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Title: Silvicultural Impacts of Sheep Grazing in Oregon's Coast Range

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A three-year investigation was conducted during 1980-1982 to evaluate the potential of using herded sheep as a silvicultural tool to suppress brush in Douglas-fir (*Pseudotsuga menziesii*) plantations of Oregon's Coast Range. Sheep browsing of Douglas-fir was highest in May soon after bud break. Averaged over the 2 years of grazing, sheep consumed 28% of the Douglas-fir current year's growth (CYG) in two May-grazed plantations. Browsing was generally light (2% CYG) during July and August. Browsing of terminal leaders by sheep decreased as seedling height increased. Less than 3% of the study trees were mechanically impacted by sheep.

In a 2-year-old plantation in which seedlings were heavily browsed by sheep in both May and August, annual height and mean diameter increment were reduced by sheep grazing. However, annual mean diameter increment was 8 to 17% higher in the grazed portion of three 4-6-year-old study plantations. Survival of regeneration over the 2 years of investigation was high in all study plantations and was unaffected by grazing. Increased available nitrogen deposited as urine in grazed plantations may have contributed to the increased diameter growth.

Vegetational composition of sheep diets varied by year, season, and plantation age class. Averaged over the 2 years of grazing, graminoids and forbs were nearly equal, at approximately 40% each, in sheep diets from older plantations. In contrast, diets of sheep in young grass seeded plantations averaged 70% graminoids and only 16% forbs. Ferns were a minor component (<2%) of sheep diets in both plantation age classes. Browse averaged 15 and 12% of sheep diets in older and younger plantations, respectively. Douglas-fir comprised less than 3% of sheep diets throughout the grazing season.

Weight gains followed seasonal trends typical of sheep grazing non-irrigated hill pasture in western Oregon. Average daily gain (ADG) of ewes and lambs during the 1981 grazing season was -.03 and .12 kg/sheep/day, respectively. Yearling ewes gained .08 kg/ewe/day in the 1982 gazing season. Death losses were relatively low, averaging 3% for the ewes and 5% for the lambs in 1981 and 2% for the yearlings in 1982.

SILVICULTURAL IMPACTS OF SHEEP GRAZING IN OREGON'S COAST RANGE

by

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SILVICULTURAL IMPACTS OF SHEEP GRAZING IN OREGON'S COAST RANGE

Introduction

Douglas-fir (Pseudotsuga menziesii) forests in the Coast Range of western Oregon are among the most productive forests in the world. The economy of western Oregon is heavily dependent upon fiber production from these forests. Following clearcutting and burning, herbaceous and woody plant species quickly establish in the clearcuts and soon compete with timber regeneration. Stewart (1978) observed that understory brush species could reestablish the brush cover within 3 to 4 years following logging and burning in the Coast Range. In the past, foresters have mainly relied on herbicides to control unwanted brush.

Many of the residents in the Coast Range believe that herbicide spraying in the forest constitutes a health hazard. A large number of these people draw their drinking water from streams which originate in Coast Range forests. Their opposition to herbicide use contributed to the EPA ban of 2,4,5-T ((2,4,5-trichlorophenoxy) acetic acid) and Silvex (2-(2,4,5-trichlorophenoxy) proprionic acid) on all federal forest land in the United States in March, 1979. In April, 1983, all herbicides were banned by court order on federal forests in the Five Rivers Area of the Coast Range. In addition to the public concern over health risks associated with herbicides, the high cost of vegetation control with herbicides has prompted land management agencies to look at other alternatives for vegetation management.

In June, 1980, the Alsea Ranger District of the Siuslaw National Forest contracted with the Rangeland Resources Department at Oregon State University to initiate a study to evaluate the feasibility of using herded sheep to suppress brush in young Douglas-fir plantations. In addition to potential brush control, sheep grazing also offered the potential for improvement of big game habitat and increased red meat production on the District. Sheep grazing was monitored in 5 Douglas-fir plantations within the Fleece, Benner, and Denzer units of the Alsea District from 1980-1982. In 1980, 650 ewes with lambs grazed in the forest the month of July. Seven hundred ewes with lambs and 900 dry ewes grazed from May through September 1981 and 1982, respectively. Variables monitored in this research included survival, and diameter and height growth of Douglas-fir regeneration, together with liveweight gains, death losses, and seasonal food habits of sheep.

CHAPTER I

LIVESTOCK GRAZING AND FOREST REGENERATION:
THE STATUS OF OUR KNOWLEDGE

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LIVESTOCK GRAZING AND FOREST REGENERATION: THE STATUS OF OUR KNOWLEDGE

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Background Information

Livestock operators and foresters have historically been at odds over grazing in forest land. Many silviculturists and other professional foresters believe that livestock grazing is not compatible with timber production and should be eliminated. But as the world demand for food grains continues to increase, alternative feed sources for livestock must be·sought. Therefore, a greater dependance on forages in the future will put increasing pressure on transitional ranges, including cut-over forests (Lundgren et al. 1983).

Although published accounts of grazing impacts on timber regeneration date back to the late 1800's, no comprehensive review on this subject has been published. It is the objective of this paper to summarize the world literature on the effects of livestock grazing on forest regeneration. Livestock weight gains have also been included where data were available from grazing trials in young plantations. For convenience, this paper is divided into geographical regions and pertinent research studies within each are discussed.

United States

Northwest

For the purpose of this paper, the Northwest Region is made up of northern Colorado and Wyoming westward to Washington, Oregon, and northern California. It extends from the Canadian border southward to central Colorado and Utah. Traditional range within this area consists mainly of open stands of ponderosa pine (Pinus ponderosa), pinyon-juniper (Pinus spp.- Juniperus spp.), and oak (Quercus spp.) woodlands, with their accompanying grasslands and meadow openings. The remainder of the area is largely composed of dense stands of spruce (Picea spp.), lodgepole pine (Pinus contorta), and Douglas-fir (Pseudotsuga menziesii) which produce little in the way of forest grazing values (Dutton 1953).

The earliest account of livestock grazing damage to conifer regeneration in the Northwest was given by Coville in 1898. Sheep had grazed in the central Cascades for only about 11 years prior to Coville's visit. He found that overgrazing had just begun and was limited to a few areas in the Mount Hood and Three Sisters Districts. Over most of the Forest Reserve, Coville (1898) noted that damage to timber regeneration from sheep grazing was confined to small areas, such as bedding grounds and routes of travel. In these locations, young conifers low enough to be browsed by the sheep were standing crooked and were believed by the author to be incapable of developing into sound trees of a healthy stature. Small seedlings were trampled out entirely.

Harshman (1979) investigated sheep grazing in cut-over Douglas-fir plantations in the Cascade Range near Oakridge, Oregon. During two years of late summer grazing, he found that none of the study trees were browsed. Harshman concluded that sheep grazing was practical on clearcut units on the west slope of the Cascades.

A study examining the effects of sheep grazing on natural regeneration in Douglas-fir cut-over land in southwestern Washington was conducted by Ingram (1928, 1931). Data collected in 1925 and 1926 showed seedling survival rates were 21 and 110% greater, respectively, on the moderately grazed plot than the protected control. A heavily grazed plot had survival levels which were 27% less in 1925 and 63% greater in 1926 than those on the control plots. In 1927, seedling survival was highest on the ungrazed plot (Ingram 1931).

In April 1928, Ingram seeded Douglas-fir on two areas which were then grazed later that summer. Of 63 seedlings germinating on one site that year, 28 died from natural causes and 7 from sheep grazing, while 28 survived. On the other plot, where 87 seedlings germinated, 25 died from natural causes, 3 were destroyed by sheep, and 59 survived. Both of these plots were subjected to heavy sheep grazing, and on the second one the sheep bedded (Ingram 1928).

Over the four years of the study, Ingram (1931) found a 52% reduction of inflamable understory which he attributed to sheep grazing. Sheep, in trailing, trampled down much of the dry material on the ground which was partly worked into the soil where it was more apt to absorb moisture. This reduced both the percentage of inflamable material and its inflamability. Ingram concluded that moderate grazing use was not seriously inimical to forest regeneration and that damage is more than compensated for by the protection it provided through the reduction in fire hazard. He pointed out that the problem of assessing the compatibility of livestock grazing and conifer regeneration was one of weighing the loss of seedlings due to grazing against the benefits derived from grazing protection, rather than the simpler one of numerically weighing actual losses sustained.

Reid et al. (1938) continued the plant successional studies initiated by Ingram for an additional 7 years. Their data indicated that considerable forage was available to livestock in the first 3 to 7 years following timber harvest and burning, but dwindled thereafter due to the encroachment of shrubs, bracken fern (Pteridium aquilinum), and the timber crop. They estimated that the potential duration of grazing in cut-over, burned forests in the Cascades was approximately 11 to 15 years.

Phelps (1979) reported that impacts of sheep grazing on conifer regeneration were minimal when the band was moved prior to exhausting the forage supply. Her study was conducted in 5-to 15-year-old plantations in the Cascade Range of western Washington. On the first study site, which was grazed from late July to early August, only 3% of the conifers had laterals browsed. None had terminals damaged. Fourteen percent of the regeneration showed lateral browsing and 3% had their terminals damaged on the second site which was grazed in early September. An extended period of continuous precipitation combined with a persistent heavy fog precluded the movement of sheep on one 38 ha plantation. The 792 dry ewes remained on the site for 21 days instead of the 7 days originally scheduled. This heavy stocking resulted in lateral and terminal browsing on 29 and 22% of conifers, respectively.

Terminal browsing was restricted to seedlings .96m in height and below. Sheep preferred to browse terminals on seedlings which were between .46 and .76 m in height, but lateral damage wasn't limited to any specific size of conifer. The majority of impacted trees were planted stock which were considered "off site" (Phelps 1979).

The ewes lost an average of 10.5 kg/head while grazing in the forest. Phelps (1979) speculated that animal performance was influenced by the cool, wet weather which she believed decreased feed intake. Of the 49 days sheep grazed in the study, 39 were either cloudy or rainy. In excess of 15 cm of rain occurred during the month of August.

One of the objectives of a study conducted by Minore et al. (1979) near Mount Adams in southwestern Washington was to assess the effects of sheep grazing on huckleberry (<u>Vaccinium</u> spp.) growth and berry production and on forest regeneration. Eighty sheep grazed each of four .13 ha plots for 3 days. The resulting grazing intensity far exceeded anything that occurred under normal grazing operations in the area. The stocking intensity even exceeded the local intensity produced in bedding grounds. The year following grazing, mean annual conifer height growth was 4.6 and 6.7 cm in grazed and ungrazed areas, respectively. In the third year after grazing, the mean annual height growth of the trees on the grazed plots was 5.4 cm, compared to 6.0 cm on the ungrazed controls. Although conifer density was significantly lower for grazed (10,391 /ha) compared to ungrazed (20,071 /ha) plots, stocking levels on the former were still in excess of those required for full stocking on the site.

Black and Vladimiroff (1963) made a preliminary report on an experiment conducted in southwestern Oregon which combined sheep grazing with Douglas-fir regeneration. They found that 44% of the nearly 1500 planted seedlings were browsed by the sheep at the end of 5 weeks of spring grazing. All browsing damage was classed as either light or moderate. The majority of injury occurred after 3 weeks of grazing and was believed to be associated with a decrease in the availability of preferred forage species. Forage utilization was very high on the two grazed plots, particularly on compartment 2 where only 65 kg/ha of herbaceous forage remained at the termination of grazing. The authors found little evidence that the observed level of browsing had any effect on mortality of seedlings.

Average daily gains for ewes and lambs in the 4 to 5 weeks of spring grazing in this study were .27 and .25 kg/head/day, respectively. Total liveweight gain averaged 117kg/ha (Black and Vladimiroff 1963).

Grazing significantly reduced height growth of both 2-0 and 2-1 stock the first growing season. Growth was 4.0 cm for the 2-0 stock in the control area compared with 2.3 cm in the grazed plots. The respective growth for the 2-1 seedlings was 6.5 and 2.7 cm (Black and Vladmiroff 1963).

Cleary (1978) reported that the heavy, repeated spring browsing (Black 1965 cited by Hedrick and Kenniston 1966) in the above study prolonged the conifer establishment period by 2 years. His data indicate that height growth of Douglas-fir seedlings on the grazed sites was slowed until the trees were about 1 m tall. Thereafter, the growth rate paralleled that of trees grown on ungrazed plots. Ten years after planting, regeneration in the grazed area averaged about 1.3 m less in height than control trees. This was equivalent to about a 20% reduction in height growth due to sheep grazing (Cleary 1978).

The influence of sheep grazing on Douglas-fir establishment (Hall et al. 1959) and growth (Hedrick and Kenniston 1966) was investigated in the Oregon white oak (Quercus garryana) type. Douglas-fir seedlings were planted in 1952 and the plantations were grazed each spring from 1954 through 1960. For the first 2 years of the study, the percentage of browsed trees in the grazed treatments exceeded the levels of wildlife browsing in the ungrazed plots. But from the third year on, browsing by wildlife in the ungrazed plots was greater than the sheep plus wildlife browsing on the grazed plots.

Seedling height growth was slightly less for trees in the grazed area for the first 3 years, but from the 4th year through the end of the study, growth rates were greater in the grazed area. The residual effects of grazing resulted in increased growth rates for 4 years after termination of grazing. Ten years after grazing was initiated, Douglas-fir trees averaged 64 cm taller (27% greater) in the grazed area than in the ungrazed control (Hedrick and Kenniston 1966). The authors found no conifer mortality attributable to browsing.

Thinning of the oak canopy was of primary importance in determining sheep weight gain; the more open the tree stand the greater were the average daily gains (ADG) and gain per ha. Grazing season mean ADG and gain per ha for the yearling ewes were .09 kg/head /day and 6.4 kg/ha for untreated oak plots, .16 kg/head/day and 18.8 kg/ha for oak thinned and underplanted to Douglas-fir, .25 kg/head/day and 29.2 kg/ha for oak clearcut and planted to Douglas-fir, and .20 kg/head/day and 35.1 kg/ha for plots which were clearcut and seeded to grasses and clover (Hall et al. 1959).

In the above study, the authors attributed the light level of grazing damage to conifers to proper stocking and timing of the grazing season. By the time the animals started to graze in the spring, an abundance of forage was available. Also, the animals were removed when forage became rank and utilization of the palatable herbage reached about 50%. In contrast, Black and Vladimiroff (1963) reported utilization levels as high as 89% on one plot. This extreme intensity of grazing undoubtedly contributed to the heavier levels of conifer browsing reported by them. The inconsistency in conifer growth response to grazing in the two studies probably reflects differences in browsing damage during the establishment period.

Howell (1948) summarized findings from a study initiated in the Coast Range of northwestern Oregon designed to evaluate the suitability of logged-off and burned-over forests for livestock production. He reported that seeding clearcuts to grasses and legumes followed by livestock grazing controlled most brush species except vine maple (_Acer circinatum_) and red alder (_Alnus rubra_). He also noted that the effect of seeding and grazing on natural regeneration depended on the type of livestock and the intensity of grazing employed. Data showed that cattle did very little damage to Douglas-fir. But they browsed western red cedar (Thuja plicata). In contrast, sheep damaged most conifer seedlings whose terminal leader was within their reach. Angora goats severely damaged all conifers.

Howell stated that fire was the greatest enemy of forest reproduction. He further stated that the successful control of brush and other native species by forage seeding coupled with livestock grazing had proven an effective fire break in helping to control the disastrous fires that occasionally swept cut-over lands in the area.

A recent study conducted by Sharrow and Leininger (1983) investigated controlled sheep grazing in Douglas-fir plantations in the Coast Range near Alsea, Oregon. They observed that the percentage of study trees having lateral branches browsed by sheep grazing ranged from nearly 100% in the spring to 11% in the summer. Many of the impacted trees had only a few branches browsed, especially during the summer period. Less than 5% of the study trees were subjected to mechanical impacts (trampling, debarking, etc.). Study clearcuts were heavily grazed, particularly in the spring when utilization of ground vegetation was 67%.

Grazing significantly reduced the amount of brush present in the treated areas. At the end of the second season of grazing, current years growth (CYG) of brush ranged from 25 to more than 300% greater in the ungrazed compared to the grazed areas. Trees in four of the five study plantations had diameter growth after one or two years of grazing which was from 7 to 14% greater for trees in the grazed compared to those in the ungrazed exclosures. No significant differences in height growth were noted for these trees. Heavy browsing of terminal leaders and lateral branches on seedlings in one spring grazed plantation reduced growth rates. Height growth one year after grazing in this plantation was reduced by 51% and diameter growth by 23% (Leininger and Sharrow 1983).

Average daily gain of ewes and lambs in the above study during the 1981 grazing season was -.03 and .12 kg/head/day, respectively. Yearling ewes gained .08 kg/ewe/day in the 1982 grazing season. In both years, ADG was higher the first half of the grazing season (Rhodes et al. 1983).

Kosco and Bartolome (1983) examined the effects of cattle and deer grazing on regenerating mixed conifer clearcuts in northern California. They found significantly less total brush on areas grazed by cattle and deer (14% cover) than in an ungrazed exclosure (39% cover). Cattle plus deer grazing didn't significantly increase the level of conifer browsing over areas grazed by deer alone. White fir (Abies concolor) was more heavily browsed than Douglas-fir, ponderosa pine, or sugar pine (Pinus lambertiana) (Kosco 1980). The ungrazed treatment had the lowest percentage of healthy trees. Percent healthy trees was higher in the deer only treatment than ungrazed plots, and was highest in plots grazed by both deer and cattle. After one or two years of grazing treatment, no significant differences in conifer height or basal diameter growth were noted. Kosco and Bartolome (1983) concluded that livestock grazing cannot only be a compatible use of mixed conifer forests, but is also a potential tool for brush control on new clearcuts.

Several researchers investigated cattle grazing on a clearcut-burn within the mixed conifer type in northeastern Oregon (Pettit 1968, Wood 1971, Erickson 1974). During the first year of livestock grazing, only 2 out of 1347 seedlings were killed by cattle browsing. An additional fourteen died from trampling (Pettit 1968). Some browsing occurred the second year, but was believed to be the result of too high an animal concentration within a small area. Although ponderosa pine was browsed the heaviest, lodgepole pine also received considerable use. Douglas-fir, western white pine (Pinus monticola) and western larch (Larix occidentalis) were only occassionally browsed (Pettit 1968). Erickson (1974) also found no appreciable conifer browsing and only slight damage by trampling (2% of trees) from late summer cattle grazing. Over a 5-year period (1966-70), weight gains of yearling heifers grazing the study plots in June and July were .77 kg/head/day and 57.3 kg/ha (Hedrick 1975).

Wheeler et al. (1980) reported that after 12 years of cattle grazing, livestock trampling accounted for 8% of the total seedling mortality and was of no significance after the fourth year of the study. Thirteen years after planting, survival of planted conifers was similar in all grazing treatments (game only, cattle only, and cattle and game). At this time, height growth of Douglas-fir and ponderosa pine was significantly greater in the pasture subjected to grazing by cattle and big game than it was in the other treatments. Whereas, western larch and western white pine were significantly taller under both treatments including cattle grazing (Krueger 1983). Krueger (1983) stated that this 20 year study clearly showed that it is possible to clearcut a mixed coniferous forest and manage it for forestry, range, and wildlife uses during the forest regeneration period.

Edgerten (1971) also reported on the effects of cattle and big game grazing on timber regeneration in a mixed conifer clearcut. The plantation in northeastern Oregon was seeded to timothy (Phleum pratense) and planted with 2-0 ponderosa pine. A comparison of browsing damage between areas jointly grazed by cattle, deer, and elk and sites only grazed by big game showed that the planted pines were lightly browsed in both grazing situations. Nearly 30% of the pines showed evidence of browsing at the end of the third growing season, while only 10% were browsed at the end of the fifth. Four years after initiation of annual summer livestock grazing, survival of the regeneration was considered to be good. After five growing seasons, both grazing treatments had produced small increases (3 to 10%) in ponderosa pine height growth compared to trees in the ungrazed control. Edgerton's conclusion that summer grazing by deer, elk, and cattle can be compatible with reforestation practices in mixed conifer clearcuts was in close agreement with Krueger's (1983).

A study in the pumice region of central Oregon was designed to quantify tree damage by sheep and deer as influenced by season of grazing and forage conditions (Winward and Rudeen 1980). Only 2 of the 800 marked lodgepole pine seedlings were browsed by sheep in trials conducted the first year, while 38 were browsed during the second year's trials. No seedlings were damaged after July 19th either year (Rudeen 1978). Sheep normally did not browse seedlings in areas supporting a high density of shrubs (>3460 shrubs/ha). In areas of low shrub density (<3640 shrubs/ha), conifer browsing was less if the site had a high herbaceous production (>75 kg/ha). The sheep didn't display any preference for planted over natural regeneration.

Rummell (1951) reported on a project in central Washington which compared two plateaus which were similar in all respects except livestock grazing. Meeks Table was a relic ponderosa pine forest and range, while Devils Table had been heavily used by livestock for 40 years prior to study. He found that the density of herbaceous understory vegetation on the ungrazed Meeks Table was 183 to 254% greater than the density on the grazed Devils Table. Although the overstory of the two areas was similar, the ungrazed one had a dearth of advance reproduction (210 trees /ha $\leq$ 10 cm dbh), while Devils Table supported 8359 trees /ha ($\leq$ 10cm dbh). This study supports Heerwagen's (1954) observation that heavy livestock grazing reduced ground cover and made conditions more favorable for seedling establishment. Rummell stated that continued heavy grazing held the range vegetation at lowered densities and permitted the conifer regeneration to grow without severe grass competition. In this study, livestock did little browsing damage and had a minimal effect in thinning seedlings.

A classic study by Sparhawk (1918) was designed to determine just how much harm was done to ponderosa pine reproduction by sheep grazing and how this damage could be reduced by more careful use of the range. The research was conducted in the Payette National Forest in central Idaho. A comparison of height growth between uninjured seedlings and those whose leaders had been removed several years before showed no perceptible difference in the rate of growth, except for the loss of the year's increment removed. In contrast, if terminal injury was repeated every year or two, seedlings were permanently stunted and never became a tree. This latter level of damage was seldom reached by livestock grazing, except along driveways and on bedgrounds which were used several nights at a time year after year.

On a lightly grazed area, 1.1% of the older seedlings and 8.8% of those less than a year old were killed annually by sheep. In comparison, on a closely grazed site respective losses were 2.5% and 14.8%. Damage from browsing was low compared to injuries resulting from trampling the natural regeneration. Of the three most important conifers present, ponderosa pine was most frequently browsed, lodgepole pine was somewhat less preferred, and Douglas-fir was the least preferred by sheep. In contrast to Kosco (1980), who found white fir to be preferred by cattle, Sparhawk indicated that this species was practically never browsed by sheep.

