be looked on as a "blessing, not just a fire hazard."

Another action which could be taken to protect the seedlings from browsing would be to require loggers to employ logging techniques which would minimize damage to bitterbrush. Stuth (1975) stated that 42.3 percent of the bitterbrush plants on his study area were lost during logging operations. Although it is beyond the scope of this thesis to go into specific recommendations in this respect, it would be reasonable to assume that some relatively simple changes could be implemented in logging procedures which would protect the bitterbush to a much greater degree than is now the case. This in turn could potentially reduce browsing damage on pine seedlings by providing alternative deer and sheep forage.

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Appendix A. Abbreviations, scientific names and common names of plants sampled on the study area. (Designations following Garrison et al., 1976)

Abbr.	Scientific Name	Common Name
Trees		
Pico	Pinus contorta Dougl.	lodgepole pine
Shrubs		
Habl	Haploppapus bloomeri Gray	rabbitbrush goldenweed
Putr	Purshia tridentata (Pursh) DC.	antelope bitterbrush
Rice	Ribes cereum Dougl.	wax currant
Grasses and grass-likes		
Caro	Carex rossii Boott	Ross sedge
Dagl	Dactylis glomerata L.	orchardgrass
Feid	Festuca idahoensis Elmer	Idaho fescue
Sihy	Sitanion hystrix (Nutt.) J. G. Sm.	bottlebrush squirreltail
Stoc	Stipa occidentalis Thurb. ex Wats.	western needlegrass
Forbs		
Acmi	Achillea millefolium lanulosa Piper	western yarrow
Ange	Antennaria geyeri Grey	Geyer pussy-toes
Cisc	Cirsium scariosum Nutt.	elk thistle
Epil	Epilobium sp. L.	willowweed
Gara	Gayophytum ramosissimum Nutt. ex T. & G.	hairstem groundsmoke
Lule	Lupinus lepidus Dougl.	prairie lupine
Mina	Mimulus nanus H. & A.	dwarf purple monkeyflower
Phha	Phacelia hastata Dougl. ex Lehm.	whiteleaf phacelia
Plhi	Plagiobothrys hispidus Gray	bristly popcorn-flower
Sein	Senecio integerrimus Nutt.	western groundsel
Vinu	Viola nuttallii Pursh	Nuttall violet

Appendix B. 1975 shrub and seedling density on the Bootleg sampling area and Jack Creek sampling area.

		High shrub-High herbaceous				High shrub-Low herbaceous				Low shrub-High herbaceous				Low shrub-Low herbaceous			
		Grp #1		Grp #2		Grp #1		Grp #2		Grp #1		Grp #2		Grp #1		Grp #2	
		#/Ha	#/m^2	#/Ha	#/m^2	#/Ha	#/m^2	#/Ha	#/m^2	#/Ha	#/m^2	#/Ha	#/m^2	#/Ha	#/m^2	#/Ha	#/m^2
1975 shrub and seedling density on the Bootleg sampling area																	
Putr:	< 20 cm	1500	0.15	1800	0.18	2300	0.23	2100	0.21	600	0.06	600	0.06	1700	0.17	700	0.07
	20-40 cm	2000	0.20	1800	0.18	1600	0.16	1600	0.16	100	0.01	0	0	100	0.01	30	0.003
	> 40 cm	1200	0.12	900	0.09	1000	0.10	900	0.09	0	0	0	0	0	0	30	0.003
Rice		100	0.01	400	0.04	200	0.02	300	0.03	300	0.03	300	0.03	0	0	0	0
Habl		600	0.06	100	0.01	100	0.01	100	0.01	200	0.02	100	0.01	500	0.05	0	0
Total		5400	0.54	5000	0.50	5200	0.52	5000	0.50	1200	0.12	1000	0.10	2300	0.23	760	0.076
Pico:	Planted	0	0	0	0	0	0	0	0	1200	0.12	1100	0.11	700	0.07	1000	0.10
	Natural	6600	0.66	6800	0.68	8000	0.80	4900	0.49	400	0.04	1800	0.18	200	0.02	400	0.04
Total		6600	0.66	6800	0.68	8000	0.80	4900	0.49	1600	0.16	2900	0.29	900	0.09	1400	0.14
1975 shrub and seedling density on the Jack Creek sampling area																	
Putr:	< 20 cm	2100	0.21	1700	0.17	2200	0.22	2100	0.21	1100	0.11	1300	0.13	900	0.09	1100	0.11
	20-40 cm	2100	0.21	2400	0.24	2100	0.21	2300	0.23	1300	0.13	400	0.04	200	0.02	200	0.02
	> 40 cm	1400	0.14	800	0.08	1900	0.19	1400	0.14	200	0.02	100	0.01	0	0	0	0
Rice		100	0.01	100	0.01	300	0.03	0	0	100	0.01	0	0	100	0.01	200	0.02
Habl		2300	0.23	100	0.01	0	0	500	0.05	100	0.01	100	0.01	100	0.01	100	0.01
Total		8000	0.80	5100	0.51	6500	0.65	6300	0.63	2800	0.28	1900	0.19	1300	0.13	1600	0.16
Pico:	Planted	700	0.07	700	0.07	900	0.09	600	0.06	1000	0.10	1000	0.10	700	0.07	600	0.06
	Natural	400	0.04	1400	0.14	500	0.05	400	0.04	400	0.04	1700	0.17	100	0.01	400	0.04
Total		1100	0.11	2100	0.21	1400	0.14	1000	0.10	1400	0.14	2700	0.27	800	0.08	1000	0.10

Appendix B. (Continued) 1976 shrub and seedling density on the Bootleg sampling area and Jack Creek sampling area

		High shrub-High herbaceous				High shrub - Low herbaceous				Low shrub-High herbaceous				Low shrub -Low herbaceous			
		Grp #1		Grp #2		Grp #1		Grp #2		Grp #1		Grp # 2		Grp #1		Grp #2	
		#/Ha	#/m^2	#/Ha	#/m^2	#/Ha	#/m^2	#/Ha	#/m^2	#/Ha	#/m^2	#/Ha	#/m^2	#/Ha	# m2	#/Ha	#/m^2
1976 shrub and seedling density on the Bootleg sampling area																	
Putr:	< 20 cm	1400	0.14	1000	0.10	1700	0.17	1400	0.14	200	0.02	200	0.02	700	0.07	400	0.04
	20-40 cm	1500	0.15	1400	0.14	1200	0.12	1700	0.17	30	0.003	0	0	30	0.003	30	0.003
	> 40 cm	1300	0.13	900	0.09	1600	0.16	1100	0.11	0	0	0	0	30	0.003	30	0.003
Rice		100	0.01	400	0.04	200	0.02	200	0.02	300	0.03	100	0.01	0	0	0	0
Habl		700	0.07	100	0.01	100	0.01	100	0.01	300	0.03	70	0.007	500	0.05	0	0
Total		5000	0.50	3800	0.38	4800	0.48	4500	0.45	830	0.083	370	0.037	1260	0.126	460	0.046
Pico:	Planted	0	0	0	0	0	0	0	0	600	0.06	700	0.07	500	0.05	700	0.07
	Natural	5100	0.51	8700	0.87	7700	0.77	5000	0.50	800	0.08	2400	0.24	500	0.05	600	0.06
Total		5100	0.51	8700	0.87	7700	0.77	5000	0.50	1400	0.14	3100	0.31	1000	0.10	1300	0.13
1976 shrub and seedling density on the Jack Creek sampling area																	
Putr:	< 20 cm	1533	0.15	2100	0.21	1800	0.18	2000	0.20	1000	0.10	1100	0.11	500	0.05	600	0.06
	20-40 cm	1533	0.15	1400	0.14	1500	0.15	1300	0.13	800	0.08	400	0.04	200	0.02	100	0.01
	> 40 cm	2300	0.23	1500	0.15	2300	0.23	1400	0.14	800	0.08	200	0.02	100	0.01	30	0.003
Rice		100	0.01	100	0.01	300	0.03	0	0	100	0.01	0	0	100	0.01	300	0.03
Habl		500	0.05	300	0.03	30	0.003	700	0.07	100	0.01	100	0.01	300	0.03	100	0.01
Total		5900	0.59	5400	0.54	5930	0.593	5400	0.54	2800	0.28	1800	0.18	1200	0.12	1130	0.113
Pico:	Planted	700	0.07	500	0.05	900	0.09	400	0.04	1000	0.10	400	0.04	700	0.07	700	0.07
	Natural	400	0.04	2100	0.21	500	0.05	500	0.05	400	0.04	2300	0.23	200	0.02	500	0.05
Total		1100	0.11	2600	0.26	1400	0.14	900	0.09	1400	0.14	2700	0.27	900	0.09	1200	0.12