Of the 1782 seedlings killed by sheep in Sparhawk's study, 1293 (73%) were less than a year old, while only 11 (1%) were over 15 cm in height. Just one seedling over 46 cm tall was killed by sheep during the 3 year study. Injury from grazing was so slight after seedlings were 3 years old that Sparhawk concluded there was no need to close reproduction areas to sheep after that time. He added that it may be best to graze these areas lightly for a few additional years until the seedlings reach a height of 15 cm. Over all the study plots, more than 3 times as many seedlings were killed by other causes as perished from sheep grazing, and 5 times as many were injured by the former than the latter.

Like Rummell (1951), Sparhawk found that conifer germination was highest on the most closely grazed areas, but unlike Rummell, Sparhawk discovered that sheep grazing didn't help seedlings live through the summer growing season. Sparhawk felt that the most important benefit to the forest from sheep grazing was the reduction in the quantity of inflamable ground cover and subsequent decrease in fire hazard.

Young et al. (1942), working in cut-over western white pine forests in northern Idaho, found many of the same results as Sparhawk (1918). Their data showed that sheep grazing reduced the fire hazard by decreasing the amount of inflamable forage in the forest understory. They also noted that seedling mortality in the period following grazing was higher in heavily grazed areas than ungrazed sites. Field records indicated that during the first year after germination, natural regeneration suffered most heavily from sheep trampling due to the shallow root systems and lack of woody stems of the young seedlings. Mortality attributable to grazing decreased as the seedlings matured with practically no loss occuring after the seedlings were 5 years of age.

Results from an experiment along a sheep driveway showed that plots on the driveway supported an average of 351 western white pine seedlings, while those .8 km away from the driveway contained only 193 (Young et al. 1942). Other coniferous species averaged 68 seedlings in the former plots and 333 in the latter. The removal of litter by sheep foraging and trampling increased the amount of bare mineral soil on the driveway. Apparently this was conducive to germination of western white pine seedlings. The authors felt that proper sheep grazing could increase white pine reproduction and therefore increase stocking and purity of future stands.

Some of the research initiated by Young et al. was continued for an additional 16 years. The main findings of these studies were summarized by Tisdale (1960). He noted that on moderately grazed plots, adequate reproduction for full stocking of western white pine, Douglas-fir, grand fir (Abies grandis), and other commercial species was attained. But on heavily utilized plots, although no reduction in the establishment of white pine was apparent, a decrease in the reproduction of other species occurred, with western redcedar being most adversely affected.

Eissenstat (1980) and Eissenstat et al. (1982) reported on the susceptibility of Douglas-fir to browsing and trampling in first year plantations in northern Idaho. They observed that 19% of the 842 monitored seedlings were trampled during the first summer. Cattle were responsible for at least 60% of the trampling damage. Wildlife and unidentified sources were responsible for the remaining 40% of trampling damage. Only 36% of the trampled trees survived until October (6 months after planting). This was in contrast to a 77% survival rate for the untrampled seedlings. By the second year, bark on the Douglas-fir seedlings was apparently much firmer and less susceptible to tearing. Although wildlife browsed several of the study trees, no cattle browsing was identified.

Southwest

Although the Southwest Region is generally considered to be made up of the states of Arizona and New Mexico (Parker 1947), for the purpose of this paper, the entire area west of eastern Texas and south of central Colorado is included in the Region.

The first published report of livestock damage to conifer regeneration in the Southwest was made by Leiberg et al. (1904) in the San Francisco Mountains Forest Reserve in north central Arizona. They found that livestock, especially sheep, were destructive to tender aspen (Populus spp.) seedlings as well as to sprouts and suckers sent up by older roots of this species. They noted that when close-bunched sheep grazed through areas of young ponderosa pine seedlings (2.5 - 5.0 cm tall) they destroyed from 50 to 100% of the regeneration in a single pass. Damage to ponderosa pine from livestock grazing was believed to be greatest while the seedlings were in the cotyledon stage. Once the young pines were 3 or 4 years in age, the danger of destruction was believed to be small. In more recent studies, Pearson (1923, 1950) found that the period of greatest damage extended beyond the cotyledon stage through the primary and secondary leaf stages and into the second year's growth.

Research conducted by Hill (1917) in north central Arizona concerning grazing effects on ponderosa pine reproduction also indicated that grazing damage was most severe to the smallest class (below 15 cm height) of reproduction. He noted that damage gradually tapered off as the trees increased in size. The highest level of damage occurred during the latter half of June to early July, coinciding with the severest portion of the summer dry period. Browsing damage was confined to current year's growth and generally the early succulent growth. Hill theorized that the severity of damage varied inversely with the amount of succulent feed available. Data showed that severe damage to natural regeneration by sheep was 7.7 times as high as levels of damage by cattle. Injury on overgrazed range varied from 3 times the amount of damage observed on a normally stocked range to total destruction. The principal damage caused by cattle was from rubbing, while sheep inflicted more damage through browsing. Comparison of growth rates between extensively browsed young trees on an overgrazed range and uninjured ones showed the former had an annual height growth from 1/3 to 1/2 the latter.

Literature summarizing studies conducted by G. A. Pearson on grazing effects on ponderosa pine in the Southwest span nearly 30 years. In his earliest study, Pearson (1923) reported that the elimination of ground cover by overgrazing was unfavorable to ponderosa pine seed germination. He noted that weed clumps were more than 8 times as conducive for germination of pine seed than the intervening bare areas. Ponderosa pine seedlings were about 10 times more numerous in ungrazed as compared to heavily grazed sites. Pearson confirmed Hill's (1917) conclusion that damage to regeneration by cattle and horses was relatively light. He found that 80 - 90% of all grazing damage to young seedlings was attributable to sheep. In a pasture heavily grazed by cattle, horses, and sheep, annual height growth of ponderosa pine seedlings was only 50% of the growth of seedlings in a pasture grazed by only cattle and horses.

Pearson (1923) stated that controlled livestock grazing benefited conifer regeneration by reducing herbaceous vegetation which (1) decreased the fire hazard, (2) prevented the suppression of seedlings, and (3) lessened competition for soil moisture.

Pearson (1931) examined the growth response of ponderosa pine regeneration over a 17 year period in a plantation that had been overgrazed by cattle and sheep. Approximately 10% of the study trees died during the first 14 years of the study. All of these trees were in the lowest height group of the severely injured class. He noted that if the stem was defoliated low enough to remove all of the leaves, death of the seedling was nearly certain. But if a fascicle of permanent leaves or several of the younger leaves remained, the seedlings generally survived. Pearson concluded that unless a young pine was completely defoliated, it had a good chance to grow into normal form once the damage ceased. If severe browsing was repeated over a period of several years, height growth was checked and vitality generally reduced to a point where death became inevitable. But after a seedling had attained a height of 10.1 to 15.2 cm, it was only under extreme grazing that defoliation was likely to approach the danger point year after year. These findings led to a new recommendation; natural regeneration needs protection from browsing up through about 3 years of age (Pearson 1931) instead of the exclusion of sheep grazing for 20 years (Pearson 1923).

An article detailing the silvicultural merits of livestock grazing was authored by Pearson (1934) nearly 50 years ago. He believed that heavy grazing for several years after seed germination aided initial establishment of seedlings by reducing grass competition and the habitat of animals which feed on conifers. Pearson indicated that the best method of livestock grazing included grazing conservatively in the forest until a good cone crop, then increasing the intensity of grazing only for such time as required to save the seedlings from suppression.

In stands of mixed composition, Pearson (1950) reported that white fir and Douglas-fir were more preferred by livestock than ponderosa pine. He found that sheep consumed both growing shoots and needles on ponderosa pine, while cattle ate only the shoots. Stem or shoot browsing by livestock in the Southwest generally started several weeks after bud break. The shoots were rarely browsed by cattle and sheep after they ceased to elongate and began to acquire a mature texture. The period of active shoot browsing usually extended from 15 June to 15 July (Pearson 1950). In contrast, needle browsing by sheep began when the needles were 5 to 7.5 cm long, usually about August 1, and continued into November.

Since pine shoots were not browsed appreciably after 15 July, Pearson (1950) recommended that turn-in on livestock ranges subject to shoot browsing be deferred until after this date. Because significant damage from needle browsing by sheep was largely restricted to bedding grounds, Pearson (1950) advised strict enforcement of a 1-night bedding rule, supplemented by a provision that bed grounds be at least .8 km apart.

Because restocking of Douglas-fir cutover areas in southern New Mexico was occurring too slowly to meet the requirements of good silviculture, Krauch (1936) initiated a study to elucidate factors influencing reproduction. He found that although areas open to cattle grazing were heavily used, no direct evidence of grazing damage to seedlings could be ascribed to livestock. Rodents, on the other hand, had an extremely deleterious effect on regeneration establishment. Since rodents also had access to the plots grazed by cattle, Krauch hypothesized that destruction of the seedlings by the rodents precluded the identification of cattle caused damage.

Examination of grazed areas revealed little evidence of livestock browsing on coniferous seedlings. Krauch felt that trampling could be destructive to seedlings, particularly on slopes where loosening of the soil in dry periods caused excessive soil movement. He believed grazing helped reduce competition from herbaceous vegetation and aided in covering conifer seeds.

The results of a 10 year investigation into ways to reduce damage to ponderosa pine reproduction by cattle (Cassidy 1937a) and sheep (Cassidy 1937b) indicated that thirst in animals was the main factor influencing browsing. Cassidy (1937a) also found that where browsing damage occured only every other year or at greater intervals, there was little or no adverse effects on height growth of ponderosa pine. But when injury occurred 2 or 3 years consecutively, height growth was reduced. Severe browsing for many successive years often killed the regeneration. In order to reduce browsing damage, Cassidy (1937b) recommended management calling for (1) stocking rates based only on the volume of available green feed within reasonable proximity to water for livestock, (2) watering animals every day in periods of dry weather and less frequently than every third day during wet weather, (3) bedding sheep for only one night on a bed ground and coming onto and leaving the bed grounds over different routes, (4) not using the same bed ground, where practical, more often than once every other year, and (5) avoiding trailing sheep over the same routes when going from feed to water.

Cooperrider (1937, cited by Currie et al. 1978) stated that livestock grazing areas should be provided which are accessible from watering places to control browsing of seedlings. He also recommended that additional water should be provided, if needed, on poorly watered ranges.

Schubert et al. (1970) summarized the information to the time of writing on artificial reforestation practices for the Southwest. They noted that livestock damage to conifer regeneration varied by (1) kind of animal, (2) season of use, (3) intensity of grazing, and (4) size of trees. They shared Pearson's (1950) view that sheep were more destructive to conifer reproduction than either cattle or horses.

Recent guidelines for reducing livestock damage to ponderosa pine regeneration have been proposed by Schubert et al. (1970) and Schubert (1974). Schubert (1974) indicated that light cattle grazing may cause little damage during the summer wet season after seedlings are .3 m tall. Also, after seedlings are out of danger (approximately 1 m high) cattle cause minimal damage if there is sufficient forage available. Schubert (1974) recommended that sheep be excluded from regeneration areas until seedlings are 1.5 to 1.8 m high.

The objective of a study by Currie et al. (1978) was to evaluate the recommendations and conclusions of the above research as they apply to ponderosa pine - bunchgrass rangeland in central Colorado. Their evaluation consisted of 2 phases. In the first phase, grazing damage as it related to grazing intensity was investigated. They found that ponderosa pine seedling damage was greatest with the heavy (> 50% CYG removed of principal bunchgrasses) grazing intensity. In the 8 years of the study, 73% of the seedlings received grazing damage with this level of use. Under moderate (30 -40% CYG) grazing, only 4 (10%) seedlings were damaged during the 8 years. Six (15%) seedlings were impacted under light grazing. Total height growth of the ponderosa pine regeneration for the 8 year period averaged 25.8, 27.6, and 42.4 cm for the heavy, moderate, and light intensities of grazing, respectively.

Data from phase 2 showed that light to moderate rates of cattle grazing from mid-June to mid-October was not a major source of damage to natural pine regeneration. Damage to seedlings was less than 1% after 1 year's grazing. Total damage and mortality from all causes were 5 and 2%, respectively.

Another portion of the second phase of the study was a 3 year investigation into damage to planted ponderosa pine (2-0) from light to moderate cattle grazing. The first year, 4 out of 750 seedlings were damaged by livestock. Two more seedlings were damaged the second year and none the last. Both browsing and trampling impacts were included in the number of seedlings damaged.

Southeast

Forested rangeland in the southeastern United States extends from Virginia to eastern Oklahoma and south through eastern Texas. More than 90% of the 197 million-acre southern range area is classified as forest land (Duvall and Hilmon 1965). Mild winters and good rainfall have allowed yearlong cattle grazing with little supplemental feed or herd management. In the past, open range grazing has been accompanied by low animal productivity, inefficient utilization of forage, and frequent damage to timber (Smith et al. 1958).

The earliest research on the effects of livestock grazing on conifer regeneration in the Southeast was conducted by Wahlenberg et al. (1939) from 1923 - 1933 at McNeill, Mississippi. The objective of their research was to answer questions concerning dual use of forest land for growing longleaf pine (*Pinus palustris*) and producing forage for cattle.

Direct damage to seedlings from browsing the needles, breaking or injuring buds, stems, or bark, was rare and appeared to Wahlenberg et al. (1939) to be entirely negligible except under conditions of heavy stocking or in areas where cattle habitually concentrated. They found that the larger and older longleaf pine seedlings developed a heavy plume of resinous foliage that was avoided by the cattle. Reduced seedling growth in grazed compared to ungrazed areas was attributed to the indirect effects of grazing through trampling and compacting the soil or other unknown factors. In contrast to cattle, both sheep and goats were identified as being more destructive to natural regeneration (Wahlenberg et al. 1939, Campbell 1947, 1954) and hogs were categorized as notorious despoilers of pine plantations (Wahlenberg et al. 1939, Campbell 1954, Hopkins 1917, 1947).

In a more recent study at McNeill, Smith et al. (1958) confirmed Wahlenberg et al.'s findings that damage to longleaf pine reproduction by cattle was negligible under light to moderate grazing, except in a few localized areas where cattle concentrated. During the spring and summer grazing period when palatable herbaceous and browse forage was abundant, no pine browsing was observed. However, cattle browsed several hardwood species in early spring, and Smith et al. found it necessary to protect natural or planted yellow poplar (Liriodendron tulipifera) reproduction until the trees were past the seedling stage.

The effects of sheep grazing on longleaf pine in southern Missouri were summarized by Mann (1947) and Maki and Mann (1951). They found that during two years of continuous grazing, 86% of the "tagged" longleaf seedlings had their terminal buds nipped by sheep. Fifty percent of the seedlings were browsed two or more times and 27% were nipped at least three times. The most vulnerable height was from 28 to 51 cm, where 78% of the seedlings had their terminal buds browsed at least twice. Browsing was greatest during the winter and early spring period, which was also the time of the year when the quantity of palatable forage was the lowest (Mann 1947).

During two years of grazing, 4.6% of all "tagged" seedlings on the grazed plots died, compared to 2.3% on the ungrazed plots. Average two year height growth of "tagged" seedlings was 29 cm on grazed plots in contrast to 39 cm inside fenced control plots. Reduction of growth was greatest on the smaller seedlings. During the four years following the termination of grazing, height growth of the surviving seedlings averaged 1.95 m in the grazed plots compared with 2.01 m in the nongrazed plots, indicating satisfactory recovery of height growth from any deleterious effects of browsing (Maki and Mann 1951).

Boyer conducted a 5 year study designed to assess the effects of cattle grazing upon the establishment, survival, and growth of long leaf pine seedlings in southwestern Alabama. Grazing had only a negligible effect on first year seedling establishment (Boyer 1958). After five years, the total loss of seedlings ascribable to grazing ranged from 6% on lightly grazed plots to 37% under moderate and heavy grazing. Most of the injuries were attributed to trampling. At age five, the seedlings in the controls averaged 1.01 cm diameter at the rootcollar, while those in the grazed plots averaged .88 cm. This difference was significant and amounted to about two-thirds of a year's growth (Boyer 1967).

Bruce (1956) subjected longleaf pine seedlings grown in a nursery bed in southern Mississippi to removal of 30, 60, or 90% of the average needle length on one of three different dates: July, November, or February. The seedlings were 1&1/2 years old at the July defoliation. Some of the seedlings were clipped twice, first at about 60% and later at about 90% defoliation.

All defoliations caused growth loss approximately in proportion to the amount of foliage removed. Bruce found the two-stage defoliation to be generally worse than a single 90% clipping. Clipping in November reduced growth significantly more than July treatments, while defoliation in February was the least damaging. He concluded that the degree to which the seedlings were clipped was more important than the date on which clipping was done.

Results from 8 studies which represented the most serious cattle grazing damage encountered in pine plantations in central Louisiana from 1946 to 1955 were summarized by Cassady et al. (1955). They found that browsing of pine seedlings increased when palatable forage became limiting in either variety or quantity. Although cattle rarely browsed pine foliage when other green forage was available, some browsing and trampling damage could always be expected in young plantations. Treatments such as burning, disking, scalping, etc. which drew livestock in and concentrated them, greatly increased the likelihood of excessive damage to young regeneration.

Bennett and Halls (1954) examined the effect of cattle grazing on planted slash pine (Pinus elliottii) under different intensities of grazing in central Georgia. Forage utilization on their study plots ranged from not evident to 95%. They found no correlation between intensity of grazing and first-year seedling survival. The authors concluded that factors other than grazing appeared to be more important in obtaining good survival of planted slash pine, and like Boyer (1958) believed that cattle need not be excluded from regeneration areas during the first growing season.

Light, moderate, and heavy year long grazing treatments were compared to a control in central Louisiana (Pearson et al. 1971). Light and moderate grazing had no significant effect on slash pine survival compared to the control. But, heavy grazing reduced survival 13 and 18% evaluated at the first and fifth years after planting, respectively.

At age 5, planted pines in the control averaged 3.2 m tall, while those in the grazed plots averaged 2.9 m. However, the difference was significant only for the moderately grazed site. Height of seeded pines at age five was not significantly affected by grazing treatments. Seeded trees in the controls averaged 2 m tall compared to 1.8 meters in the grazed plots.

Working in the same plantation as Pearson et al., Clary (1979) reported on the effects of grazing and tree overstory development in 13-to 16-year-old stands of slash pine. He found that grazing did not significantly affect tree canopy, but heavy grazing reduced basal area by 11% compared to ungrazed controls. He ascribed this decrease to the reduction in tree numbers during the first year after planting (Pearson et al. 1971).

Studies which have simulated cattle injury to slash pine have corroborated many of the research findings on grazing impacts to this species. Hughes (1976) and Lewis (1980a) defoliated slash pine at 6, 18, or 30 months after planting. Foliage of trees from each date were clipped at one of five levels: 0, 25, 50, 75 or 100% of the length of all needles on a seedling. Seedling survival was only significantly reduced when 100% of the needles were removed within 6 months after planting. Defoliation, regardless of intensity, had little effect on survival of older seedlings (Hughes 1976, Lewis 1980a). Both studies showed that height growth was significantly reduced by only the most severe clipping. While Hughes (1976) reported that losses in height growth tended to be recovered as trees grew older, Lewis (1980a) found that removing 75 and 100% of the needles had a longer lasting effect when applied 30 months after planting than on younger seedlings. When foliage defoliation was combined with shoot removal and stem breakage, both survival and height growth was reduced (Hughes 1976, Lewis 1980b).

The effects of grazing, overstory, and seedbed preparation on loblolly pine (Pinus taeda) establishment in Arkansas were studied by Gemmer (1941). He found that cattle grazing significantly reduced the number of germinating pine seeds. Ungrazed plots supported nearly twice the density of seedlings as the grazed areas. Data indicated that grazing during the first growing season following germination had little effect on reproduction. The mean height of regeneration 16 months after seeding was 9.4 and 11.4 cm for the grazed and ungrazed plots, respectively. Gemmer concluded that grazing should not be permitted during the winter and spring following a seedfall. No information on class of stock, season of grazing, or level of forage utilization was presented.

King et al. (1978) correlated first year loblolly pine survival and damage (browsing and/or trampling) from cattle grazing with percent forage utilization. They found a fairly good correlation between change in percent of undamaged trees (increase in damage associated with grazing) and percent forage use. Their regression equation, $Y = 1.7397 + .7715x$, explained 59% of the variation in the percent of trees damaged. On the other hand, only 35 percent of the variation in seedling survival could be explained by forage use.

Biswell and Hoover (1945) conducted a study in a hardwood forest in western North Carolina. Their research objectives were to determine which plants were preferred by cattle, and to what extent trees were browsed. They found that a few species were browsed so extensively the first year of grazing that they were killed. For example, 75% of the yellow-poplar trees below 1.5 m along a stream died the first season as a result of grazing. Over the two years of the study, removal of tree foliage by cattle ranged from 95% for black locust (Robinia pseudoacacia) to 0 for red maple (Acer rubrum), pitch pine (Pinus rigida), and eastern hemlock (Tsuga canadensis). Cattle showed a marked preference for herbs. Herbs were closely grazed prior to extensive tree browsing. Grazing pressure was very high in this study, as indicated by the near 100% utilization of the herbs prior to the end of grazing the first year.

The authors speculated that intensive cattle stocking would eliminate the more palatable trees such as yellow-poplar and allow less palatable species such as red maple and hemlock to replace them.

A forest grazing study was initiated by Kaufman (1948) in the North Carolina Piedmont to assess the effects of cattle grazing on pine reproduction. He found the species preferences of cattle to be very similar to those obtained by Biswell and Hoover (1945). Some species of trees, especially yellow-poplar and ash (Fraxinus spp.) were browsed without regard to the amount of forage available for grazing. The level of browsing on these preferred species, however, increased as the forage supply decreased. Under heavy grazing pressure, Kaufman reported that 67% of the yellow-poplar trees examined, 65% of the blackgum (Nyssa sylvatica), and 57% of the ash showed signs of browsing. In contrast, with less intensive grazing the respective percentages of browsed trees were only 22, 30, and 16%. Loblolly and shortleaf pine foliage was not browsed.

Kaufman noted that the degree of defoliation of individual trees also varied widely among species. Yellow-poplar, ash, and blackgum were almost completely defoliated under heavy grazing. In contrast, red maple and sweetgum (Liquidambar styraciflua) and other common species generally had only one or two lateral twigs torn off.

In the less intensively grazed plantation (2.4 ha/animal) the steers made average daily gains of about .45 kg/head/day during each of the 4 years of spring grazing. Steers in the plantation stocked at a rate of 1.8 ha/head began to lose weight by the end of 6 weeks of grazing and in no year did ADG exceed .23 kg/head/day. In all grazing situations, steers either made no gains or lost up to 9 kg/steer in the first 2 weeks of each grazing season due to a change in forage from barley or clover pasture to forest plants (Kaufman 1948).

The author concluded that cattle grazing was advantageous to the farm forest because pines were not browsed while the danger of damage from fires was reduced. Kaufman suggested that intensive cattle browsing on hardwood seedlings and sprout growth for several years following logging could have an effect similar to weeding the plantation.