Appendix C. Herbaceous production on the Bootleg sampling area in 1975 in Kg/Ha (O.D.).

High shrub - High herbaceous

	Grp #1	Grp #2	Aver.
Stoc	63.1	45.3	
Sihy	19.3	3.7	
Caro	9.4	9.0	
Vinu	1.1	T*	
Gara	2.0	T	
Plhi	1.2	T	
Cisc	T		
Ange	T		
Epil	T		
Phha		T	
Acmi		T	
	96.1	58.0	77.1

High shrub - Low herbaceous

	Grp #1	Grp #2	
Stoc	20.0	10.1	
Sihy	3.5	5.0	
Caro	4.1	6.4	
Vinu	T	T	
Gara	T	T	
	27.6	21.5	24.6

Low shrub - High herbaceous

	Grp #1	Grp #2	
Stoc	80.6	77.9	
Sihy	2.2	4.8	
Caro	43.8	10.4	
Vinu	T	1.0	
Gara	T	0.8	
	126.6	94.9	110.8

Low shrub - Low herbaceous

	Grp #1	Grp #2	
Stoc	12.1	6.7	
Sihy	9.7		
Caro	4.7	0.5	
Vinu	T	T	
Gara	T	T	
	26.5	7.2	16.9

*T = Trace ($<$ 0.5 Kg/Ha)

Appendix C. (Continued) Herbaceous production on the Jack Creek sampling area in 1975 in Kg/Ha (O.D.).

High shrub - High herbaceous

	Grp #1	Grp #2	Aver.
Stoc	58.0	72.9	
Sihy	2.3	0.5	
Caro	4.2	5.2	
Vinu	T*		
Gara	0.7	0.8	
	65.2	78.6	71.9

High shrub - Low herbaceous

	Grp #1	Grp #2	
Stoc	16.5	40.0	
Sihy	T	T	
Caro	T		
Gara	1.1	0.7	
Lule		T	
	17.6	40.7	29.2

Low shrub - High herbaceous

	Grp #1	Grp #2	
Stoc	103.4	102.2	
Sihy	7.8	3.6	
Caro	16.6	31.0	
Vinu	T	T	
Gara	0.6	T	
Lule	T		
	128.4	136.8	132.6

Low shrub - Low herbaceous

	Grp #1	Grp #2	
Stoc	34.9	11.8	
Sihy	3.1	9.6	
Caro	2.4	6.9	
Vinu	T		
Gara	T	T	
Phha	T		
	40.4	28.3	34.4

*T = Trace (<0.5 Kg/Ha)

Appendix C. (Continued) Herbaceous production on the Bootleg sampling area in 1976 in Kg/Ha (O. D.).