Northeast

Forested land which is grazed in the Northeast extends from the Missouri Ozarks to the Central and Eastern States Hardwoods (Dutton

1953). Forest grazing is a minor portion of norhteastern agriculture. For the most part, northeastern forests are too dense to permit the growth of grass, except in clearings and openings (Lunt 1948). According to Lunt (1948), forest grazing in this region by domestic livestock consists mainly of (1) woodlot grazing, and (2) grazing neglected permanent pastures or abandoned cultivated land which, in both cases, is being invaded by brush and trees.

DenUyl and Day (1939) investigated grazing injuries to hardwood regeneration in northern Indiana. They closely observed the grazing habits of steers in an oak-hickory (_Quercus_ spp.- _Hicoria_ spp.) forest. Observations showed that at the beginning of the six-month grazing season steers utilized mostly grasses, but as the season progressed and percent utilization of grasses increased, the cattle consumed substantial amounts of hickory and black cherry (_Prunus serotina_). In this study, animals were not removed from the forest until after they lost weight. After 3 years of intensive grazing, black cherry and hickory regeneration had largely been eliminated from the understory.

Following 12 years of livestock exclusion, DenUyl (1947) reported that tree seedlings had not completely reestablished and concluded that woodlands required complete protection from livestock in order for tree reproduction to become established.

DenUyl (1945) summarized his findings from more than 15 years of investigation into the relationship of livestock grazing to the farmwoods in Indiana. The scenerio he presented to describe successional changes following the introduction of cattle into a previously ungrazed hardwood forest included: (1) the devastation of all forest reproduction, (2) the invasion of bluegrass (Poa spp.), and (3) the eventual transition to an open pasture with scattered trees. Both DenUyl (1945) and Diller (1935) maintained that evidence and cumulative experience clearly showed that livestock grazing ultimately destroyed farmwoods, and continuous protection by complete exclusion of livestock was essential for perpetual forest production.

Plantations with a history of grazing were investigated by Stickel and Hawley (1924) in order to determine whether damage from livestock was severe enough to warrant exclusion of the stock. Their study was conducted in red and eastern white pine (Pinus resinosa and P. strobus) plantations in southern Conneticut. They found that removal of understory vegetation by cattle and horse grazing reduced the fire hazard. The paths created by livestock trailing also served as fire lines. Livestock were observed to selectively graze on the hardwood sprouts, which helped free the pines from competition. Reducing the grass cover by grazing was also believed to be beneficial to pine regeneration.

Stickel and Hawley (1924) felt that horses were more destructive than cattle to pine plantations due to their biting habits and greater restlessness. Grazing livestock in the winter resulted in greater injury to the pines, since other palatable forage was scarce. The authors stated that grazing horses in winter should never be permitted. Data showed that regeneration which exceeded .9 m in height was generally safe from livestock damage. Livestock damage was restricted to exposed zones in the plantations such as watering holes and lanes. These zones of significant damage amounted to less than 2% of the total plantation area. Within these zones, only 26% of the pines were severely injured. The authors concluded that on the whole, the benefits of controlled grazing outweighed the damage done to pine plantations.

Because of a lack of reliable data on the reproduction and growth of timber trees in pastured areas of western Wisconsin, Ninman and Thompson (1927) initiated a study on eastern white pine reproduction. They found that 2.9% of the eastern white pine under 20 years of age had leaders which had been damaged by cattle and horses. An additional 12.5, 26.3, and 2.9% had livestock caused injuries to branches, trunks, and roots, respectively. This study led them to conclude that the custom at the time of writing, of over-pasturing the woodlots was highly detrimental to the timber and neither a good grade of timber nor a high yield could be expected where excessive grazing was practiced.

Data from studies of natural reproduction in Vermont forests gathered by Burns (1933) contradicts Ninman and Thompson's (1927) conclusion. Burns found that an eastern white pine forest could not be reproduced in northern Vermont by natural methods or by any of the common thinning practices employed. Under all conditions of thinning, a birch - red maple (Betula spp.-Acer rubrum) forest was the immediate result. When, however, a thinned area was heavily pastured, cattle kept down the hardwoods and eastern white pine dominated the reproduction.

Trenk (1954), working in the lake states, observed that heavy grazing on recently logged eastern white pine sites could be instrumental in successful regeneration of this species. He noted that heavy grazing reduced vegetative competion and disturbed the soil sufficiently for good seed germination. Additionally, grazing reduced the accumulation of bluegrass sod which smothered the seedlings and created a fire hazard and habitat for field and orchard mice.

Hitchcock (1937) visited 96 farms in northeastern Vermont which had sugar maple (Acer saccharum) orchards. He reported that about 80% of the woodlots were pastured. Examination of the orchards indicated that in a high percentage of them maple reproduction had been destroyed by grazing. This precluded the replacement of harvested and diseased maple with like species. He also noted that grazing reduced the underbrush in the orchards which facilitated the collection of syrup.

Findings from a research project conducted in central Ohio by Dambach (1944) were very similar to those from the above study. In Dambach's study, two contiguous sugar maple woods, one grazed and one ungrazed, were compared. Prior to livestock exclusion, sugar maple reproduction had been completely eliminated and only a few stunted herbaceous plants made up the understory. Dambach reported that many tree roots were exposed and bruised by cattle and horse grazing.

After 2 years of protection from grazing, few vegetative changes were identified in the ungrazed orchard. But by the third growing season of protection, thousands of new sugar maple seedlings had established in the section of the woods which had been least severely overgrazed and trampled. In succeeding years the density of maple regeneration increased rapidly until by 6 years after fencing the entire forest floor was covered with seedlings. In contrast, across the fence in the grazed woods the understory continued to be devoid of seedlings. Annual reproduction counts in the grazed pasture indicated that a large number of maple seedlings appeared each year. By fall, though, the majority of them were eaten by livestock or died from moisture stress.

Soil properties and floristic composition were compared on six pairs of adjacent grazed and ungrazed farm woodlots in southern Wisconsin (Steinbrenner 1951). All grazed woodlots had a history of heavy livestock use. The largest reduction of natural hardwood regeneration was in the .9 to 1.8 m size class. Ungrazed woodlots averaged 3372 seedlings /ha while grazed ones supported only 217 in this class. In the 0 to .9 m size class, the stocking levels were 5813 and 2920 for the ungrazed and grazed woodlots, respectively. The respective values for the sapling (2.5 to 10 cm dbh) class were 805 and 320. Hard maple (_Acer nigrum_) was particularly sensitive to heavy grazing. Regeneration density of this species was reduced by 2/3 in heavily grazed woodlots.

Foreign

Many recent studies on the effects of livestock grazing on forest regeneration have been conducted outside the United States. That portion of the available literature summarizing these studies and printed in English is given below. Adams (1975) reviewed several additional studies which he translated into English.

Canada

Research conducted near Kamloops, British Columbia investigated the effects of cattle grazing on the establishment, survival, and growth of coniferous tree species (Clark and McLean 1974, 1978, McLean and Clark 1980). The following four scenerios summarize research findings of Clark and McLean (1974) on cattle impacts on regeneration:

1. When cattle numbers and period of grazing were rigidly controlled, damage to conifer regeneration was negligible.
2. When period of grazing was too long, eventhough the numbers of cattle were regulated, forage was over-utilized and damage to seedlings was extensive.
3. When cattle concentrated in a limited area and forage was over-utilized, the level of damage was unacceptable.
4. Even in situations where forage was over-utilized and damage to seedlings high, damage was insignificant relative to natural mortality.

McLean and Clark (1980) assessed the damage to conifer regeneration as a result of cattle grazing on eight study areas. They found no significant relationship between cattle related tree mortality and degree of forage utilization. Although cattle were responsible for a sizeable portion of the seedling mortality, the absolute losses were insignificant. For example, on four seeded clearcuts the mortality attributed to cattle ranged from 20 to 56% of total seedling mortality. The stocking level for these two sites was high being 6110 and 5609 trees /ha, respectively. This suggested to the authors that grazing damage did not prevent adequate stocking levels of trees.

Seedling height growth didn't show any consistent response to grazing treatment.

When damage to lodgepole pine and Engelmann spruce (Picea engelmannii) occurred, it was the result of cattle trampling rather than browsing (Clark and McLean 1978). Therefore, the authors suggested that clearcuts be intensively grazed for a short period of time only, especially during the first year of tree establishment. Data also indicated that overstocking of lodgepole pine on some sites may be reduced by a heavy grazing treatment.

Four year average daily gains for cattle grazing young lodgepole pine-Englemann spruce plantations were .64 kg for calves and .13 kg for their dams. These plantations had been seeded to a grass-legume mixture and produced an average of 60 kg of beef/ha/year (Clark and McLean 1978, McLean and Clark 1980).

Europe

S.N. Adams (1976) reported on the first formal experimental investigation of the effects of livestock grazing on forest plantations in the British Isles. He examined sheep grazing in a 6-year-old Sitka spruce (Pica sitchensis) plantation in northern Ireland. Grazing reduced leader growth all 5 years of the study. At the termination of the study, trees in the grazed plots were approximately one year behind those in the ungrazed controls in total height. Except during the first year of grazing when the plots were too heavily stocked with animals, there wasn't any sign of browsing damage to the Sitka spruce seedlings. Of approximately 240 trees in the grazed plots, only 2 very small seedlings were killed by the sheep.

Grazing increased foliar nitrogen levels slightly the first 3 years and decreased it the fifth. Fertilizer treatment increased the foliar nutrient status all years. In the first two years after application the increases in foliar N and K were highly significant.

The reason for the reduction of height growth of the grazed regeneration was unclear to Adams. He speculated that grazing with the extremely wet soil conditions in the study, may have damaged the tree roots by trampling.

New Zealand

One of the earliest reports of livestock grazing in young radiata pine (Pinus radiata) plantations in New Zealand was given by Beveridge and Klomp (1973). They examined the role that sheep and cattle play in assisting site preparation, releasing radiata pine regeneration from competition, and improving access for early tending operations. The authors found that on some sites it was advantageous to graze livestock for several years prior to planting in order to break down slash, produce a good pasture, and suppress the invasion by fireweeds (Erechtites and Senecio spp.), thistles (Cirsium spp.), coarse grasses, bracken fern and shrub hardwoods (Fuschia, Aristotelia, and Melicytus spp.). Data from a trial where a first year radiata pine plantation established on farmland was periodically grazed by sheep throughout the growing season showed: (1) the annual height increment of trees with undamaged leaders was 37 cm, (2) trees with leaders damaged by early spring grazing prior to bud flush grew 31 cm, and (3) trees damaged during the period of active growth had an annual increment of only 5 centimeters.

In another study, Beveridge and Klomp (1973) examined sheep grazing in 2- and 3-year-old radiata pine plantations. Close grazing the second year resulted in some needle and side shoot browsing and also leader damage on smaller trees. The height growth of trees which suffered terminal browsing was 28 cm compared to 51 cm for trees that were unbrowsed. They noted that most browsing occured as a result of a short period of overstocking which could have been avoided with more strict livestock control. No damage was observed the third year. Third year height increment averaged 63 cm for all trees.

Beveridge et al. (1973) found that cattle grazing in established 5- to 6- year-old radiata pine plantations improved access which resulted in a 67% reduction in walking time for pruning compared to walking time in ungrazed sites. No significant damage to crop trees from cattle grazing was noted. Trees which were pushed over by cattle were generally those with defective root stems that were susceptible to toppling and unthrifty stunted trees which were scheduled for removal at thinning. Cattle browsing on side branches was not common, and no damage caused by bark biting was observed.

In first year radiata pine plantations, Knowles et al. (1973) reported that spring or summer grazing to release small seedlings from grass competition without significantly reducing tree development was largely unsuccessful. They indicated that grazing was less hazardous in late autumn when trees had completed the first seasons growth. Even during the second year, animal stocking rates high enough to contain rapid spring grass growth often resulted in excessive damage to regeneration. When grazing pressure was reduced in order to avoid tree damage, herbaceous forage soon became rank and unpalatable to sheep. The authors suggested that grazing be delayed until summer the second year when terminal leaders would be beyond the reach of sheep. Knowles et al. (1973) pointed out that where livestock have successfully maintained the sward and released the seedlings from grass competition, the following conditions had usually been met: (1) livestock had previous experience grazing young plantations, (2) the site had adequate feed, especially roughage, and was large enough for the animals to move about and obtain a diverse diet, and (3) careful management had been employed until terminals were completely out of reach of livestock.

Gillingham et al. (1976) summarized research findings on livestock grazing in young radiata pine plantations in New Zealand. They noted that "preconditioning" mature cattle by grazing among older trees before introduction into 3-year-old stands reduced the likelihood of damage. A study they reported compared browsing damage from three breeds (Border Leicester/Romney cross, Romney, and Perendale) of hoggets (9 to 15 month old sheep) with preconditioned dry Romney ewes and Friesian (dairy breed) calves. As a group, the hoggets caused a higher incidence of browsing damage than ewes in the spring. The Border Leicester/Romney and Perendale breeds showed a low severity ratio of tree browsing (% trees severely browsed/% all trees browsed) compared with ratios for the other classes of livestock. Freisian calves were particularly damaging to regeneration. They caused more damage in 9 days of grazing than other stock caused in 16 days. The authors stated that sheep have been generally more reliable than cattle in grazing forested pastures without inflicting severe damage and consequently have been used in the majority of the experiments. Dairy cattle have shown a propensity to browse and debark trees, and therefore should not be grazed in young pine plantations (Anonymous 1975).

Several authors have reported that if lateral branches have not been completely stripped of needles and the terminal remains intact, browsing damage will not significantly reduce seedling growth (Anonymous 1975, Gillingham et al. 1976, Tustin et al. 1979). But on the other hand, repeated browsing of the terminal can severely reduce height growth increment. Gillingham et al. (1976) found that 2 year height growth for planted radiata pine with unbrowsed leaders averaged 100 cm for the four sites they examined on the central North Island. Growth for the same period for seedlings which had leaders browsed the first spring was 90 cm. Seedlings with terminals browsed the first spring and autumn grew only 57 cm. Trees browsed the first spring and autumn plus the following spring produced just 39 cm of height growth. Under moderate grazing pressure, the same authors stated that as seedling height increased above 58 cm, the number of terminals browsed by sheep decreased. Terminal growth on trees over 94 cm was only lightly browsed.

Research trials designed to find the grazing management scheme most compatible with tree establishment were summarized by Tustin et al. (1979). They felt a suitable grazing system for sheep called for deferment of a new plantation until autumn the first year. The second year the site should not be grazed for 3 to 4 months during the critical spring period when the seedlings were most apt to be significantly damaged. By the third year, no restrictions were made on season of use. This system provided grazing returns for the first 3 years which were 20, 40, and 80%, respectively, of those achieved for open pastures.

Australia

The objective of a study conducted in Tasmania by Neilsen (1981) was to simulate "browsing" to radiata pine seedlings at levels similar to those observed in young plantations grazed by livestock and wildlife. He subjected seedlings (1-0) to three intensities of defoliation at three different dates. Seedling survival was not significantly reduced by any "browsing" treatment. But increasingly severe "browsing" progressively reduced height at age 2 years. Severe "browsing" (seedling clipped to 2.5cm of ground) reduced 2 year height by 36 to 54% compared to seedlings which had been lightly "browsed" (10 cm of foliage clipped off all shoots). Late "browsing" (6 or 12 months after planting) reduced height at age 2 years more than early "browsing" (at planting) and repeated "browsing" (at planting and 6 months after planting or at planting and 6 and 12 months after planting) reduced height still further. Following severe "browsing", height at 2 years was 3 to 40% less when "browsing" was late or repeated than when it was early. Height growth for all "browsed" treatments in the year following treatment (from age 2 to 3 years) did not differ significantly from the unbrowsed treatments. When growth was expressed as a percentage of height at the beginning of a growth period, it was higher on the more heavily "browsed" seedlings. This enabled them to retain their absolute position in relation to total height. Neilsen (1981) summarized his research findings by stating that moderate "browsing" in the first year after planting does not have a serious adverse effect on survival and growth of radiata pine, and control of animals should be directed towards preventing severe browsing which can reduce seedling growth.

A pilot trial which evaluated the feasibility of using sheep to control weeds in radiata pine plantations was conducted by McKinnell (1975) in western Australia. The trial was carried out in the following two areas: (1) a 2-year-old pine plantation established in a former Eucalyptus forest, and (2) a 1-year-old plantation in former pastureland.

In the 2-year old plantation, mature crossbred and Merino wethers ate scrub down to an unpalatable level with little or no damage to the pines. In contrast, 2-tooth (12 to 24 month) crossbred ewes and Merino wethers caused considerable damage to the regeneration. In both breeds, the younger sheep were not as effective as the older animals in reducing scrub competition. Weight gains for the first 16 days averaged .35 kg/head/day for the mature sheep and .06 kg/head/day for the younger animals (McKinnell 1975).

Sheep grazing in the 1-year-old stands was not as successful as in the two-year-old stands. The grass had been allowed to grow too long before the sheep were turned into the plots. McKinnell (1975) felt this may have contributed to the poor results obtained. Damage to the pines by sheep was noted soon after initiation of grazing. Both breeds and age classes of sheep browsed pines to some extent. After 16 days of grazing, sheep had made little impression on the pasture and had only prevented the competition from becoming any worse. Average daily gains for the first 16 days were .25 kg/head/day for the older wethers and -.06 kg/head/day for the 2-tooths.

McKinnell (1975) believed that results of this trial confirmed the feasibility of using sheep grazing for controlling scrub competition in pine plantations established in former forest sites in western Australia.

McKinnell and Batini (1978) summarized research findings from agro-forestry trials in southwest Australia. They felt there were several major benefits to the forester from integration of grazing and pine silviculture. These included: (1) control of pasture and scrub growth which reduced competition with regeneration, provided easier access, produced better tree growth, and greatly reduced fire hazard, (2) trampling of needle litter into the ground which speeded nutrient cycling, (3) the assurance of optimum tree nutrition in plantations having legume understories that were periodically fertilized with superphosphate and stock manure, and (4) income from grazing leases which provided early financial returns.

Relatively few problems with livestock browsing pines have been encountered in western Australia when the following guidelines were followed (Anonymous 1978):

1. Plantations not grazed by sheep until pines have reached an

average height of 2 m (approximately 2- to 3-years-old).

2. Sheep removed when the pasture becomes dry and sheep start nibbling on the bark of the pines.

3. Plantation deferred from cattle grazing until pines exceed 4 meters height (a minimum of 3 years on good sites).

Summary

Several important concepts have emerged from this literature review of livestock grazing impacts on forest regeneration. Concepts which have been elucidated by various studies include:

1. Controlled livestock grazing can potentially benefit timber regeneration by decreasing the fire hazard (Ingram 1928, 1931, Howell 1948, Sparhawk 1918, Young et al. 1942, Kaufman 1948, Stickel and Hawley 1924, Trenk 1954, McKinnell and Batini 1978), preventing the suppression of seedlings (Pearson 1923, Trenk 1954), reducing competition (Hall et al. 1959, Hedrick and Keniston 1966, Sharrow and Leininger 1983, Kosco and Bartolome 1983, Rummell 1951, Stickel and Hawley 1924, McKinnell and Batini 1978), and decreasing the habitat of rodents which damage seedlings (Pearson 1934, Trenk 1954).

2. Removal of brush by livestock grazing can increase access to the plantation and make forest tending easier (Hitchcock 1937, Beveridge and Klomp 1973, Beveridge et al. 1973, McKinnell and Batini 1978).

3. Big game grazing may aid in reforestation by reducing the biomass of competing brush (Kosco 1980, Wheeler et al. 1980, Krueger 1983).

4. When livestock numbers and period of grazing have been appropriate, damage to conifer regeneration has been negligible (Harshman 1979, Phelps 1979, Hall et al. 1959, Kosco and Bartolome 1983, Wahlenberg et al. 1939, Adams 1976, Smith et al. 1958, Clark and Mclean 1974, Beveridge et al. 1973, Currie et al. 1978).

5. When animal numbers, distribution, or season of grazing have not been controlled, damage to timber reproduction has frequently been unacceptable (Phelps 1979, Leiberg et al. 1904, Cassady et al. 1955, DenUyl and Day 1939, Clark and McLean 1974).

6. The severity of livestock damage to regeneration increases as the amount of palatable forage available to stock decreases (Black and Vladimiroff 1963, Hill 1917, Smith et al. 1958, Cassady et al. 1955, King et al. 1978, DenUyl and Day 1939, Sharrow and Leininger 1983).

7. Browsing damage may be reduced when a variety of forage is available to the grazing animal (Cassady et al. 1955, Knowles et al. 1973).

8. Browsing of regeneration is normally confined to current year's growth and generally to the early succulent growth (Hill 1917, Pearson 1950, Sharrow and Leininger 1983).

9. Conifer palatability is highest in the spring shortly after bud break (Hall et al. 1959, Sharrow and Leininger 1983, Pearson 1950).

10. There is little correlation between the degree of forage utilization by livestock and survival of planted seedlings (Black and Vladimiroff 1963, Bennett and Halls 1954, Pearson et al. 1971).

11. Seedling mortality as a result of livestock grazing is often insignificant compared to natural losses (Sparhawk 1918, Clark and McLean 1974, McLean and Clark 1980).

12. The most susceptible period for natural regeneration mortality as a result of livestock grazing is from germination through 1 year of age (Sparhawk 1918, Young et al. 1942, Leiberg et al 1904, Currie et al. 1978).

13. If the terminal remains intact, seedling growth will not be greatly affected by browsing on lateral branches (Anonymous 1975, Gillingham et al. 1976, Tustin et al. 1979, Sharrow and Leininger 1983, Hughes 1976, Lewis 1980a, Neilsen 1981).

14. The repeated removal of a seedling's terminal leader as the result of animal browsing will reduce the seedling's growth (Sparhawk 1918, Hill 1917, Pearson 1931, Sharrow and Leininger 1983, Cassidy 1937a, Beveridge and Klomp 1973, Gillingham et al. 1976, Tustin et al. 1979).

15. Once regeneration which had been subject to terminal browsing is released from damage, the rate of height growth is similar to non browsed trees of similar height (Cleary 1978, Sparhawk 1918, Maki and Mann 1951, Neilsen 1981).

16. Terminal browsing by sheep is largely confined to trees which are less than 1 m tall (Phelps 1979, Gillingham et al. 1976, Maki and Mann 1951).

17. Although cattle may browse or bark trees, the majority of damage to conifers by cattle results from trampling and rubbing (Kosco 1980, Clark and McLean 1978, Boyer 1967, Eissenstat et al. 1982, Erickson 1974, Pettit 1968).

18. While sheep primarily injure planted seedlings by browsing their foliage (Sharrow and Leininger 1983, Phelps 1979, Hall et al. 1959, Black and Vladimiroff 1963, Winward and Rudeen 1980), they damage natural regeneration by both browsing and trampling the young seedlings (Ingram 1931, Sparhawk 1918, Hill 1917).