	June			August		
High shrub - High herbaceous	Grp #1	Grp #2	Aver.	Grp #1	Grp #2	Aver.
Stoc	51.9	35.0		51.9	55.8	
Sihy	21.1	7.1		5.5	12.4	
Caro	29.4	7.4		74.2	65.4	
Vinu	T*	T		T	T	
Gara		T		T	T	
Plhi	T	T		T	T	
Mina	T					
Phha	8.0					
Cisc	T			1.5		
Ange	T					
	110.4	49.5	80.0	133.1	133.6	133.4
High shrub - Low herbaceous	Grp #1	Grp #2		Grp #1	Grp #2	
Stoc	11.1	12.3		22.8	18.7	
Sihy	7.1	9.8		5.5	6.6	
Caro	1.3	10.4		36.8	18.7	
Vinu	T	T		T	T	
Gara	T	T		T	T	
Plhi	T				T	
Mina	T					
Phha				T		
Cisc	1.0					
Sein	T					
	20.5	32.5	26.5	65.1	44.0	54.6
Low shrub - High herbaceous	Grp #1	Grp #2		Grp #1	Grp #2	
Stoc	87.8	91.1		168.7	96.8	
Sihy	16.2	73.5		15.8	56.1	
Caro	191.8	61.2		461.1	146.9	
Vinu	1.4	T		T	T	
Gara	T	T		T	T	
Plhi				T		
Phha		T			T	
	297.2	225.8	261.5	825.6	299.8	562.7
Low shrub - Low herbaceous	Grp #1	Grp #2		Grp #1	Grp #2	
Stoc	23.8	24.1		25.2	27.8	
Sihy	T	T		T	0.7	
Caro	5.6	5.8		2.3	4.7	
Vinu	T	T		T	T	
Gara	T	T		T	T	
Acmi		T				
	29.4	29.9	29.7	27.5	33.2	30.4

*T = Trace (< 0.5 Kg/Ha)

Appendix C. (Continued) Herbaceous production on the Jack Creek sampling area in 1976 in Kg/Ha (O.D.).

	July			September		
High shrub - High herbaceous						
	Grp #1	Grp #2	Aver.	Grp #1	Grp #2	Aver.
Stoc	101.4	91.4		61.4	87.8	
Sihy	11.8	5.1		14.5	2.5	
Caro	29.6	45.1		14.0	79.8	
Vinu	T*	T		T		
Gara	T	T		T	T	
Plhi	T	T				
Mina	T					
Phha		T			T	
Lule				T		
Feid	T					
	142.8	141.6	142.2	89.0	170.1	130.0
High shrub - Low herbaceous						
	Grp #1	Grp #2		Grp #1	Grp #2	
Stoc	46.4	44.8		46.3	55.0	
Sihy	1.3	1.5				
Caro	59.1	0.6		30.5	12.0	
Vinu	T	T		T		
Gara	0.7	0.8		T	T	
Plhi	T					
Mina	T					
	107.5	47.4	77.6	76.8	67.0	71.9
Low shrub - High herbaceous						
	Grp #1	Grp #2		Grp #1	Grp #2	
Stoc	103.8	110.2		118.3	124.3	
Sihy	2.6	31.1		0.8	8.6	
Caro	43.6	96.0		51.9	61.0	
Vinu	T	T		T		
Gara	1.2	0.5		T	T	
Plhi		T				
Phha		T				
Lule		T				
	151.2	237.8	194.5	171.0	193.9	182.5
Low shrub - Low herbaceous						
	Grp #1	Grp #2		Grp #1	Grp #2	
Stoc	37.6	54.3		75.0	66.7	
Sihy	8.0	1.8		8.4	5.9	
Caro	T	30.1		4.3	5.7	
Vinu	T	T		T		
Gara	3.7	1.2		2.5	2.5	
Plhi	0.6	1.0				
Phha					3.5	
Cisc				T		
Dagl				3.5		
Feid				T		
	49.9	88.4	69.2	93.7	84.3	89.0

*T = Trace (<0.5 Kg/Ha)