19. Younger sheep (< 2-years-old) appear to be more destructive to conifer regeneration than older ewes (Gillingham et al. 1976, McKinnell 1975).

20. Livestock which have had previous grazing experience in forests (preconditioned) may be less harmful to regeneration than inexperienced animals (Knowles et al. 1973, Gillingham et al. 1976).

21. Hogs and goats are more damaging to timber reproduction than sheep and cattle (Howell 1948, Wahlenberg et al. 1939, Campbell 1947, 1954, Hopkins 1917, 1947).

22. Livestock which are thirsty are more likely to browse seedlings than when well watered (Cassidy 1937a, 1937b, Cooperrider 1937).

23. Hardwood trees are generally more preferred by livestock than conifer species (Smith et al. 1958, Biswell and Hoover 1945, Kaufman 1948, Stickel and Hawley 1924, Burns 1933).

24. When recommendations for management of livestock grazing in young timber plantations have been given, they have generally called for either the exclusion of livestock until seedlings are well established (2 to 3 years) (Sparhawk 1918, Pearson 1931) or exclusion until seedlings' terminal leaders are out of reach of grazing livestock (Schubert 1974, Knowles et al. 1973, Anonymous 1978, Cleary 1978).

25. The majority of studies reporting weight gains for sheep in young plantations have given average daily gains of about .25 kg/head/day (Black and Vladimiroff 1963, Hall et al. 1959, McKinnell 1975).

26. Reported gains for steers and calves have ranged from .23 (Kaufman 1948) to .77 (Hedrick 1975) kg/head/day. Several studies (Kaufman 1948, Clark and McLean 1978, McLean and Clark 1980) have reported intermediate weight gains of aproximately .45 to .65 kg/head/day.

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CHAPTER II

SHEEP PRODUCTION IN DOUGLAS-FIR PLANTATIONS IN WESTERN OREGON[1]

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SHEEP PRODUCTION IN DOUGLAS-FIR PLANTATIONS IN WESTERN OREGON

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Abstract

Sheep live weight gains and death losses are presented from a two-year grazing study conducted in cut-over forests in the Coast Range. Stocking rate averaged 125 ewe with lamb days/ha in 1981 and 143 yearling days/ha in 1982. Average daily gain (ADG) of ewes and lambs during the 1981 grazing season was -.03 and .12 kg/sheep/day, respectively. Yearling ewes gained .08 kg/ewe/day in the 1982 grazing season. In both years, ADG was higher the first half of the grazing season. Death losses were 3% for the ewes and 5% for lambs in 1981 and 2% for the yearlings in 1982. Only 3 sheep were killed by predators during the two seasons of grazing.

Introduction

In the past 10 years, there has been renewed interest in reintroducing sheep into cut-over forests in the Pacific Northwest. This interest has been prompted by two factors: the desire to use energy sources more efficiently and the current emphasis on biological tools for resource management in a period of environmental concerns (Hedrick 1975). Controlled livestock grazing has been shown to (1) reduce the biomass of herbaceous and shrubby vegetation which competes for nutrients and light with timber regeneration (Leininger and Sharrow 1982, 1983, Sharrow and Leininger 1983, Kosco and Bartolome 1983, Krueger 1983), (2) decrease the fire hazard in young plantations (Sparhawk 1918, Ingram 1928, 1931, Young et al. 1942), and (3) improve big game habitat (Rhodes and Sharrow 1983, Longhurst et al. 1982, Reiner and Urness 1982).

Presently, forest grazing in the Cascade and Coast mountain ranges is limited by the lack of adequate numbers of sheep to efficiently utilize the forage resources now available. Before new permittees will make the large investment required to purchase sheep, questions concerning the expected animal liveweight gains and death losses must be answered. The objective of this study was to provide information on sheep production which livestock operators can use in assessing the profitability of grazing cut-over forests in the Pacific Northwest.

Materials and Methods

The study was conducted in the Coast Range, approximately 15 km west of Alsea, Oregon. Climate is maritime with cool, rainy winters and warm, dry summers. Evening and early morning fog is common, even in summer. Most of the approximately 250 cm of precipitation falls as low intensity rain from October through May (Corliss 1973). Elevation of the study area ranges from 75 to 450 m and the slope varies from 0 to more than 100%.

The major vegetation type in the study area is the vine maple-sword fern (Acer circinatum-Polystichum munitum) community (Corliss and Dyrness 1965). Other important woody species in the understory are salmonberry (Rubus spectabilis), California dewberry (Rubus ursinus), and red alder (Alnus rubra). Dominant herbaceous plants include orchardgrass (Dactylis glomerata), common velvetgrass (Holcus lanatus), bentgrass (Agrostis spp.), tansy ragwort (Senecio jacobaea), and big deer vetch (Lotus crassifolius). Current year's growth of phytomass available to sheep ranged from approximately 850 kg/ha in the spring to 2940 kg/ha in late summer (Leininger 1983).

Seven-hundred Columbia ewes and their lambs and 900 Columbia yearling ewes grazed the forest from May to September in 1981 and 1982, respectively. Both years, all sheep were managed as a single flock under the constant supervision of a herder with dogs. A series of small plantations ranging in size from 10 to 40 ha each was grazed. Sheep were moved from plantation to plantation on a predetermined route, spending from 1 to 7 days in each. Altogether, approximately 665 ha were grazed in 1981 and 815 ha in 1982.

Sheep were vaccinated for sore mouth and with seven-way Clostridium bacterin and dewormed prior to entering the forest. They were periodically monitored for internal parasites and dewormed as needed (Kistner 1982). Trace mineralized salt was available *ad libitum*.

Livestock weight gain was evaluated in 1981 by weighing and ear tagging 100 ewes and 100 lambs prior to turnout in the forest. A sample of these marked animals was reweighed near the middle and at the end of the grazing season. In 1982, weights from random samples of 100 to 150 sheep were taken at the forementioned times. Average daily gain (ADG) was calculated as weight change between two dates. Standard errors of ADG were computed using a pooled error derived from dates involved (Steel and Torrie 1980). Death loss and cause of death were recorded by the permittee and Forest Service personnel (Pers. Comm. S. P. Smith, Range Conservationist, Alsea Ranger District, U.S. Forest Service).

Results and Discussion

In 1981, grazing use averaged 5.8 ha/band day or 125 ewe with lamb days/ha. Stocking rate was similar in 1982 when use averaged 6.17 ha/band day (143 yearling days/ha). These values compare favorably with Harshman's (1979) estimate of 125 to 200 dry ewe days/ha for cut-over forests in the Cascade Range. Blackwood (1975) and Throckmorton (1978) reported higher stocking rates of 333 dry ewe days/ha and 250 ewe with lamb days/ha, respectively for young plantations in southwestern Oregon. Ingram (1928) found that cut-over forests in southwestern Washington had a grazing capacity which ranged from 15 to 333 ewe with lamb days/ha, depending on the type of vegetation and the length of the time since cutting.

Ewes lost an average of 3.4 kg/head in live weight during the 1981 grazing season (Table II.1.). During the first half (8 May to 3 July) of the season, ewes lost .01 kg/head/day compared to a loss of .04 kg/head /day during the second half (4 July to 9 September). Negative ewe live weight gains were understandable in light of the high nutritional demands placed on them by lactation. Most lambs were less than one month of age when they entered the forest. Also, the ewes were in poor body condition and many of them suffered from foot rot when the grazing season began in 1981.

Lambs gained 14.2 kg/head during the 115 day grazing season (Table II.1.). Similar to ewes, live weight gain of lambs was highest during the 8 May to 3 July period when average daily gain was .14 kg/lamb/day. During the second half of the grazing season, ADG was .09 kg/lamb/day.

In 1982, the yearlings gained 9.8 kg/head while in the forest. Average daily gain for the first half of the summer (.17 kg/head/day) was nearly ten times the rate gain for the second half (.02 kg/head/day).

Sheep weight gains in this study followed seasonal trends typical of animals grazing non-irrigated, hill pastures. Sharrow et al. (1981), Sharrow and Krueger (1979), and Warner (1983) reported negative weight gains for ewes grazing improved hill pasture in western Oregon during the summer dry feed period (July to November). In contrast, weight gains exceeding 22 kg/head/day for sheep grazing cutover forests (Hall et al. 1959, Black and Vladimiroff 1963) and foot-

Table II.1. Live weights (kg/sheep) and average daily gains (ADG is kg/sheep/day) of sheep on 3 dates for the 1981 and 1982 grazing seasons.

		Ewes			Lambs	
1981	8 May	3 July	9 Sept	8 May	3 July	9 Sept
Weight	58.2±.72[1]	57.5±1.0	54.8±.84	7.4±.15	15.5±.37	21.6±.58
ADG from last weighing		-.01±.02	-.04±.02		.14±.01	.09±.01
ADG for grazing season			-.03±.01			.12±.01
Number of animals in sample	127	52	85	125	80	66

		Yearlings	
1982	11 May	2 July	14 Sept
Weight	43.1±.49	51.7±.50	52.9±.44
ADG from last weighing		.17±.01	.02±.01
ADG for grazing season			.08±.01
Number of animals in sample	101	110	150

[1] Mean ± standard error.

hill pastures (Sharrow et al. 1981, Sharrow and Krueger 1979, Warner 1983) in the Coast Range have been reported during the spring green forage period (April to June). In our study, sheep came into the forest about midway through the green forage period. Consequently, this reduced the length of grazing time when forage quality was highest and live weight gains the greatest. Rhodes (1983), working in the same area, reported that adequate forage phytomass was available to the sheep throughout the grazing season both years. Likewise, crude protein levels of forage plants generally met the National Research Council (1975) recommendations for lactating ewes. However, forage digestibility, while adequate for dry ewes, was often inadequate to meet the nutritional requirements of lactating ewes and growing lambs during the last half of the grazing season (Rhodes 1983). Ingram (1928) stressed the importance of early season sheep grazing in cut-over forests of the Cascade Range in order to obtain the most efficient use of the forage resources.

Death losses were low both years of the study, being approximately 28 ewes (3%) and 25 lambs(5%) in 1981 and 21 yearlings (2%) in 1982. The poor physical condition of the ewes when they entered the forest in 1981 probably contributed to the 3% death loss during that grazing season. Several ewes were too weak to keep up with the band and a few were unable to traverse the steeper plantations. These sheep generally died as the result of accidents such as falling over logs and breaking legs or being trampled by the band. Most lamb deaths were related to their young age and inability to survive when separated from their dams.

These death loss figures are similar to the 3% losses during the grazing season reported for sheep and goats averaged over all U.S. Forest Service lands for the 1967-1976 period (U.S. Fish and Wildlife Service 1978). A comprehensive survey conducted by the U.S.D.A. Economic Research Service in 1974 listed average annual death losses in Oregon of 19.5 and 12.5% for lambs and ewes, respectively (Gee et al. 1977). A more recent survey carried out by de Calesta (1979) in Oregon reported average losses of 8.4 and 6.5% for lambs and ewes, respectively, for a 17 month period (February 1976 - June 1977).

As with other forests in the Pacific Northwest where sheep have grazed transitory range (Phelps 1979, Harshman 1979, Ingram 1928), losses in this study from predation were very low. Two coyote strikes on neighboring plantations resulted in the loss of three yearlings in 1982. No other verified losses of sheep to preditors occurred either year of the study. Higher death losses from predators have been reported during the grazing season for other types of rangeland in Oregon (de Calesta 1979) and for Forest Service lands in general (U.S. Fish and Wildlife Service 1978).

Harshman (1979) speculated that (1) grazing dry ewes which were less susceptible to coyote predation and (2) grazing in areas where cougars and bears had not had access to sheep for 40 years were major reasons for the lack of predation on sheep which grazed cut-over forest land in the Cascade Range. In our study, we believe these reasons plus the presence of a herder with dogs and the relatively short time spent in each plantation largely explain the low number of animals lost to predators.

Management Implications

Forage resources and the steep topography of the Coast Range appear to be best suited for dry ewes or young vigorous ewes with lambs which are 10 to 12 weeks of age. Hedrick et al. (1968) and Young et al. (1967) found younger livestock were more suited for grazing the rougher areas of mixed conifer forests. They stated that mixed coniferous forests are most effectively used by steers, replacement heifers, cows from which calves have been weaned, and cows with calves in decreasing order of efficiency. Hedrick et al. (1968, 1969) also stressed the advantage of grazing stock which had prior aquaintance with the area.

Sheep grazing should be initiated as early in the spring as vegetation and soils permit. This will maximize the time that animals graze during the green feed period when forage quality is highest. The potential for sheep browsing on conifer regeneration must also be considered when setting the grazing season (Leininger and Sharrow 1983, Sharrow and Leininger 1983). Traditional forest grazing schemes which have been employed in much of the Intermountain Region allow livestock to follow green feed up the mountain as the grazing season progresses. Since the Coast Range lacks the elevational change required for this type of livestock management, we suggest that plantations be grazed in a rotational sequence which maximizes the time that animals spend grazing forage regrowth in previously grazed plantations during the latter half of the summer. Rhodes (1983), working in the Coast Range, found that in late summer forage plants which had been grazed by sheep in the spring had significantly higher crude protein and *in vitro* dry matter digestibility values than plants which were not grazed.

Our data support conclusions by Hall et al. (1959) and Ingram (1928) that sheep can be profitably grazed in young cut-over forests of the Pacific Northwest.

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CHAPTER III

SEASONAL FOOD HABITS OF HERDED SHEEP GRAZING CUT-OVER DOUGLAS-FIR FORESTS OF WESTERN OREGON[1]

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SEASONAL FOOD HABITS OF HERDED SHEEP GRAZING CUT-OVER DOUGLAS-FIR FORESTS OF WESTERN OREGON

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Abstract

A study was conducted during 1981 and 1982 to determine seasonal food habits of herded sheep grazing cut-over Douglas-fir (*Pseudotsuga menziesii*) forests in the Coast Range. Study sites included both 4-to 6-year-old non-seeded and 2-year-old grass-seeded plantations. Sheep grazing was monitored in spring, summer, and late summer. Forage on offer ranged from 764 to 2459 kg/ha. Vegetational composition of sheep diets varied by year, season, and plantation age class. Averaged over the 2 years of grazing, graminoids and forbs were nearly equal, at approximately 40% each, in sheep diets in older plantations. In contrast, diets of sheep in young grass-seeded plantations averaged 70% graminoids and only 16% forbs. Ferns were a minor component (<2%) of sheep diets in both plantation age classes. Browse averaged 15 and 12% of sheep diets in older and younger plantations, respectively. Douglas-fir was most palatable to sheep in spring soon after bud break. However, it only comprised from less than 1 to 3% of sheep diets throughout the grazing season.

Introduction

According to the Forest-Range Task Force (1972), a 50% increase in demand for grazing within forest-range ecosystems in the United States will occur by the year 2000. In 1970, only 69% of this 486 million ha resource was grazed by livestock (Forest-Range Task Force 1972). During the past 10 years, there has been renewed interest in reintroducing sheep into cut-over forests in the Pacific Northwest. This interest has been prompted by two factors: (1) the desire to use energy sources more efficiently, and (2) the current emphasis on biological tools for resource management in a period of environmental concerns (Hedrick 1975). Relatively little information has been published concerning food habits of sheep grazing cut-over forests in western Oregon and western Washington. Such information is needed by resource managers to assess the nutrient intake of animals, aid in the evaluation of potential forage competition among herbivore species (Buchanan et al. 1972, Holecheck et al. 1982), and predict seasonal differences in the relative preference between tree crop and forage species.

Vavra (undated) reported on diets of sheep grazing cut-over forests on the west slope of the Cascades in southwestern Oregon. He noted that summer diets of sheep consisted of 56% graminoids, 8% forbs, 3% ferns, 31% shrubs, and 2% conifers. Collectively, reed fescue (_Festuca arundinacea_)[1], western fescue (_F. occidentalis_), blackberries (_Rubus_ spp.), buckbrush (_Ceanothus_ spp.), and winter

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[1] Plant names follow Garrison et al. (1976).

currant (Ribes sanguineum) comprised approximately 50% of sheep diets in the summer. Conifers, principally pondersoa pine (Pinus ponderosa), were consumed only during mid-June. Harshman (1979) noted that sheep, which grazed in young Douglas-fir plantations in the Cascades, changed their forage preferences throughout summer. When released into the forest in mid-June, sheep preferred the succulent growth of small forbs and grasses. They also consumed willows (Salix spp.), box blueberry (Vaccinium ovatum), elder (Sambucus spp.), and buckbrush. By the end of July, their preferences shifted more towards browse species; at this time thimbleberry (Rubus parviflorus) was classified as an "ice cream" plant. By September, sheep concentrated on leaves and terminal branches of shrubs such as vine maple (Acer circinatum). Ingram (1931) recorded a similar shift towards browse in diets of sheep grazing forests during late summer in southwestern Washington.

Fireweed (Epilobium angustifolium) made up between 70 and 80% of the diet of sheep foraging in cut-over forests in western Washington (Phelps 1979). According to Phelps, sheep "sought out" willows and European red elder (Sambucus racemosa) when they entered a plantation. Ingram (1928) also observed that fireweed made up a major portion of summer diets of sheep grazing regenerating forests in southwestern Washingon. Graminoids and blackberries were also utilized extensively.

Western yarrow (Achillea millefolium), Oregon iris (Iris tenax), sheep sorrel (Rumex acetosella), and spotted catsear (Hypochaeris radicata) were heavily utilized by sheep grazing young Douglas-fir plantations in spring in the Coast Range (Black and Vladimiroff 1963). Creambush rockspirea (Holodiscus discolor), kidneywort baccharis (Baccharis pilularis), and red whortleberry (Vaccinium parvifolium) were also preferred by sheep. In contrast, Hall et al. (1959) noted that sheep did not browse shrubs appreciably during spring in a clearcut oak forest in the Willamette Vally near the Coast Range.

The purpose of this study was to : (1) determine the amount of forage on offer to sheep in two different age classes of Douglas-fir plantations, (2) identify the kinds and amounts of forage eaten by sheep, and (3) evaluate seasonal preferences of sheep for different forage species, including Douglas-fir.

Study Area

The study was conducted in the Coast Range, approximately 15 km west of Alsea, Oregon. Climate of the area is characterized by wet winters, relatively dry summers, and small variation in mean monthly temperatures (Corliss and Dyrness 1965). Evening and morning fog is common, even in summer. Most of the approximately 250 cm of precipitation falls as low intensity rain from October through May (Corliss 1973).

Five Douglas-fir plantations in the Alsea District, Siuslaw National Forest, were selected for observation. Elevations range from 170 to 440 m. Soils are slickrock gravelly loams (Pachic Haplumbrept, Corliss 1973). Study plots were restricted to the vine maple-sword fern (Acer circinatum - Polystichum munitum) vegetation type because it is the most extensive understory plant community in the Alsea

District (Corliss and Dyrness 1965). Based on age since planting and month of sheep grazing, the 5 study plantations were distinguished as follows: (1) a 4-year-old plantation grazed in May (OMy), (2) a 6-year-old plantation grazed in July (OJy), (3) a 5-year-old plantation grazed in August (OAg), (4) a 2-year-old plantation grazed in May (YMy), and (5) a 2-year-old plantation grazed in July (YJy). YMy was seeded with a mixture of grasses at tree planting. Although study plots in YJy were not in the portion of the plantation which had been grass-seeded, species composition of the plots was strongly influenced by the adjacent seeding. Since study plots in YJy and YMy have similar species composition (Table III.1.), both are considered to represent young grass-seeded plantations.

Materials and Methods

Phytomass on offer and amount of phytomass utilized by sheep were determined using the "before and after" technique (Cassady 1941). Current year's growth (CYG) of all plant species except vine maple on the 3 older plantations and Douglas-fir on all study plantations was estimated using the plot-harvest method. Prior to grazing, 10 pairs of .45 m^2 quadrats were randomly located in each of three .05 ha macro plots, which served as replications in each study plantation. One quadrat of each pair was randomly selected and clipped, while the other was marked and harvested immediately after sheep left the plantation. Current year's growth was separated by species, then oven dried at 50°C for 72 hours prior to weighing. Plant material trampled, lodged, or shattered was separated from previous years' litter and included in the "after" biomass samples in order to increase accuracy of the utilization estimates.

Current year's growth and utilization of vine maple in the 3 older plantations were determined as follows. Ten vine maple plants were randomly selected within each replication prior to grazing. Four branches from each plant were chosen and available CYG on 2 randomly selected branches clipped, oven-dried and weighed. The remaining 2 branches were marked and treated similarly following grazing. The number of branches on each defoliated vine maple was counted along with the number of vine maple in each replication. Multiplication of weight/branchlet X # branchlets/shrub X # shrubs/ha allowed an estimation of production on an area basis. Foliage on branches greater than 1.5 m above the soil surface was not sampled, as it was considered unavailable for sheep grazing (Ingram 1931).

Height and number of lateral branchlets within 1.5 m of the ground were determined for each of 92 Douglas-fir trees. These data were then used to develop a regression equation relating the number of branchlets on Douglas-fir regeneration within 1.5 m of the ground to tree height. The relationship (Fig. III.1.) is similar to one calculated by Mitchell (1974) which compared the number of new needles to Douglas-fir height. Height of all Douglas-fir trees within study plots was measured prior to sheep grazing. The predicted number of branchlets was then calculated for each tree. Current year's Douglas -fir growth available to sheep was estimated by multiplying the predicted # branchlets for each tree in the study plots X mean oven dry weight of 100 branchlets collected at time of grazing. Percentage

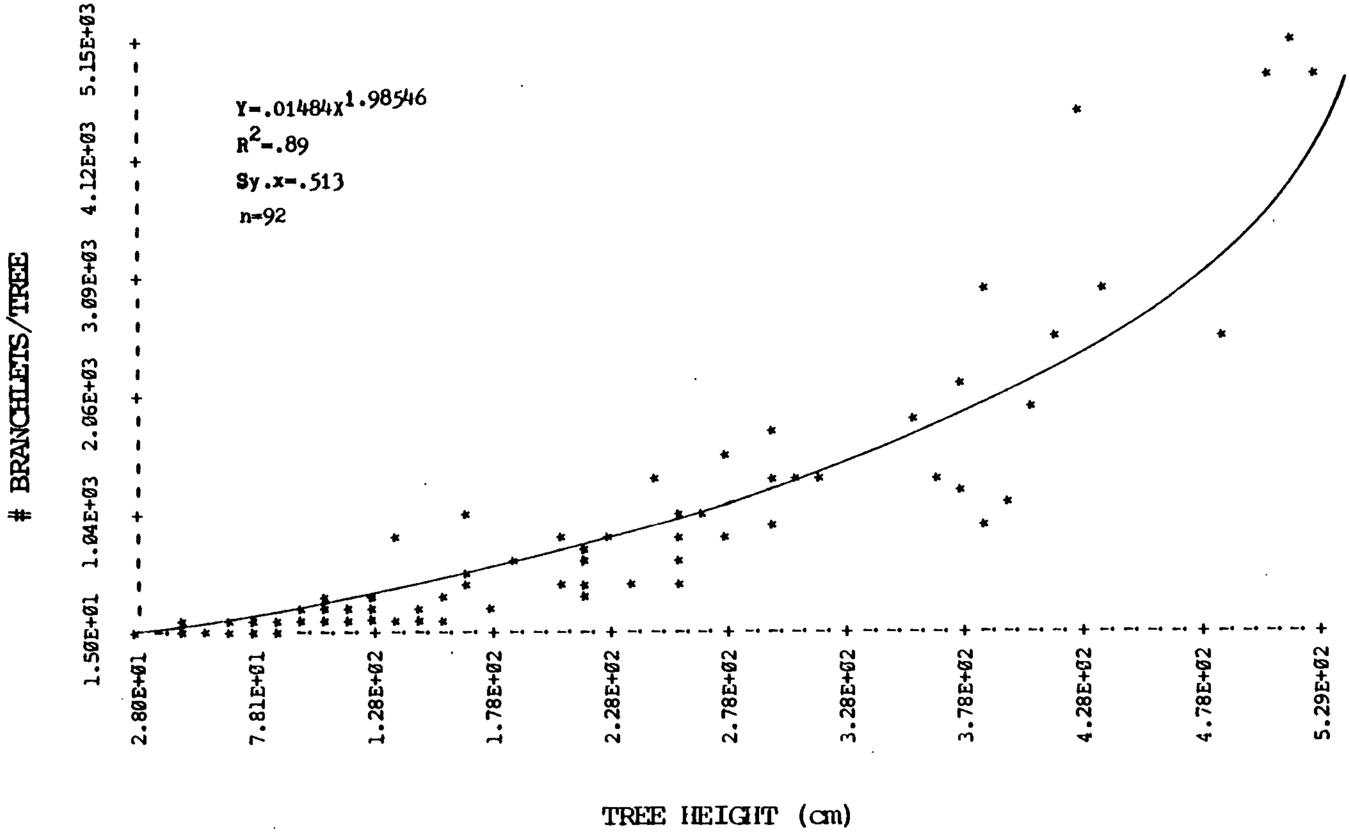

Fig. III. 1. Plot of the relationship between the number of branchlets per Douglas-fir tree and tree height.

CYG removed from each study tree by sheep was determined as the difference between ocular estimates of percentage of foliage browsed by wildlife prior to sheep entry and the percentage of foliage browsed immediately after sheep left the plantation. Weight of foliage removed from each study tree was calculated as the product of percentage CYG removed and its predicted biomass.

Sheep preference for individual plant species and forage classes were evaluated with a relative preference index (Van Dyne and Heady 1965):

$$\text{Relative Preference Index (RPI)} = \frac{\text{Percent Diet}}{\text{Percent composition in plantation}}$$

As suggested by Hobbs (1982), confidence intervals were constructed for RPI's to aid in their interpretation. Index values were interpreted as follows: (1) RPI's whose lower limit of the 90% confidence interval exceeded 1.0 indicated preference, (2) RPI's whose upper limit of the 90% confidence interval was less than 1.0 indicated avoidance, (3) RPI's whose 90% confidence interval included 1.0 indicated neutral preference.

Seven-hundred Columbia ewes and their lambs and 900 Columbia yearling ewes grazed the forest from May to September in 1981 and 1982, respectively. Both years, all sheep were managed as a single flock under the constant supervision of a herder with dogs. A series of small plantations ranging in size from 10 to 40 ha each was grazed. Sheep were moved from plantation to plantation on a predetermined route, spending from 3 to 7 days in each. Within this schedule, study plantations were grazed once each year, with the exception of YMy which was grazed once in May and again in August both years. Data from the August grazing were only taken in 1982. These data are identified as YMy/Ag.

The phytomass on offer, composition of sheep diets, and RPI's were evaluated using analysis of variance techniques. Data were analyzed as a split-, split-plot with plantations as mainplots and forage classes and years as sub-plots in a completely randomized design. Where appropriate, means were separated with Tukey's w-procedure (Steel and Torrie 1980).

Results and Discussion

Vegetational composition of sheep diets differed ($p \leq .01$) between the 2 years of the study. Graminoids averaged 42% of sheep diets in 1981 compared to 62% in 1982 (Table III.1.). Since preference values for graminoids were similar both years, the higher level of graminoids in 1982 in diets was probably a reflection of the greater graminoid biomass ($p \leq .05$) on offer that year. Both the amount of forbs on offer to sheep (Table III.2.) and the percentage of forbs in their diets (Table III. 1.) decreased ($p \leq .05$) from 1981 to 1982. The preference shown for forbs by sheep did not differ ($p \geq .10$) between years. Modest reductions ($p > .10$) in both amount on offer and preference for browse from 1981 to 1982 resulted in a substantial decrease ($p \leq .01$) in the amount of browse consumed in 1982. Browse made up 18% of sheep diets in 1981 compared to only 11% in 1982. The available CYG of Douglas-fir more than doubled from 1981 to 1982. However, there was only a minor increase ($p \leq .01$) of Douglas-fir in sheep diets from .9% in 1981

Table III.1. Vegetational compostiion (%) of sheep diets from 5 Douglas-fir plantations, 1981 and 1982. Data are mean percentage ± standard error.

	Plantation					
Forage class	OMy	OJy	OAg	YMy	YJy	YMy/Ag
1981						
Graminoids	37±3	22±2	29±6	66±4	56±10	
Forbs	43±8	56±5	44±7	18±1	19±4	
Ferns	0	<1±<1	6±3	1±<1	6±4	
Browse	18±6	20±4	20±2	14±2	20±8	
Douglas-fir	2±1	1±1	<1±<1	1±<1	<1±<1	
1982						
Graminoids	58±7	50±12	36±5	90±1	69±7	63±11
Forbs	36±8	28±10	39±6	8±1	20±3	15±8
Ferns	1±1	2±<1	<1±<1	<1±<1	<1±<1	0
Browse	2±1	19±3	21±4	2±1	11±7	19±4
Douglas-fir	3±1	1±<1	3±2	<1±<1	<1±<1	3±1

Table III.2. Above ground phytomass within 1.5 m of ground and % species composition in 5 Douglas-fir plantations, 1981 and 1982. Data are mean ± standard error.

	Plantation											
	OMy		OJy		OAg		YMy		YJy		YMy/Ag	
Forage class	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
1981												
Graminoids	408±42	32	361±41	17	867±190	31	1497±381	65	1290±236	64		
Forbs	458±76	36	787±79	37	770±100	27	498±29	22	256±53	13		
Ferns	20±10	2	115±67	5	255±129	9	31±7	1	156±15	8		
Browse	262±25	21	295±100	14	409±52	14	238±20	10	274±81	13		
Total Forage	1148±32	90	1558±246	72	2301±258	81	2263±389	99	1976±292	14		
Douglas-fir	129±9	10	598±89	28	529±59	19	34±1	1	55±3	3		
Total Phytomass	1277±26	100	2156±206	100	2830±151	100	2298±390	100	2031±291	100		
1982												
Graminoids	359±90	42	829±215	29	764±55	26	2035±78	82	1269±200	58	1276±183	62
Forbs	218±18	26	544±40	19	486±80	17	336±57	14	408±79	19	428±117	21
Ferns	10±3	1	43±9	1	31±24	1	5±4	<1	26±7	1	2±2	<1
Browse	177±25	21	298±75	10	314±97	11	83±20	3	370±100	17	245±56	12
Total Forage	764±104	90	1715±137	59	1596±47	54	2459±26	100	2073±158	94	1951±125	94
Douglas-fir	87±3	10	1174±168	41	1341±66	46	10±1	<1	130±3	6	118±11	6
Total Phytomass	850±102	100	2888±253	100	2937±112	100	2469±27	100	2203±161	100	2069±161	100

to 1.6% in 1982. Sheep generally avoided Douglas-fir both years (Table III.3.).

Sheep diets also varied ($p \leq .01$) between plantations grazed in spring (OMy and YMy) and those grazed in summer (OJy and YJy). Available graminoids decreased ($p \leq .05$) from an average of 1075 kg/ha in spring grazed study plantations to 937 kg/ha in summer grazed ones. This decrease was reflected in a reduction ($p \leq .01$) of graminoids in sheep diets from 63% in spring to 49% in summer. The relative preference indices for graminoids did not differ ($p > .10$) between seasons. Forb consumption increased ($p \leq .05$) from 26% of the diet in spring to 31% in summer. Both amount of forbs on offer, and preference displayed for them by sheep increased ($p \leq .10$) as the grazing season advanced.

Consumption of browse was lower ($p \leq .01$) in spring than in summer. This was particularly evident in 1982 when sheep diets contained only 2% browse in both spring grazed plantations (Table III.1.). Above average precipitation coupled with below average temperatures in April (NOAA 1982) delayed the phenological development of most browse by approximately 2 weeks in 1982 relative to 1981. This resulted in less ($p \leq .01$) browse on offer to sheep in plantations grazed in May 1982 compared to May 1981 (Table III.2.) Sheep exhibited less ($p \leq .05$) preference for browse in spring 1982 than spring 1981 (Table III.3.). The lower preference for browse in spring 1982 could reflect a lower palatability of the less phenologically developed shrub growth, or possibly a higher palatibility of the other forage classes in the 2 study plantations grazed in May 1982. It has been shown that both age

Table III.3. Relative preference indices for different forage classes in 5 Douglas-fir plantations grazed by sheep, 1981 and 1982. Data are mean ± standard error.

	Plantation					
Forage class[1]	OMy	OJy	OAg	YMy	YJy	YMy/Ag
1981						
Graminoids	$1.17\pm.06^{n}$	$1.34\pm.08^{p}$	$.98\pm.06^{n}$	$1.04\pm.03^{n}$	$.88\pm.11^{n}$	
Forbs	$1.19\pm.06^{p}$	$1.54\pm.12^{p}$	$1.60\pm.04^{p}$	$.75\pm.13^{n}$	$1.49\pm.20^{n}$	
Ferns	0^{a}	$.36\pm.36^{n}$	$.79\pm.48^{n}$	$.84\pm.43^{n}$	$.51\pm.37^{n}$	
Browse	$.85\pm.22^{n}$	$1.54\pm.08^{p}$	$1.47\pm.25^{n}$	$1.28\pm.08^{p}$	$1.34\pm.29^{n}$	
Douglas-fir	$.17\pm.08^{a}$	$.04\pm.03^{a}$	$.02\pm.01^{a}$	$.60\pm.10^{a}$	$.03\pm.01^{a}$	
1982						
Graminoids	$1.41\pm.07^{p}$	$1.76\pm.10^{p}$	$1.41\pm.28^{n}$	$1.09\pm.02^{p}$	$1.21\pm.01^{p}$	$1.01\pm.12^{n}$
Forbs	$1.35\pm.05^{p}$	$1.47\pm.42^{n}$	$2.38\pm.26^{p}$	$.63\pm.12^{a}$	$1.07\pm.08^{n}$	$.72\pm.31^{n}$
Ferns	$1.23\pm.15^{n}$	$1.60\pm.68^{n}$	2.04 ± 1.49^{n}	$.88\pm.88^{n}$	$.43\pm.32^{n}$	0^{a}
Browse	$.09\pm.04^{a}$	$1.97\pm.37^{n}$	$2.18\pm.39^{p}$	$.55\pm.20^{n}$	$.52\pm.17^{n}$	$1.64\pm.08^{p}$
Douglas-fir	$.27\pm.06^{a}$	$.02\pm.01^{a}$	$.08\pm.03^{a}$	$1.08\pm.04^{n}$	$.04\pm.01^{a}$	$.57\pm.26^{n}$

[1] n,p, and a are neutral, preferred, and avoided, respectively ($p\leq.10$).

(Gillingham et al. 1976, McKinnell 1975) and past grazing experience (Knowles et al. 1973, Gillingham et al. 1976, Arnold and Maller 1977, Mathews and Kilgour 1979, Stoddart et al. 1975) affect the vegetational composition of sheep diets. This may also have contributed to the different feeding habits of the 2 bands of sheep when they entered the forest.

An increase ($p \leq .05$) in available browse in July was accompanied by higher ($p \leq .01$) RPI's for browse at this time. Due to large standard errors associated with the preference estimates for browse in OAg in 1981 and OJy in 1982, RPI's for browse were statistically neutral in both plantations in spite of relatively high numerical values (Table III.3.). Observations of the sheep while they grazed these plantations suggest that browse was a preferred food of sheep in these plantations. The percentage of browse in diets of sheep was higher ($p \leq .01$) in summer than spring. Sheep diets contained nearly 10 times the percentage of browse in August 1982 when they regrazed plantation OMy than they contained in May (Table III.1.). Other studies have reported a shift towards browse in diets of sheep grazing forests as summer progressed (Ingram 1931, Harshman 1979, Cook and Harris 1968).

Palatability of Douglas-fir was highest ($p \leq .05$) in spring, especially in 1982 in plantation YMy where it had an RPI of 1.08 (Table III.3.). New growth on lateral shoots of Douglas-fir averaged approximately 4 cm when sheep were released in May-grazed plantations in 1982. Browsing was confined to this new growth. Spring growth of Douglas-fir is also quite palatable to deer and considerable use of young foliage by them may take place during this season (Hall et al. 1959, Crouch 1974, Hartwell 1973, Oh et al. 1970, Crouch and Radwan 1981, and others). Douglas-fir was avoided by sheep during the summer and late summer periods (Table III.3.). An exception to this was in YMy/Ag. Grazing in this plantation coincided with a flush of growth from secondary buds which produced conditions similar to those encountered in spring. Sheep diets never contained more than 3% Douglas-fir (Table III.1.). This level of use is considerably lower than the 15% conifers in diets of sheep in mid-June reported by Vavra (undated).

Sheep diets differed ($p \leq .01$) between the 2 plantation age classes. Graminoids made up 70% of sheep diets in the 2 younger grass- seeded plantations compared with 42% in the 2 older ones grazed during the same time period. Availability of the preferred graminoids appeared to be an important factor in determining diet composition. YMy and YJy averaged 311% more graminoids on offer to sheep than available in OMy and OJy. Sheep diets averaged 69 and 32% orchardgrass (Dactylis glomerata) in plantations YMy and YJy, respectively (Table III.4.). Velvet grass (Holcus lanatus), spike bentgrass (Agrostis exarata), and colonial bentgrass (A. tenuis) were principal foods in older plantations.

Overall, forbs made up 41% of sheep diets in plantations OMy and OJy compared to only 16% in YMy and YJy. Although the biomass of forbs available to sheep averaged approximately 500 kg/ha in both plantation age classes, the preference shown by sheep for forbs in older plantations was higher ($p \leq .10$). Common pearleverlasting

Table III.4. Percent composition of important plant species in the diet of sheep grazing Douglas-fir plantations. Data are averages of 1981 and 1982 grazing seasons.

	Plantation					
Plant species	OMy	OJy	OAg	YMy	YJy	YMy/Ag[1]
Agrostis spp.	22	8	6	1	7	2
Aira spp.	T[2]	12	3	T	T	T
Carex hendersonii	6	3	T	1	T	T
Dactylis glomerata	7	T	T	69	32	56
Holcus lanatus	3	6	20	5	3	4
Linum perenne	0	0	0	1	11	T
Other graminoids	10	7	4	2	10	1
Anaphalis margaritacea	24	2	3	2	1	2
Lotus crassifolius	9	6	3	T	T	T
Rumex acetosella	T	T	4	T	7	T
Senecio jacobaea	2	15	8	T	1	1
Scrophularia californica	T	2	T	8	2	4
Other Forbs	5	17	24	3	8	8
Polystichum munitum	1	1	3	1	3	T
Acer circinatum	5	5	14	3	T	T
Rubus parviflorus	3	4	3	3	1	7
R. spectabilis	1	4	2	T	T	1
R. ursinus	1	4	2	T	13	1
Sambucus spp.	T	T	T	1	T	7
Other Browse	T	5	T	T	2	2
Pseudotsuga menziesii	2	1	1	1	T	3

[1] Data are for 1982 grazing season only.
[2] T=<1%.

(Anaphalis margaritacea), big lotus (Lotus crassifolius) and tansy ragwort (Senecio jacobaea) were dominat herbaceous species in older plantations, as well as preferred foods of sheep. In contrast, California figwort (Scrophularia californica) and bull thistle (Cirsium vulgare) were dominant forbs in younger plantations, especially YMy, but had low preference values. Ingram (1931) noted that early seral species which inhabited young plantations were generally less palatable to sheep than species found in older plantations. Whereas fireweed is often the dominant herb in cut-over forests in the Cascade Range (Harshman 1979, Harshman and Forsman 1978, Reid et al. 1938, Ingram 1931, Phelps 1979), it rarely occurred in our study plantations.

Sheep diets averaged 15% browse for the 2 older plantations grazed in May and July compared to 12% for the 2 younger ones grazed during the same time period. Vine maple was the most common browse on offer and in the diets of sheep grazing older plantations (Table III.4.). In all study plantations and seasons, bitter cherry (Prunus emarginata), elder, and red whortleberry were preferred foods of sheep. Douglas-fir was similarly represented in diets of sheep from older and younger plantations.

Summary

Vegetational composition of sheep diets varied by year, season, and plantation age class. Diets generaly reflected forage available to sheep at the time of grazing. Graminoids were more abundant in 1982 and made up a larger portion of sheep diets than in 1981. Forbs on offer and amount ingested by sheep decreased from 1981 to 1982. The greater availability of graminoids to sheep in spring was reflected in higher amounts in sheep diets during this season. Availability, preference, and percentage of forbs in sheep diets were higher in summer than spring. Consumption of browse was lowest in spring. Douglas-fir was most palatable to sheep in spring soon after bud break. However it only ranged from less than 1 to 3% of sheep diets throughout the grazing season. Averaged over the 2 years of grazing, graminoids and forbs were nearly equal, at approximately 40% each, in sheep diets in older plantations. In contrast, diets of sheep grazing young grass-seeded plantations averaged 70% graminoids and only 16% forbs. Ferns were a minor component (<2%) of sheep diets in both age class plantations. Browse averaged 15 and 12% of sheep diets in older and younger plantations, respectively.

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CHAPTER IV

SEASONAL BROWSING OF DOUGLAS-FIR REGENERATION BY SHEEP IN THE COAST RANGE[1]

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SEASONAL BROWSING OF DOUGLAS-FIR REGENERATION BY SHEEP IN THE COAST RANGE

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Abstract

Browsing and mechanical damage to Douglas-fir (Pseudotsuga menziesii) regeneration by sheep was evaluated in 1981 and 1982 in the Coast Range. Study sites included both 4-to 6-year old non-seeded and 2-year-old grass-seeded plantations. Grazing was monitored in May, July, and August. Sheep browsing of Douglas-fir current year's growth was highest in May soon after bud break. Browsing was generally light during July and August. This seasonal pattern is very similar to the browsing pattern of deer in the Pacific Northwest. Browsing of Douglas-fir was higher in a younger plantation than an older one grazed during May. Terminal browsing by sheep was largely restricted to regeneration in a 2-year-old grass-seeded plantation grazed in May. Percent of study trees with terminals browsed by sheep decreased as seedling height increased. Only 1% of the study trees over 120 cm tall had terminals browsed in 1982 in a young May-grazed plantation compared to 96% of the study trees under 50 cm tall. No relationship between level of lateral browsing and tree height was observed. Less than 3% of the study trees were mechanically impacted by sheep.

Introduction

As the world demand for food grains increases, alternate feed sources for livestock must be sought (Lundgren et al. 1983). A potential source for additional livestock grazing is the forest-range ecosystem. According to the Forest-Range Task Force (1972), the demand for livestock grazing in this ecosystem is anticipated to increase by 50% between 1972 and the year 2000. During the same time period, the demand for timber products is projected to increase by 80% (U.S. Forest Service 1965). In order to meet these demands, timber and red meat production must by more fully integrated (Wheeler et al. 1980).

More than 50 years ago, Ingram (1931) pointed out the need for the development of grazing management principles which would assist rather than interfere with reforestation in Douglas-fir cut-over lands. Presently, little published information is available to forest managers in the Pacific Northwest describing seasonal browsing of conifers by sheep or height to which sheep browse terminal leaders. In cut-over Douglas-fir forests of western Oregon and western Washington, considerable research has been conducted on seasonal browsing of conifer regeneration by deer (Crouch 1968, 1974, Brown 1961, Crouch and Radwan 1981, Dimock 1970). However, the applicability of these findings to livestock grazing is not clear.

It is the purpose of this paper to report on (1) seasonal browsing and mechanical impacts to Douglas-fir regeneration, and (2) the relationship between seedling height and the browsing of terminal leaders or lateral branches by sheep.

Study Area and Methods

The study was conducted in 5 Douglas-fir plantations in the Coast Range, approximately 15 km west of Alsea, Oregon. Climate of the area is maritime with wet winters, relatively dry summers, and small variation in mean monthly temperatures (Corliss and Dyrness 1965). Most of the approximately 250 cm of precipitation falls as low intensity rain from October through May (Corliss 1973).

Study plots were restricted to plantations having the vine maple-sword fern (Acer circinatum-Polystichum munitum) plant community. In addition to vine maple, other important woody species are salmonberry (Rubus spectabilis), California dewberry (Rubus ursinus), and red alder (Alnus rubra). Dominant herbaceous plants include orchardgrass (Dactylis glomerata), common velvetgrass (Holcus lanatus), bentgrass (Agrostis spp.), tansy ragwort (Senecio jacobaea), big deer vetch (Lotus crassifolius), and common pearleverlasting (Anaphalis margaritacea). A detailed description of this plant community is given by Corliss and Dyrness (1965).

Based on age since planting and month of sheep grazing, the 5 study plantations were distinguished as follows: (1) a 4-year-old plantation grazed in May (OMy), (2) a 6-year-old plantation grazed in July (OJy), (3) a 5-year-old plantation grazed in August (OAg), (4) a 2-year-old plantation grazed in May (YMy), and (5) a 2-year-old plantation grazed in July (YJy) (Table IV.1.). YMy was seeded with a mixture of grasses at tree planting. Although study plots in YJy were not in the portion of the plantation which had been grass-seeded, species compostion of the plots was strongly influenced by

Table IV.1. Plantation age, year of harvest, year of burn, date of planting, and type of Douglas-fir stock for 5 study plantations.[1]

		Year of		Date of	Type of
Plantation	Age[2]	Harvest	Burn	Planting	Stock
OMy	4	1976	1976	Jan. 1977	2-1
OJy	6	1974	1974	Feb. 1975	2-1
OAg	5	1974	1975	Feb. 1976	2-1
YMy	2	1977	1978	Feb. 1979[3]	3-0
YJy	2	1977	1978	Feb. 1979	2-0

[1] Pers. Comm. S.P. Smith, Range Conservationist, Alsea Ranger District, U.S. Forest Service.

[2] Years since planting at 1981 grazing.

[3] Replanted with 2-1 stock, Feb. 1980.

the adjacent seeding. Since study plots in YJy and YMy have similar species composition (Leininger 1983), both are considered to represent young grass-seeded plantations.

Fifty Douglas-fir trees were selected and permanently tagged within each of three .05 ha macro plots, which served as replications in each study plantation. Both natural and artificial regeneration were included as study trees in the 3 older plantations. In the younger plantations natural regeneration had not yet established when the study was intitiated. Therefore, study trees in these plantations only included planted stock. Seedlings with obvious signs of sickness were not included in the study. Evidence of previous wildlife browsing on the seedlings was not considered to be reason for non-selection.

Browsing and mechanical impacts to study trees were visually assessed the day prior to sheep entry and again the day after sheep left each plantation. Mechanical impacts included trampling, debarking, and breaking of tree branches by livestock or wildlife. Estimates of current year's growth (CYG) removed by browsing and mechanical impacts to each tree were placed into one of the following 8 percentage classes: (1) 0, (2) trace to 5%, (3) 6-10%, (4) 11-20%, (5) 21-40%, (6) 41-60%, (7) 61-80%, (8) and 81-100%. Browsing of lateral branches and mechanical impacts were only recorded to a height of 1.5m since sheep browsing is largely limited to this height (Ingram 1931). Height of study trees was recorded before sheep entered each plantation each year. Impacts by deer and elk were separated from impacts attributable to other wildlife species by visual assessment of browsed trees using techniques described by Lawrence et al. (1961).

Seven - hundred Columbia ewes and their lambs and 900 Columbia yearling ewes grazed the forest from May to September in 1981 and 1982, respectively. Both years, all sheep were managed as a single flock under the constant supervision of a herder with dogs. A series of small plantations ranging in size from 10 to 40 ha each was grazed. Sheep were moved from plantation to plantation spending from 1 to 7 days in each. Within this schedule, study plantations were grazed once each year with the exception of YMy which was grazed once in May and again in August. Data from the August regraze are identified as YMy/Ag. Stocking rate averaged 125 ewe with lamb days/ha in 1981 and 143 yearling days/ha in 1982.

Chi-square contingency tables were used to compare levels of terminal and lateral browsing within different seedling height classes. Regression analysis employing a simple linear model was used to evaluate the relationship between seedling height and amount of foliage browsed by sheep. Treatment differences in browsing and mechanical impacts to seedlings were evaluated with analysis of variance using a completely randomized split-plot design with plantations as main plots and years as subplots. Where appropriate, means were separated with Tukey's w-procedure (Steel and Torrie 1980).

Results and Discussion

Heavy tree browsing was largely confined to the spring period when new, soft growth was present. Sheep removed some lateral foliage from 75 to 100% of all study trees present in both May-grazed plantations (Table IV.2.). In contrast to the spring period, the number of study trees receiving lateral browsing from sheep was lower ($p \leq .05$) during July and August (Table IV.2.). An exception to this was in YMy in 1982 when a flush of new growth from secondary bud break coincided with a second grazing period (YMy/Ag), producing conditions similar to those encountered in spring. Heavy sheep browsing in May is believed to be responsible for the secondary flush of growth, since seedlings in an ungrazed exclosure in YMy were "hardened off" when sheep regrazed the plantation in 1982. When Douglas-fir was browsed by sheep in the other plantations in July and August, use was generally confined to 1 or 2 small lateral branchlets on the browsed trees. This pattern of use often resulted in the apparent severity of damage being greatly overstated by the percent of trees browsed. Consequently, the percent of trees with lateral's browsed does not reflect the actual impact to trees from browsing as well as the percent of current year's growth consumed.

Consumption of Douglas-fir CYG by sheep was highest ($p \leq .05$) both years of the study in YMy where it averaged 40%. In comparison, sheep only consumed an average of 1.5% of the CYG of the study trees in YJy during the 2 years of investigation. Other studies have also reported that sheep browsing on conifer regeneration is normally confined to current year's growth and generally to the early succulent growth (Hill 1917, Pearson 1950, Vavra undated). High levels of forage utilization in both May-grazed plantations (Table IV.2.) undoubtedly contributed to the amount of tree browsing

Table IV.2. Percent of Douglas-fir trees impacted as a result of sheep grazing, height of trees, and utilization of ground vegetation[1] by sheep in 5 study plantations in 1981 and 1982.

	Plantation					
Item	OMy	OJy	OAg	YMy	YJy	YMy/Ag
1981						
Terminals browsed (%)	5b[2]	0b	0b	60a	1b	1b
Laterals browsed (%)	75a	37b	18b	98a	9b	3b
Mechanically impacted (%)	2a	3a	2a	3a	1a	1a
Douglas-fir CYG consumed (%)[3]	12b	2b	<1b	36a	1b	<1b
Ground vegetation CYG consumed (%)[3]	74a	59a	42b	69a	44b	45b
Average Douglas-fir height (cm)	163c	277b	299a	69e	93d	75e
1982						
Terminals browsed (%)	0c	0c	0c	69a	1c	42b
Laterals browsed (%)	87a	12b	50b	100a	21b	87a
Mechanically impacted (%)	1a	1a	0a	1a	0a	2a
Douglas-fir CYG consumed (%)[3]	18b	<1c	2c	44a	2c	19b
Ground vegetation CYG consumed (%)[3]	60a	29c	37b	39b	44b	29c
Average Douglas-fir height (cm)	228c	375b	395a	82f	130d	109e

[1] Utilization estimates from Leininger (1983).

[2] Means within rows not followed by the same letter are different at the p=.05 level.

[3] CYG is current year's growth within the reach of sheep (1.5 m above soil surface).

observed. The severity of livestock damage to regeneration has been documented to increase as the amount of palatable forage available to stock decreases (Black and Vladimiroff 1963, Hill 1917, Cassidy et al. 1955, King et al. 1978).

Observations made of the study trees throughout the growing season indicate that deer and elk browsing was largely confined to the spring period. Although deer and elk consumed some lateral foliage on as many as 49% of the study trees in one plantation (YJy), consumption of CYG of the study trees by them did not exceed 5% (Table IV.3.).

The relative preference displayed by sheep for Douglas-fir foliage was higher in the May-grazed plantations in 1982 than 1981 (Leininger 1983). Phenological development of Douglas-fir ranged from bud swell to 7.5 cm of new growth in 1982 when sheep grazing commenced in OMy and YMy. This was about 2 weeks earlier in the phenological development of Douglas-fir than when sheep were released in the same 2 plantations in 1981. Palatability of Douglas-fir has been previously reported to be higher for both sheep (Hall et al. 1959) and deer (Oh et al. 1970, Crouch and Radwan 1981, Crouch 1968, Dimock 1970) in the period of bud burst and rapid growth of new shoots. Crouch and Radwan (1981) observed that deer browsed Douglas-fir for about a month following bud break despite abundant new growth on many plant species that deer normally prefer. Seasonal differences in the palatability of Douglas-fir to deer, and presumably to sheep, likely result from accumulation of essential oils in the needles as they mature (Longhurst et al. 1968, Maarse and

Table IV.3. Percent of Douglas-fir trees impacted and current year's growth of Douglas-fir consumed by deer and elk in 5 study plantations in 1981 and 1982.

	Plantation				
Item	OMy	OJy	OAg	YMy	YJy
1981					
Terminals browsed (%)	1± .7[1]	5±2.9	0	3±.7	23±4.7
Laterals browsed (%)	30±2.3	43±3	15±2.4	1±.7	49±4
Mechanically impacted (%)	0	1± .7	0	0	1± .7
Douglas-fir CYG consumed (%)[2]	2± .2	2± .4	T[3]	T	5±1
1982					
Terminals browsed (%)	0	2±1.1	0	0	21± .7
Laterals browsed (%)	0	39±8.5	15±4.7	0	36±3.1
Mechanically impacted (%)	1±1	0	0	0	0
Douglas-fir CYG consumed (%)[2]	0	1± .1	T	0	3± .4

[1] Mean ±standard error.
[2] CYG is current year's growth within 1.5 m of soil surface.
[3] T=<1%.

Kepner 1970, Tucker et al. 1976).

Browsing of Douglas-fir foliage by sheep in May was higher ($p \leq .05$) both years of the study in YMy compared to OMy in spite of similar ($p > .05$) (1981) or heavier ($p \leq .05$) (1982) utilization of ground vegetation in OMy (Table IV.2.). The greater attractiveness of seedlings to sheep in YMy might be explained by a higher palatability of the younger trees to sheep or a lower palatability of the associated forage in YMy compared to OMy. Rhodes (1983) reported lower percent crude protein values for Douglas-fir in YMy compared to OMy at the time of sheep grazing. Although a high positive correlation between protein content and preference for other plants has been shown (Heady 1965), Tucker et al. (1976) found that crude protein content of Douglas-fir foliage was not associated with the relative preference displayed for it by blacktail deer (*Odocoileus hemionus hemionus*). They also noted that foliage from older trees was more preferred by blacktail deer than foliage from younger trees. Browsing of conifers has been observed to be greater when sheep have grazed areas with a low variety of forage on offer compared to levels of browsing in areas offering a high diversity of forage (Cassidy et al. 1955, Knowles et al. 1973). Winward and Rudeen (1980) reported that sheep browsing of lodgepole pine (*Pinus contorta*) was lower in sites supporting a high shrub density than in sites of low shrub density. Because young grass-seeded plantations offer a lower variety of forage to sheep and contain less brush than non-seeded plantations (Leininger 1983), the risk of conifer browsing may be greater in spring in young grass-seeded plantations.

Research conducted in the Coast Range (Cleary 1978, Sharrow and Leininger 1983) and elsewhere (Sparhawk 1918, Hill 1917, Pearson 1931, Beveridge and Klomp 1973, Gillingham et al. 1976, Cassidy 1937) indicates that repeated removal of a conifer seedling's terminal leader by animal browsing will reduce the seedling's growth. However, if the terminal remains intact, seedling growth will not be greatly affected by browsing of lateral branches (Anonymous 1975, Gillingham et al. 1976, Tustin et al. 1979, Sharrow and Leininger 1983, Hughes 1976). Browsing on Douglas-fir terminal leaders was greatest ($p \leq .05$) in YMy both years of the study (Table IV.2.). The majority of trees in this plantation were small enough to be totally within the reach of sheep. In contrast, few trees had terminals within the reach of sheep in OMy. Deer and elk browsed terminal leaders heaviest in YJy where an average of 22% of the study trees had terminals removed during the 2 years of the study (Table IV.3.). As was the case with lateral browsing, terminal browsing by deer and elk was largely confined to the spring period.

Data gathered in YMy in 1982 clearly shows that the risk of terminal browsing decreases as seedling height increases (Fig. IV.1.). Although 96% of the seedlings 50 cm or less in height had terminal leaders browsed by sheep, only 15% in the 111 to 120 cm height class had their terminals browsed. Just 1 out of 77 Douglas-fir greater than 120 cm tall had its terminal removed by sheep.

These findings are in close agreement with those of Gillingham et al. (1976) who observed that in spring all trees which were less than 58 cm tall had their terminals browsed by sheep. As height

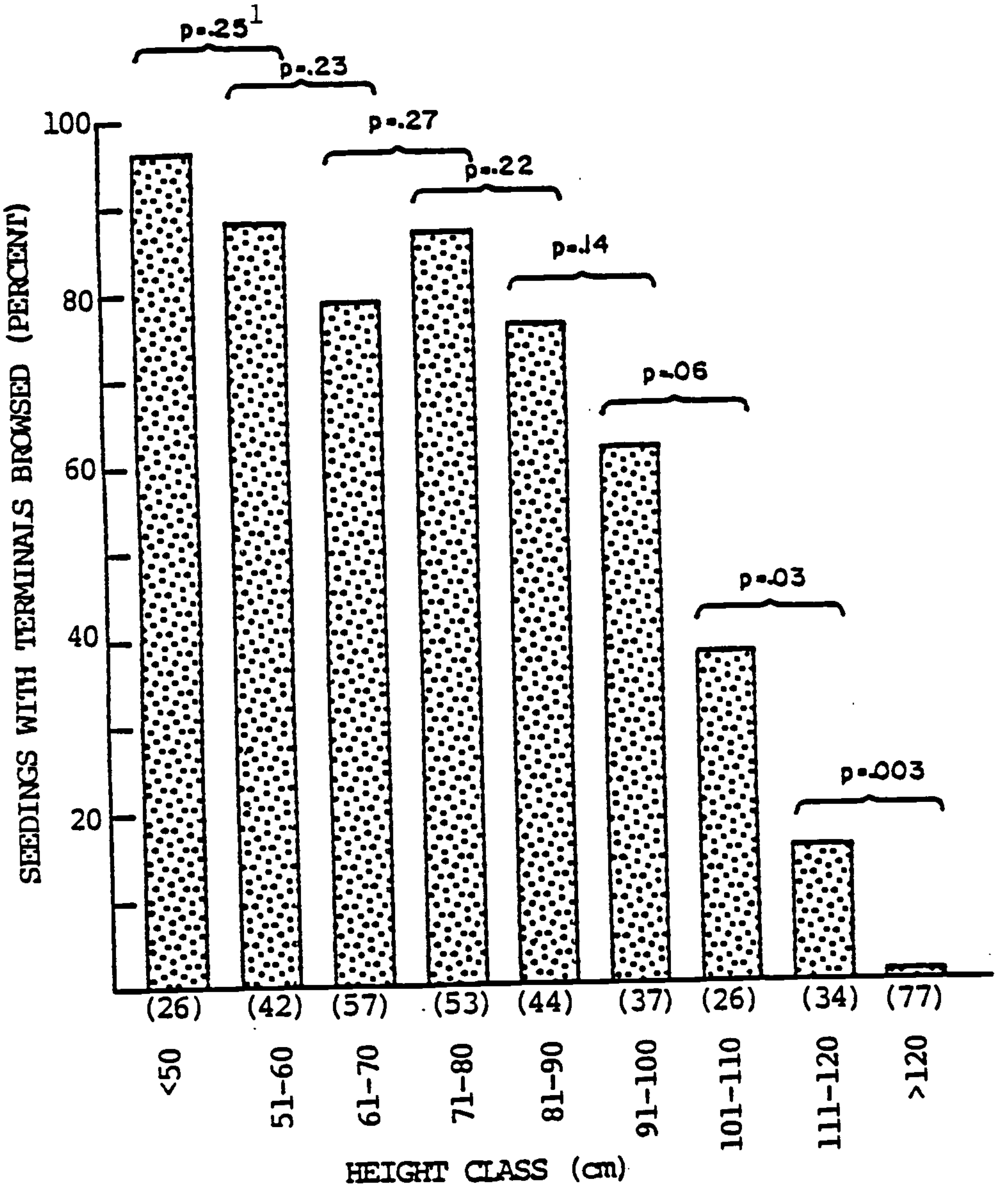

Fig. IV.1. Percent of Douglas-fir seedlings with terminals browsed as related to tree height. (Parenthesized data refer to number of seedlings in each class.)

[1] Significance of the difference between adjacent height classes.

increased above 58 cm, a sharp decline in the number of terminal leaders browsed was observed. Terminal growth of trees taller than 94 cm was only lightly browsed. Pearson (1931) reported that after conifer seedlings are approximately 1 m tall, terminals are practically out of the reach of sheep. In steep country, Beveridge and Klomp (1973) noted that trees needed to exceed 1 m in height before leader tips were above the height to which sheep browse. Both Phelps (1979) and Maki and Mann (1951) observed that sheep preferred to browse terminals on seedlings which were intermediate in height. Phelps noted that seedlings between 46 and 76 cm tall had the highest percentage of terminals browsed. Maki and Mann, however, reported that the most vulnerable height for terminal browsing by sheep was from 28 to 51 cm.

The percent of current year's growth on lateral branches removed by sheep did not differ ($p>.10$) among height classes in YMy (Fig.IV.2.). The linear relationships between seedling height and CYG removed on lateral branches had an $R^2=.04$. Similarly, when CYG removed by sheep within 1.5 m of the soil was regressed onto tree height in OMy, the R^2 for the linear model was only .001. In this data set, tree height ranged from 49 to 390 cm. Phelps (1979) also observed that the amount of lateral browsing was independent of conifer size.

Sheep showed no preference ($p>.10$) for lateral growth on planted versus naturally regenerating seedlings in OMy. Winward and Rudeen (1980) reported that sheep browsed planted and natural regeneration similarly, but deer exhibited a marked preference for planted

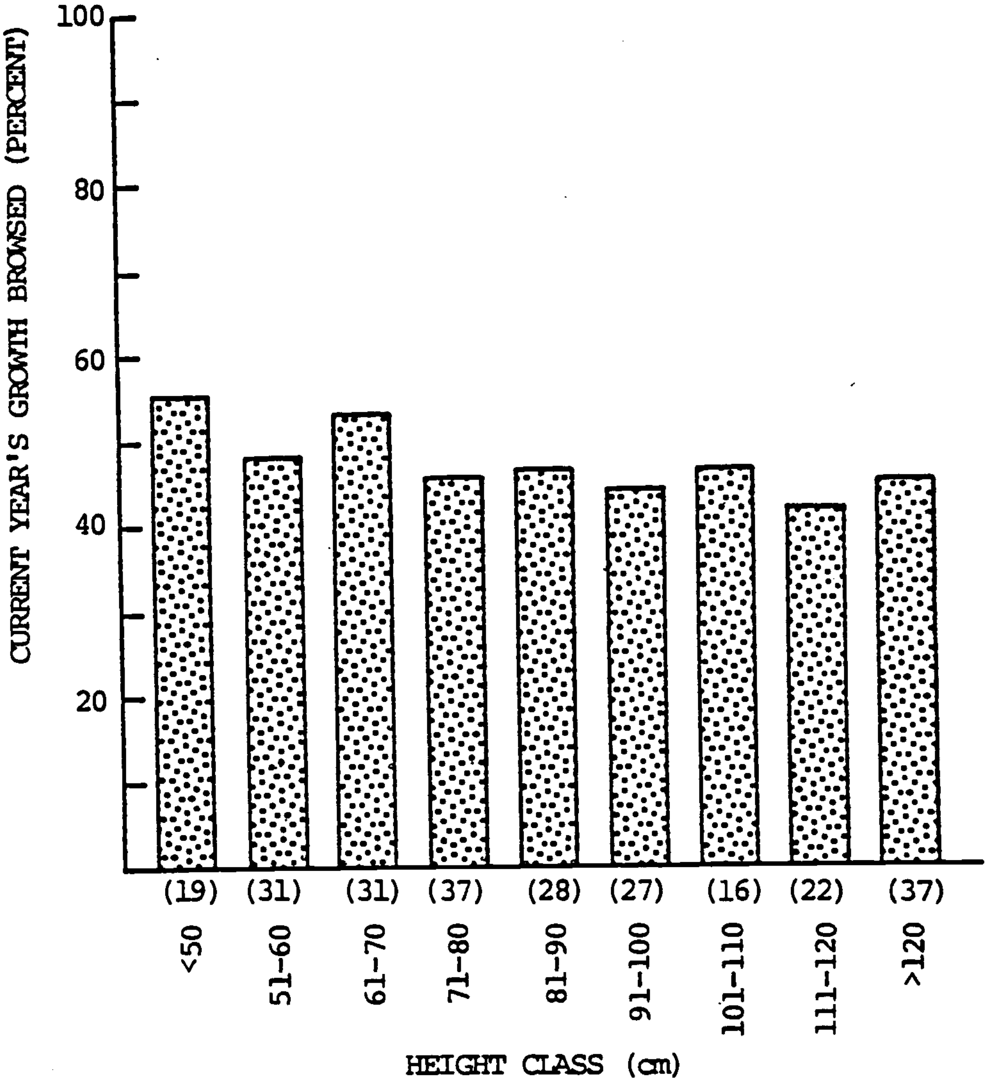

Fig. IV.2. Percent of Douglas-fir current year's lateral growth consumed by sheep as related to tree height. (Parenthesized data refer to number of seedlings in each class.)

seedlings. Crouch and Paulson (1968) noted that deer exhibited no significant difference in preference when choosing between planted and natural seedlings.

Mechanical impacts of sheep on Douglas-fir regeneration were very low during all seasons regardless of plantation age (Table IV.2.). In neither year did sheep mechanically impact more than 3% of the study trees. Generally, mechanical impacts were limited to only 1 branch on the impacted tree. Other studies have also reported that sheep primarily impact planted regeneration by browsing their foliage rather than by trampling (Phelps 1979, Hall et al. 1959, Black and Vladimiroff 1963, Winward and Rudeen 1980). Mechanical impacts to study trees from deer and elk were also very low (Table IV.3.).

Management Implications

Sheep browsing on Douglas-fir regeneration appears to be seasonal in the Coast Range. Low levels of both lateral and terminal browsing by sheep in a 2-year-old plantation grazed in mid-July compared to that grazed in May emphasizes the importance of season of grazing in determining the potential for browsing damage. This suggests that recommendations calling for complete exclusion of sheep from plantations until terminal leaders are out of reach of stock (Cleary 1978, Schubert 1974, Knowles et al. 1973, Anonymous 1978) may not be warranted in the Coast Range. Douglas-fir is sufficiently palatable to sheep in the spring after bud break that some browsing of lateral branches and terminal leaders within their reach will occur even when total forage utilization is light. In YMy in 1981, high levels of tree browsing by sheep were not observed until average utilization exceeded 35% of the CYG of ground vegetation (Sharrow and Leininger 1983). This suggests that even in spring, light sheep grazing in young plantations may be possible without adversely affecting annual growth increment of Douglas-fir seedlings when sheep are carefully managed. However, it should be stressed that the risk of sheep browsing on seedlings is highest in spring soon after bud break, and careful livestock management is crucial if damage to regeneration is to be avoided. The relationship between utilization of ground vegetation by sheep in spring and browsing on Douglas-fir needs to be further explored before grazing in young plantations at this time can be recommended.

A grazing option which has not been evaluated in this study, but should be considered, is grazing sheep in young grass-seeded plantations prior to bud break of Douglas-fir. Considerable forage is available for sheep grazing in young grass-seeded plantations by mid-April. Since Douglas-fir is approximately a month away from bud break at this time, sheep grazing may be possible without damaging regeneration. In New Zealand, Beveridge and Klomp (1973) observed that sheep could graze the early spring flush of grass before radiata pine (_Pinus radiata_) seedlings broke bud. They stressed that careful stock management which included strict control of animal numbers and proper timing of grazing was required in order to prevent browsing damage.

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CHAPTER V

THE INFLUENCE OF SHEEP GRAZING ON SURVIVAL AND GROWTH OF DOUGLAS-FIR REGENERATION IN OREGON'S COAST RANGE[1]

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THE INFLUENCE OF SHEEP GRAZING ON SURVIVAL AND GROWTH OF DOUGLAS-FIR REGENERATION IN THE COAST RANGE

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Abstract

The effect of controlled sheep grazing on survival and growth of Douglas-fir (Pseudotsuga menziesii) regeneration in Oregon's Coast Range was investigated. Annual height increment was unaffected by sheep grazing in 4 out of 5 study plantations. In a 2-year-old plantation grazed in May, height increment was reduced by sheep grazing. The seedlings in this plantation were heavily browsed by sheep. Annual mean diameter increment was higher in the grazed portions of three 4-6-year-old study plantations. Mean diameter growth was reduced by grazing in a 2-year-old May-grazed plantation. No significant growth response to grazing was observed in a 2-year old plantation grazed in July. Survival of regeneration over the 2 years of investigation was high in all study plantations and was unaffected by grazing. Differences in light and soil moisture due to grazing did not appear to explain the greater diameter growth in the older plantations. Increased available nitrogen deposited as urine in grazed plantations may have contributed to the increased growth.

Introduction

The Douglas-fir forests of western Oregon and western Washington are among the most productive forests in the world (Franklin and Dyrness 1973). Following clearcutting and burning, herbaceous and woody plant species rapidly occupy new plantations (Stewart 1978, Isaac 1940, Dyrness 1973). Invading vegetation can markedly reduce the survival and growth of young conifer seedlings directly through competition (Newton 1964, Zavitkovski and Woodard 1970, Roy 1953) and indirectly by providing habitat for animals that injure young regeneration (Tonn and Graham 1982, Crouch 1982, Preest 1975). In addition, dense stands of brush make access to plantations for forest tending difficult (Beveridge and Klomp 1973, McKinnell and Batini 1978, Hitchcock 1937).

In the past, foresters in the Pacific Northwest have generally employed herbicides to control unwanted vegetation in cut-over forests (Newton and Roberts 1979, Cleary et al. 1978). Due to increasing costs and public concern over possible health risks associated with herbicides, silviculturists are becoming increasingly interested in the potential usefulness of biological agents such as sheep to control brush (Hedrick 1975, Leininger and Sharrow 1983). In addition to potential weed suppression, sheep grazing offers the potential for increased red meat production (Leininger 1983, Rhodes et al. 1983, Throckmorton 1978) and improvement of big game habitat (Rhodes and Sharrow 1983, Jensen et al. 1972, Smith et al. 1979). A three-year study was initiated in the summer of 1980 to evaluate the potential of using herded sheep as a silvicultural tool to suppress brush species in Douglas-fir plantations. This report investigates the influence of sheep grazing on survival and growth of Douglas-fir regeneration. Brush control (Rhodes 1983, Sharrow and Leininger 1983) and browsing impacts (Leininger 1983, Sharrow and Leininger 1983) are discussed elsewhere.

Study Area

The 5 Douglas-fir plantations studied are located in the Coast Range, approximately 15 km west of Alsea, Oregon. Elevations of the study plantations range from 170 to 440 m. Size of the plantations varied from approximately 14 to 30 ha. Soils are slickrock gravelly loams (Pachic Haplumbrept, Corliss 1973). Climate of the area is maritime with cool moist winters and mild dry summers. Mean annual precipitation is about 250 cm, mainly occurring in the form of rain from October to May, with a moisture deficit from June through September (Corliss 1973). Evening and morning fog is common, even in summer. Site index (100 years McArdle et al. 1961) of the study plantations averaged 52 m (Pers. Comm. G. E. Klingler, District Silviculturist, Alsea Ranger District, U.S. Forest Service).

Study plots were restricted to the vine maple-sword fern (Acer circinatum-Polystichum munitum) vegetation type because it is the most extensive understory plant community in the study area (Corliss and Dyrness 1965). In addition to vine maple, other important woody species are salmonberry (Rubus spectabilis), California dewberry (Rubus ursinus), red alder (Alnus rubra), and thimbleberry (Rubus parviflorus). Dominant herbaceous vegetation includes orhardgrass

(Dactylis glomerata), common velvetgrass (Holcus lanatus), bentgrass (Agrostis spp.), tansy ragwort (Senecio jacobaea), big deer vetch (Lotus crassifolius), and common pearleverlasting (Anaphalis margaritacea).

Based on age since planting and month of sheep grazing, the 5 study plantations were distinguished as follows: (1) a 4-year-old plantation grazed in May (OMy), (2) a 6-year-old plantation grazed in July (OJy), (3) a 5-year-old plantation grazed in August (OAg), (4) a 2-year-old plantation grazed in May (YMy), and (5) a 2-year-old plantation grazed in July (YJy) (Table V.1.). YMy was seeded with a mixture of grasses at tree planting. Although study plots in YJy were not seeded, species composition of the plots was strongly influenced by an adjacent seeding. Since study plots in YJy and YMy have similar species composition (Leininger 1983), both are considered to represent young grass seeded plantations.

Methods

A 30 m by 30 m livestock exclosure was established in each study plantation prior to grazing. Exclosures were constructed of 1 m high woven wire in order to allow wildlife continued access to the exclosed areas (Yoakum et al. 1980). Fecal groups, tracks, and beds indicated deer and elk frequently inhabited the exclosures. The effect of sheep grazing on tree growth was evaluated by comparing measurements of tree height and diameter for 100 permanently "tagged" trees within the exclosure to those of 100 adjacent trees in the grazed region of each study plantation. Measurements were taken in

Table V.1. Plantation age, tree height, year of harvest, year of burn, date of planting, and type of Douglas-fir stock for 5 study plantations.[1]

Plantation	Age[2]	Tree Height[3] (cm)	Year of Harvest	Year of Burn	Date of Planting	Type of Stock
OMy	4	163	1976	1976	Jan. 1977	2-1
OJy	6	277	1974	1974	Feb. 1975	2-1
OAg	5	299	1974	1975	Feb. 1976	2-1
YMy	2	69	1977	1978	Feb. 1979[4]	3-0
YJy	2	93	1977	1978	Feb. 1979	2-0

[1] Pers. Comm. S. P. Smith, Range Conservationist, Alsea Ranger District, U.S. Forest Service.

[2] Years since planting at 1981 grazing.

[3] Average height at 1981 grazing.

[4] Replanted with 2-1 stock, Feb. 1980.

each plantation prior to sheep grazing each year. Tree height was measured on the uphill side of the tree. Measurements were taken from the soil surface to the tip of the leader with a graduated pole. Diameter measurements were taken with a caliper placed between the 2 lowermost whorls of branches. Tree mortality was recorded immediately prior to grazing for the above trees and for an additional 50 trees within each of three .05 ha macro plots in the grazed area of each plantation.

Gravimetric soil moisture (Gardner 1965) inside the exclosure was compared to levels in grazed areas on sites OMy and YMy in early August 1981 and 1982. Douglas-fir was in the bud set growth stage when the soil moisture samples were taken. Thirty and 20 randomly located soil samples (2.5 cm diameter cores) were taken from the grazed and ungrazed areas, respectively. Samples were taken in 15 cm increments from the soil surface to a depth of 90 cm. Gravimetric soil moisture was calculated from wet weight of samples and weight of samples dried in a forced-air oven at 50°C for 7 days. One compounded sample for each soil depth was analyzed for 15 bar moisture using a membrane apparatus as described by Peters (1965). These samples were compounded by combining all the soil cores for a particular depth.

Current year's foliage was collected from 50 Douglas-fir trees within both the grazed and ungrazed portions of all study plantations in November 1982. Foliage collection and preparation followed techniques outlined by Lavender (1970). Samples were collected from lateral branchlets at a height of 1 m from the soil surface. The micro-kjeldahl technique (AOAC 1970) was used to determine total nitrogen from 5 composite samples from grazed and ungrazed portions of each plantation. Composite samples were obtained by combining needles from each of 10 trees.

The amount of nitrogen consumed by sheep was estimated from diet data reported by Leininger (1983) and chemical analyses of forage reported by Rhodes (1983). This was done for each major plant species by multiplying the amount of forage consumed by its nitrogen content. The total amount of nitrogen consumed by sheep was estimated by summing the species totals for each plantation. The amount of nitrogen consumed by sheep which is returned in urine depends on the animal's diet (Barrow 1967) and ranges from 60% to 80% (Wilson 1978, Whitehead 1970, Walker 1962). For our estimates, we assumed 70% of the nitrogen consumed was returned as urine nitrogen.

Sheep grazed from 3 to 7 days in each of the study plantations in 1981 (700 ewes with lambs) and 1982 (900 dry ewes). Plantations were grazed only once each year with the exception of YMy which was grazed once in May and again in August both years. In 1980, 650 ewes with lambs grazed for 11 days in OAg. This was the only study plantation grazed that year.

Treatment differences in annual tree height and diameter increment were corrected for initial height and diameter with analysis of covariance prior to analysis. Soil moisture data were analyzed as a split-, split-plot with grazing treatment as main plots and soil depth and year as subplots. Treatment differences in foliar nitrogen were analyzed as a split-plot with plantations as mainplots and grazing treatment as subplots. All parameters were analyzed using a completely randomized design. Where appropriate, means were separated with Tukey's w-procedure (Steel and Torrie 1980).

Results and Discussion

Height growth was unaffected ($p \geq .05$) by sheep grazing in all plantations with the exception of YMy (Table V.2.). In YMy, 2-year height growth of Douglas-fir seedlings in the grazed area averaged only 57% of the height growth of seedlings growing in the ungrazed exclosure. Repeated, heavy browsing by sheep may have been responsible for the decreased height growth in this plantation. Sheep removed terminal leaders from an average of 64% of the seedlings during the 2-years of May-grazing (Leininger 1983). When the plantation was regrazed in August 1982, sheep again browsed heavily on terminal leaders of seedlings. Heavy browsing of lateral current year's growth also occurred in May 1981 and May 1982 in this plantation.

Studies conducted in the United States (Cleary 1978, Hill 1917, Sparhawk 1918, Pearson 1931, Cassidy 1937) and abroad (Beveridge and Klomp 1973, Gillingham et al. 1976, Tustin et al 1979) have also reported that heavy sheep browsing of terminal leaders reduced annual height increment during the growing season in which the browsing event occurred. The long-term effects of such growth losses are unclear. Cleary (1978) and Mitchell (1964) noted that although browsing temporarily reduced the height of Douglas-fir seedlings, it had a negligible effect upon the subsequent rate of growth if no

Table V.2. Height growth and diameter growth of Douglas-fir trees from grazed (G) and ungrazed (U) portions of 5 study plantations, 1980-1983.

Plantation	Growing Period	Height (cm) G	Height (cm) U	Diameter (cm) G	Diameter (cm) U
OMy	1981-82	69.0	71.4	14.0*	13.0
	1982-83	100.3	100.6	15.4**	13.1
OJy	1981-82	104.7	104.8	17.3*	15.3
OAg	1980-81	89.4	85.7	15.7**	14.3
	1981-82	92.4	89.9	17.8**	15.5
YMy	1981-82	11.0**	22.6	4.2**	5.6
	1982-83	41.0**	68.6	6.4**	10.8
YJy	1981-82	38.2	41.5	7.4	6.9

*,**Grazed differs form ungrazed $p \leq .05$, $p \leq .01$, respectively.

additional browsing of terminal leaders occurred. Crouch and Radwan's (1981) data suggested to them that heavily browsed Douglas-fir trees developed nearly normal root systems and were capable of accelerated growth when released from browsing pressure.

Mean diameter growth of Douglas-fir regeneration in the 3 older plantations was stimulated ($p \leq .05$) by sheep grazing during the course of this study (Table V.2.). OMy was the only one of the 3 older study plantations which received considerable use of current year's growth of lateral branches by sheep. Although sheep consumed 12 and 18% of the current year's Douglas-fir growth in OMy in 1981 and 1982 (Leininger 1983), mean diameter growth was 8 and 17% greater, respectively, for trees the following year in the grazed portion of the plantation compared to trees in the ungrazed exclosure. This supports the view (Hines and Land 1974, Anonymous 1975, Gillingham et al. 1976, Hughes 1976, Lewis 1980) that while browsing of terminal leaders may reduce height growth, light to moderate browsing of lateral growth alone is unlikely to adversely affect tree growth.

The explanation for the observed positive response of diameter growth to grazing in older plantations compared to the lack of response in height growth may relate to differences in the timing of cambial and leader growth. Emmingham (1977) reported that Douglas-fir leader elongation in the Coast Range ended by late-July. In contrast, cessation of cambial growth was not observed until October. Site resources (e.g. light, soil moisture, nitrogen) which may become available to trees as a result of sheep grazing, therefore, would likely be available at a time when only cambial growth is occuring.

In contrast to the older plantations which showed a clear pattern of diameter increase due to sheep grazing, diameter response in younger plantations was less clear. As was the case with height growth, mean diameter growth was lower ($p \leq .01$) for seedlings in the grazed portion of YMy compared to those in the exclosure (Table V.2.). Mean diameter increase for 1981-1982 was numerically higher in grazed versus ungrazed portions of YJy. However, this difference was not large enough to be statistically significant.

Survival of study trees was unaffected ($p \geq .05$) by grazing treatment in all plantations. No seedling mortality occurred in either grazed or ungrazed portions of OMY, OJY, OAg, and YJy. Only 2 out of 250 "tagged" seedlings in the grazed portion of YMy died between 1981 and 1983, despite repeated heavy sheep browsing. Studies which have investigated the effects of both wildlife (Crouch and Paulson 1968, Staebler et al. 1954, Dimock 1970) and sheep (Black and Vladimiroff 1963, Hedrick and Keniston 1966) browsing on survival of Douglas-fir in the Pacific Northwest have also reported that survival was unaffected by browsing.

The positive effects of sheep on annual diameter growth increment of Douglas-fir may relate to differences in the amount of light, soil moisture, or nutrients in grazed versus ungrazed portions of the plantations. Generally, sheep grazing reduced current year's growth of both total phytomass and brush phytomass in the grazed compared to ungrazed portion of the study plantations (Fig. V.1.). Although no quantitative measurements were made, grazed areas appeared to be more open with more solar radiation reaching the crop

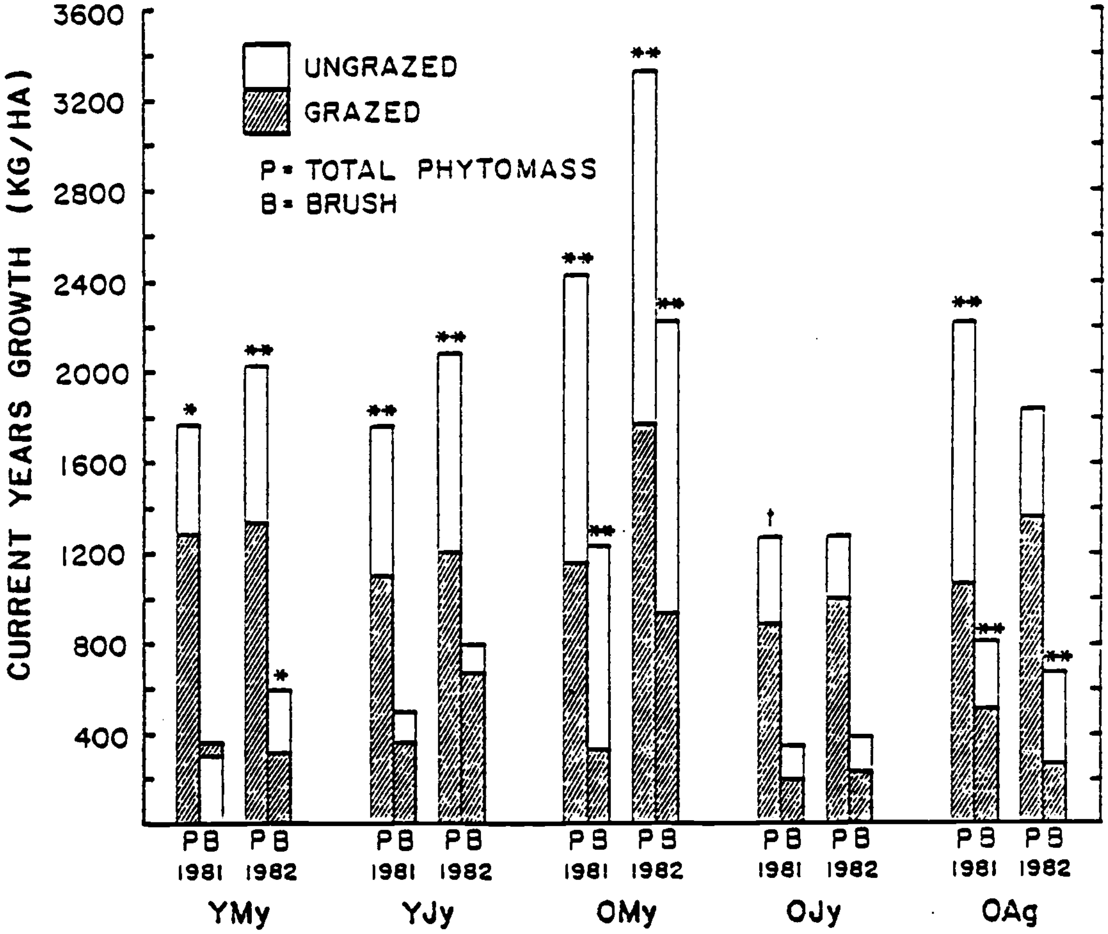

Fig. V.1. Current year's growth of total phytomass and total brush in October in grazed and ungrazed portions of 5 plantations, 1981 and 1982.[1]

$\dagger, *, **$ Grazed differs from ungrazed $p \leq .10$, $p \leq .05$, $p \leq .01$, respectively.

[1] Taken from Rhodes (1983).

trees than was the case for the ungrazed areas. In Idaho, Young et al. (1942) reported that sheep grazing on brush species reduced competition for light with conifer regeneration.

Hall et al. (1959) working in a drier site than ours observed that grazing was beneficial to young Douglas-fir trees primarily because it reduced competition for moisture between planted trees and the ground vegetation. Wood (1971) also noted that grazing reduced soil moisture withdrawl by reducing transpirational losses form ground vegetation. In contrast, Black and Vladimiroff (1963) reported that sheep grazing had no effect on soil moisture. In our study, differences in soil moisture between grazed and ungrazed areas were dependant ($p \leq .01$) on soil depth. In the 2 plantations studied, a little over 3% more soil moisture was available in the upper 15 cm of soil in the ungrazed compared to grazed portions of OMy and YMy in 1981 (Table V.3.). The only other difference observed in 1981 was a 5% higher soil moisture content for the 75 to 90 cm depth for the grazed compared to ungrazed portion of YMy. No treatment differences in soil moisture were evident ($p \geq .10$) in 1982. Moisture levels in both grazed and ungrazed portions of both plantations in 1981 and 1982 were considerably above the 15 bar moisture level regardless of soil depth (Table V. 3). Douglas-fir seedlings grown in growth chambers were observed by Zavitkovski and Ferrell (1970) to maintain maximum photosynthesis over a wide range of soil moisture. In contrast, Emmingham and Waring (1977) reported that mid-day photosynthetic rates of Douglas-fir trees found *in situ* were reduced by moisture stress as low as 3 bars.

Table V.3. Soil moisture (%) for 6 depths in grazed and ungrazed areas in 2 plantations, August 1981 and 1982.

		Depth (cm)					
Plantation	Treatment	0-15	15-30	30-45	45-60	60-75	75-90
OMy	15 bar	25	21	22	20	20	19
1981	Grazed	28.3	32.7	33.2	33.4	34.5	33.6
	Ungrazed	31.4*	32.8	31.7	32.3	32.3	34.2
1982	Grazed	34.9	34.7	33.6	32.2	31.9	31.9
	Ungrazed	33.8	32.7	32.3	32.5	31.9	32.2
YMy	15 bar	23	20	21	15	16	16
1981	Grazed	30.6	33.7	33.2	34.4	35.4	37.2*
	Ungrazed	34.1^{+}	36.2	35.4	35.9	32.7	32.2
1982	Grazed	33.3	33.9	35.0	35.5	34.7	33.7
	Ungrazed	34.3	34.2	32.6	33.2	31.9	30.8

$^{+,*}$Grazed differs from ungrazed $p \leq .10$, $p \leq .05$, respectively.

Eissenstat (1980) speculated that competition between Douglas-fir seedlings and ground vegetation for nutrients was more important in determining tree growth than competition for water. Nitrogen is often considered to be the principal limiting nutrient element of growth of Douglas-fir in the Pacific Northwest (Waring and Youngberg 1972, Gessel et al. 1965, Miller and Williamson 1974). We estimate that sheep returned between 13 and 29.5 kg/ha of urine nitrogen to the study plantations over the duration of this investigation (Table V.4.). Because urine nitrogen is soluble in water, it is readily available to plants. The efficacy of returned nitrogen was likely enhanced by the distributional pattern of sheep which encouraged deposition of excreta near trees. Higher ($p \leq .10$) foliar nitrogen levels from trees in the grazed compared to ungrazed portions of OMy, OJy, OAg, and YMy (Table V.5.) suggest that trees may have benefited from the nitrogen made available by sheep grazing. Several authors (Beaton et al. 1964, Heilman 1971, Heilman et al. 1982) have noted increased levels of foliar nitrogen in Douglas-fir following application of nitrogen fertilizer. The relatively high foliar nitrogen values present in both grazed and ungrazed portions of YMy and YJy compared to the low levels (Krueger 1967) in the 3 older plantations may partially explain the apparent lack of increased diameter growth due to sheep grazing in the 2 younger plantations.

Summary and Conclusions

While no effect on annual height growth increment due to sheep grazing was observed in the 3 older plantations, an increase in mean

Table V.4. Estimated nitrogen (kg/ha) cycled through sheep in 5 Douglas-fir plantations, 1980-1982.

	Plantation				
Year	OMy	OJy	OAg	YMy	YJy
1980			17.4		
1981	13.3	8.4	7	20.6	7
1982	7	5.7	5.1	14.5	6
Total	20.3	14.1	29.5	35.1	13

Table V.5. Douglas-fir foliar nitrogen (%) from grazed and ungrazed portions of 5 plantations, November 1982.

	Percent Nitrogen	
Plantation	Grazed	Ungrazed
OMy	1.75^{**}	1.65
OJy	1.58^{+}	1.52
OAg	1.63^{+}	1.57
YMy	1.94^{*}	1.86
YJy	1.92	1.90

$^{+,*,**}$Grazed differs from ungrazed $p \leq .10$, $p \leq .05$, $p \leq .01$, respectively.

annual diameter growth was noted. The response to grazing in the 2 younger plantations was less clear. Both annual height and diameter increment were reduced in a young May-grazed plantation. Heavy tree browsing by sheep may have been responsible for the decreased growth. Sheep grazing had no significant effect on growth in the young plantation grazed in July. Seedling survival was high in both grazed and ungrazed areas of all study plantations and was not affected by grazing.

The reason for the positive diameter growth response in Douglas-fir regeneration to sheep grazing in the older plantations is poorly understood. It is unlikely that reducing the competition for light was a major factor because trees were already above the canopy of the brush. It is also doubtful that differences in soil moisture between grazed and ungrazed areas were responsible for the observed growth differences. Soil moisture levels were generally similar in both grazed and ungrazed portions and were considerably above 15 bar moisture levels. Nitrogen was cycled through the sheep and picked up by the trees as evidenced by higher foliar nitrogen levels of Douglas-fir in the grazed portions of 4 out of 5 study plantations. Our data suggest that impacts of sheep on nitrogen cycling may have contributed to increased diameter growth of trees in grazed areas. The role of herbivores such as sheep in the cycling of nutrients within forested ecosystems deserves further consideration.

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APPENDICIES

APPENDIX A. Plant species growing in 5 Douglas-fir plantations.

Table A-1. Plant species growing in 5 Douglas-fir plantations.

Plant Species^1		Plantation				
Scientific Name	Common Name	OMy	OJy	OAg	YMy	YJy
Graminoids						
Agropyron spp.	wheatgrass				X	
Agrostis exarata	spike bentgrass	X	X	X	X	X
A. tenuis	colonial bentgrass	X	X	X	X	X
Aira caryophyllea	silver hairgrass	X	X	X	X	X
A. praecox	early hairgrass	X	X	X	X	X
Anthoxanthum odoratum	sweet vernalgrass				X	
Arrhenatherum eliatus	tall oatgrass					X
Bromus sp.	brome	X	X	X		
Carex sp.	sedge		X		X	
C. hendersonii	Henderson's sedge	X	X	X	X	X
Dactylis glomerata	orchardgrass	X	X	X	X	X
Elymus glaucus	blue wildrye	X	X	X	X	X
Festuca arundinacea	reed fescue	X	X	X	X	X
F. rubra	red fescue	X	X	X	X	X
Holcus lanatus	common velvetgrass	X	X	X	X	X
Lolium perenne	perennial ryegrass					X
Luzula parviflora	millet woodrush	X	X	X	X	X
Phleum pratense	Timothy	X			X	X
Poa pratensis	Kentucky bluegrass	X				
Trisetum cernuum	nodding trisetum	X	X	X		X
Vulpia sp.	annual fescue			X	X	X
Forbs						
Anaphalis margaritacea	common pearleverlasting	X	X	X	X	X
Cardamine sp.	toothwort	X		X	X	
Cerastium arvense	starry cerastium	X	X	X	X	
Chrysanthemum leucanthemum	oxeyedaisy			X		
Cirsium vulgare	bull thistle	X	X	X	X	X
Conyza canadensis	horseweed		X	X	X	X
Crepis capillaris	smooth hawksbeard		X	X	X	X
Dicentra formosa	Pacific bleeding heart	X	X	X	X	X
Digitalis purpurea	foxglove	X	X	X	X	X
Epilobium angustifolium	fireweed	X	X	X	X	X
Gallium sp.	bedstraw	X	X	X	X	X
Hypochaeris radicata	spotted catsear	X	X	X		X
Iris sp.	iris					X
I. tenax	Oregon iris			X	X	
Lotus crassifolius	big lotus	X	X	X	X	X
Lupinus sp.	lupine	X	X			X
Maianthemum dilatum	beardruby	X	X	X		X
Mimulus sp.	monkeyflower	X				
Montia siberica	Siberia montia	X	X	X	X	
Oxalis oregana	Oregon oxalis	X				X
Phacelia sp.	phacelia					X
Ranunuculus sp.	buttercup				X	

Table A-1. (Continued)

Plant species Scientific name	Common name	Plantation OMy	OJy	OAg	YMy	YJy
Rumex acetosella	sheep sorrel		X	X		X
Scrophularia californica	California figwort	X	X	X	X	X
Senecio jacobaea	tansy ragwort	X	X	X	X	X
S. sylvaticus	woodland groundsel				X	
S. vulgaris	common groundsel	X	X	X	X	X
Smilacina sp.	Solomonplume	X				X
Stachys mexicana	hedge-nettle			X	X	X
Taraxacum officinale	common dandelion		X			
Trientalis latifolia	western starflower	X	X			X
Trifolium repens	white clover				X	X
T. subterraneum	subterraneum clover					X
Trillium sp.	trillium				X	
Viola sp.	violet	X	X		X	X
Ferns						
Polystichum munitum	swordfern	X	X	X	X	X
Pteridium aquilinum	bracken fern	X	X	X	X	X
Browse						
Acer circinatum	vine maple	X	X	X	X	X
Baccharis pilularis	kidneywort baccharis		X		X	
Berberis sp.	Oregon-grape	X		X		X
Corylus cornuta californica	California hazel			X	X	X
Ceanothus integerrimus	deerbrush		X			
Gaultheria shallon	sallal	X	X	X	X	X
Holodiscus discolor	creambush rockspirea	X	X	X	X	X
Rosa sp.	rose					X
Rubus laciniatus	cutleaf blackberry				X	
R. leucodermis	whitebark blackberry	X	X	X	X	
R. parviflorus	thimbleberry	X	X	X	X	X
R. spectabilis	salmonberry		X	X	X	X
R. ursinus	California dewberry	X	X	X	X	X
Salix sp.	willow	X				
Sambucus spp.	elder	X	X	X	X	X
S. callicarpa	Pacific red elder				X	
Vaccinium ovatum	box blueberry	X	X	X		
V. parvifolium	red whortleberry	X	X	X		X
Trees						
Acer macrophyllum	bigleaf maple	X		X	X	
Alnus rubra	red alder	X	X	X	X	X
Prunus emarginata	bitter cherry	X	X	X	X	X
Pseudotsuga menziesii	Douglas-fir	X	X	X	X	X
Tsuga heterophylla	western hemlock	X	X	X	X	X

[1] Plant names follow Garrison et al. (1976).

APPENDIX B. Grazing schedule for 5 study plantations, 1980-1982.

Table B-1. Grazing schedule for 5 study plantations, 1980-1982.

Plantation	1980	1981	1982
OMy - Missouri/Tie (53C3)		5/22 - 5/26	5/15 - 5/17
OJy - Bear Creek (67B3)		7/11 - 7/14	7/14 - 7/18
OAg - Denzer (33D4)	7/20 - 7/31	8/18 - 8/25	8/22 - 8/24
YMy - Benner/Digger (33C2)		5/28 - 6/02	5/20 - 5/26
		8/01 - 8/03	8/07 - 8/10
YJy - Fleece/Bear (76D3)		7/20 - 7/26	7/19 - 7/24

APPENDIX C. Above ground phytomass on offer, amount and percent of phytomass utilized by sheep, percent of forage component in sheep diet, and the relative preference index of plants in 5 study plantations, 1980-1982.

Table C-1. Above ground phytomass on offer, amount and percent of phytomass utilized by sheep, percent of forage component in sheep diet, and the relative preference index (RPI) of plants in plantation OMy, 1981. Data are mean ± standard error.

	Phytomass (kg/ha)		Percent		
Plant species	On offer	Utilized	Utilization[1]	In diet	RPI[1]
Agrostis spp.[2]	237±87	199±72	85±1	22±7	1.26±.09
Carex hendersonii	81±51	63±41	68±13	7±5	1.00±.19
Dactylis glomerata	28±5	19±4	73±13	2±<1	1.07±.19
Festuca rubra	34±30	25±25	86±13	3±3	1.20±.10
Holcus lanatus	11±8	7±5	51±27	1±1	.72±.37
Luzula parviflora	15±3	11±2	75±4	1±<1	1.10±.07
Misc. Graminoids[3]	3±3	1±1	60±41	<1±<1	.81±.52
Total Graminoids	408±42	325±41	79±3	37±3	1.17±.06
Anaphalis margaritacea	254±51	202±41	80±4	24±6	1.18±.06
Lotus crassifolius	122±42	116±41	94±2	13±4	1.39±.07
Senecio jacobaea	31±10	14±6	43±4	2±1	.64±.08
Misc. Forbs[3]	52±9	40±7	77±1	5±1	1.14±.08
Total Forbs	458±76	372±67	81±4	43±8	1.19±.06
Polystichum munitum	20±10	0	0	0	0
Acer circinatum	112±31	75±35	56±22	9±4	.80±.30
Rubus parviflorus	86±29	33±3	51±22	4±<1	.72±.26
R. spectabilis	14±10	7±5	37±19	1±1	.57±.29
R. ursinus	19±9	17±8	90±1	2±1	1.27±.12
Misc. Browse[3]	31±25	24±19	76±14	3±2	.93±.48
Total Browse	262±25	156±52	60±17	18±6	.85±.22
Total Forage	1148±32	853±42	74±5	98±1	1.09±.01
Pseudotsuga menziesii	129±9	16±10	12±7	2±1	.17±.08
Total Phytomass	1277±26	869±52	68±4	100	1.00

[1] Values derived from only those replications containing the species.

[2] Includes *Agrostis exarata* and *A. tenuis*.

[3] Species included in miscellaneous category listed in Appendix C.

Table C-2. Above ground phytomass on offer, amount and percent of phytomass utilized by sheep, percent of forage component in sheep diet, and the relative preference index (RPI) of plants in plantation OMy, 1982. Data are mean ± standard error.

	Phytomass (kg/ha)		Percent		
Plant species	On offer	Utilized	Utilization[1]	In diet	RPI[1]
Agrostis spp.[2]	162±69	122±55	73±5	23±7	1.33±.08
Carex hendersonii	11±5	3±3	24±24	<1±<1	.39±.39
Dactylis glomerata	70±37	60±32	85±4	12±4	1.56±.14
Festuca rubra	47±43	43±38	63±32	10±9	1.24±.63
Holcus lanatus	28±14	20±10	69±3	5±3	1.26±.13
Luzula parviflora	27±3	22±4	82±8	5±1	1.48±.04
Phleum pratense	11±<1	10±<1	86±2	2±<1	1.56±.06
Misc. Graminoids[3]	3±2	3±2	92±5	1±<1	1.67±.08
Total Graminoids	359±90	280±79	77±4	58±7	1.41±.07
Anaphalis margaritacea	145±11	110±5	76±3	25±6	1.39±.04
Lotus crassifolius	25±7	21±7	82±7	5±1	1.49±.10
Senecio jacobaea	12±3	6±3	43±23	1±1	.76±.38
Misc. Forbs[3]	36±3	24±3	67±7	6±2	1.12±.12
Total Forbs	218±18	161±16	74±5	36±8	1.35±.05
Polystichum munitum	10±3	7±2	68±10	1±<1	1.23±.15
Acer circinatum	106±19	4±1	3±1	1±<1	.06±.01
Rubus parviflorus	49±4	6±3	12±6	1±1	.22±.10
R. spectabilis	8±4	0	0	0	0
R. ursinus	14±10	2±2	6±6	<1±<1	.09±.09
Misc. Browse[3]	1±<1	<1±<1	34±17	<1±<1	.59±.30
Total Browse	177±25	10±6	5±3	2±1	.09±.04
Total Forage	764±104	462±87	60±3	97±1	1.09±.02
Pseudotsuga menziesii	87±3	13±3	15±4	3±1	.27±.06
Total Phytomass	850±102	475±89	55±4	100	1.00

[1] Values derived from only those replications containing the species.

[2] Includes *Agrostis exarata* and *A. tenuis*.

[3] Species included in miscellaneous category listed in Appendix C.

Table C-3. Above ground phytomass on offer, amount and percent of phytomass utilized by sheep, percent of forage component in sheep diet, and the relative preference index (RPI) of plants in plantation OJy, 1981. Data are mean ± standard error.

Plant species	Phytomass (kg/ha)		Percent		
	On offer	Utilized	Utilization[1]	In diet	RPI[1]
Agrostis spp.[2]	65±4	48±4	74±3	5±1	1.78±.28
Aira spp.[3]	80±45	35±18	46±13	4±2	1.01±.15
Carex hendersonii	61±34	46±26	63±14	6±4	1.50±.39
Holcus lanatus	98±19	31±22	35±22	3±2	.80±.54
Luzula parviflorus	16±6	10±6	54±27	1±1	1.27±.66
Misc. Graminoids[4]	41±21	34±18	57±28	3±2	1.20±.61
Total Graminoids	361±41	204±24	57±6	22±2	1.34±.08
Anaphalis margaritacea	35±11	29±11	80±3	4±2	1.92±.33
Digitalis purpurea	276±104	111±60	40±22	11±6	.81±.42
Lotus crassifolius	82±40	74±33	95±4	8±3	2.27±.32
Senecio jacobaea	328±133	248±108	73±7	27±10	1.75±.32
Misc. Forbs[4]	65±24	57±22	87±5	7±7	2.06±.27
Total Forbs	787±79	519±82	66±7	56±5	1.54±.12
Polystichum munitum	115±67	2±2	13±13	<1±<1	.36±.36
Acer circinatum	55±22	45±21	78±6	5±2	1.83±.11
Rubus parviflorus	77±53	54±41	68±11	5±4	1.56±.14
R. spectabilis	26±14	12±9	35±18	2±1	.84±.47
R. ursinus	59±33	38±22	60±3	4±2	1.55±.05
Vaccinium parvifolium	73±45	37±18	70±16	4±2	1.72±.57
Misc. Browse[4]	5±2	4±2	64±32	1±1	1.51±.80
Total Browse	295±100	190±55	72±8	20±4	1.54±.08
Total Forage	1558±246	915±117	59±6	99±1	1.40±.11
Pseudotsuga menziesii	598±89	12±8	2±2	1±1	.04±.03
Total Phytomass	2156±206	927±118	43±6	100	1.00

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[1] Values derived from only those replications containing the species.
[2] Includes *Agrostis exarata* and *A. tenuis*.
[3] Includes *Aira caryophyllea* and *A. praecox*.
[4] Species included in miscellaneous category listed in Appendix C.

Table C-4. Above ground phytomass on offer, amount and percent of phytomass utilized by sheep, percent of forage component in sheep diet, and the relative preference index (RPI) of plants in plantation OJy, 1982. Data are mean ± standard error.

	Phytomass (kg/ha)		Percent		
Plant species	On offer	Utilized	Utilization[1]	In diet	RPI[1]
Agrostis spp.[2]	83±21	39±16	43±10	10±6	2.65± .84
Aira spp.[3]	318±61	117±55	32±12	20±8	1.72± .57
Carex hendersonii	24±18	8±8	29±17	1±1	1.07± .65
Festuca rubra	126±95	55±44	45±8	9±8	2.85± .87
Holcus lanatus	246±104	34±22	9±5	6±4	.46± .25
Luzula parviflorus	17±5	6±5	29±17	1±1	1.56± .99
Misc. Graminoids[4]	16±8	13±8	60±30	2±1	3.12±1.62
Total Graminoids	829±215	271±92	30±4	50±12	1.76± .10
Anaphalis margaritacea	8±7	5±5	33±19	1±1	1.80±1.15
Digitalis purpurea	247±30	28±16	10±5	7±5	.69± .40
Lotus crassifolius	29±17	18±9	72±8	5±3	4.24± .44
Senecio jacobaea	161±60	19±11	12±7	4±2	.79± .52
Scrophularia californica	32±28	18±18	31±31	3±3	1.41±1.41
Viola spp.	38±19	26±12	72±5	6±4	4.27± .37
Misc Forbs[4]	29±6	13±3	44±5	3±<1	2.67± .44
Total Forbs	544±40	127±17	24±3	28±10	1.47± .42
Polystichum munitum	43±9	10±4	30±13	2±<1	1.60± .68
Acer circinatum	69±45	31±24	35±11	5±4	1.95± .43
Rubus parviflorus	89±56	14±7	12±6	3±2	.77± .39
R. spectabilis	34±12	11±5	44±30	2±1	2.13±1.39
R. ursinus	77±30	19±11	47±29	3±2	2.33±1.33
Vaccinium parvifolium	26±25	16±14	49±26	5±4	2.82±1.42
Misc. Browse[4]	2±2	2±2	65±33	1±<1	4.35±2.21
Total Browse	298±75	92±11	36±12	19±3	1.97± .37
Total Forage	1715±137	501±88	29±3	99±<1	1.67± .08
Pseudotsuga menziesii	1174±168	5±2	<1±<1	1±<1	.02± .01
Total Phytomass	2888±253	505±89	17±3	100	1.00

[1] Values derived from only those replications containing the species.
[2] Includes *Agrostis exarata* and *A. tenuis*.
[3] Includes *Aira caryophyllea* and *A. praecox*.
[4] Species included in miscellaneous category listed in Appendix C.

Table C-5. Above ground phytomass inside and outside exclosure, amount and percent of forage utilized by sheep, percent of forage component in sheep diet, and the relative preference index (RPI) of plants in plantation OAg, 1980.[1]

	Phytomass (kg/ha)[2]		Forage Utilized	Percent		
Species	Inside	Outside	(kg/ha)	Utilization	In diet	RPI
Agrostis spp.[3]	181.75	155.94	25.81	14	1	.25
Aira spp.[4]	2.80	2.80	0	0	0	0
Carex hendersonii	25.80	21.32	4.48	17	<1	.30
Elymus glaucus	—	6.73	0	0	0	0
Holcus lanatus	304.03	468.95	0	0	0	0
Total Graminoids	514.38	655.74	30.29	6	1	.10
Cirsium vulgare	94.24	42.63	51.61	55	2	.95
Digitalis purpurea	222.14	179.50	42.63	19	2	.33
Iris tenax	107.70	11.22	96.48	90	4	1.55
Senecio jacobaea	1112.92	102.09	1010.83	91	41	1.57
Misc. Forbs	81.90	24.68	57.22	70	1	1.21
Total Forbs	1618.90	360.12	1258.77	78	52	1.35
Polystichum munitum[5]	1232.97	573.29	659.68	54	27	.93
Acer circinatum	507.10	269.26	237.84	47	10	.81
Prunus emarginata	16.83	2.24	14.58	87	1	1.50
Rubus parviflorus	20.19	8.98	11.22	56	<1	.96
R. ursinus	136.87	66.19	70.68	52	3	.89
Vaccinium parvifolium	171.65	17.95	153.70	90	6	1.55
Total Browse	852.64	364.62	488.02	57	20	.99
Total Forage	4218.89	1953.77	2436.77	54	100	1.00

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[1] *Pseudotsuga menziesii* not included in estimates.
[2] Data are means derived from ten .45 m^2 clip plots.
[3] Includes *Agrostis exarata* and *A. tenuis*.
[4] Includes *Aira caryophyllea* and *A. praecox*.
[5] Standing crop.

Table C-6. Above ground phytomass on offer, amount and percent of phytomass utilized by sheep, percent of forage component in sheep diet, and the relative preference index (RPI) of plants in plantation OAg, 1981. Data are mean ± standard error.

	Phytomass (kg/ha)		Percent		
Plant species	On offer	Utilized	Utilization[1]	In diet	RPI[1]
Agrostis spp.[2]	185±130	53±52	15±10	5±5	.41±.28
Aira spp.[3]	8±6	3±3	16±16	<1±<1	.45±.45
Holcus lanata	652±179	227±50	36±4	23±3	1.06±.11
Misc. Graminoids[4]	23±10	16±7	71±4	2±1	2.12±.28
Total Graminoids	867±190	299±85	33±4	29±6	.98±.06
Anaphalis margaritacea	25±8	18±8	70±11	2±1	2.13±.48
Cirsium vulgare	21±2	18±2	87±3	2±<1	2.49±.11
Crepis capillaris	31±18	21±15	55±14	2±1	1.67±.45
Digitalis purpurea	283±105	47±25	15±10	5±3	.44±.27
Hypochaeris radicata	75±25	66±23	86±3	6±2	2.56±.13
Iris tenax	75±42	67±40	91±3	7±4	2.69±.13
Lotus crassifolius	26±17	21±14	76±4	2±1	2.18±.15
Rumex acetosella	22±13	18±10	84±4	2±1	2.57±.46
Senecio jacobaea	190±56	113±50	57±11	14±8	1.74±.44
Misc. Forbs[4]	22±4	17±3	79±2	2±<1	2.35±.14
Total Forbs	770±100	410±23	54±5	44±7	1.60±.04
Polystichum munitum	238±112	63±35	28±17	6±3	.79±.48
Pteridium aquilinum	17±17	0	0	0	0
Total Ferns	255±129	63±35	28±17	6±3	.76±.48
Acer circinatum	286±120	120±29	46±6	13±3	1.38±.28
Prunus emarginata	9±3	6±3	63±15	1±<1	1.90±.54
Rubus parviflorus	47±23	28±15	71±16	3±2	2.12±.47
R. ursinus	14±10	1±1	12±12	<1±<1	.32±.32
Misc. Browse[4]	52±50	39±37	87±13	3±3	2.73±.74
Total Browse	409±52	194±15	49±6	20±2	1.47±.25
Total Forage	2301±258	966±123	42±2	100±<1	1.24±.05
Pseudotsuga menziesii	529±59	4±2	<1±<1	<1±<1	.02±.01
Total Phytomass	2830±151	970±121	34±3	100	1.00

[1] Values derived from only those replications containing the species.

[2] Includes *Agrostis exarata* and *A. tenuis*.

[3] Includes *Aira careophyllea* and *A. praecox*.

[4] Species included in miscellaneous category listed in Appendix C.

Table C-7. Above ground phytomass on offer, amount and percent of phytomass utilized by sheep, percent of forage component in sheep diet, and the relative preference index (RPI) of plants in plantation OAg, 1982. Data are mean ± standard error.

Plant species	Phytomass (kg/ha) On offer	Phytomass (kg/ha) Utilized	Percent Utilization[1]	Percent In diet	RPI[1]
Agrostis spp.[2]	195±78	51±13	36±13	8±2	1.74± .60
Aira spp.[3]	45±21	13±4	47±18	2±1	2.27± .92
Carex hendersonii	2±2	1±1	54±29	<1±<1	2.65±1.44
Elymus glaucus	62±13	46±13	71±9	8±2	3.42± .44
Holcus lanatus	450±73	101±51	20±11	16±8	.98± .51
Luzula parviflora	6±3	6±3	65±33	1±1	3.17±1.59
Misc. Graminoids[4]	5±3	1±1	28±28	<1±<1	1.30±1.30
Total Graminoids	764±55	219±32	29±6	36±5	1.41± .28
Anaphalis margaritacea	30±20	21±15	69±12	3±2	3.31± .57
Cirsium vulgare	17±6	11±6	71±21	2±1	3.40± .97
Crepis capillaris	45±7	36±10	78±14	6±2	3.79± .72
Digitalis purpurea	138±68	38±19	23±13	6±3	1.10± .61
Hypochaeris radicata	46±12	28±10	57±6	4±1	2.76± .33
Iris tenax	63±19	20±9	35±17	3±1	1.69± .84
Lotus crassifolius	20±8	17±7	88±8	3±1	4.28± .44
Rumex acetosella	53±53	35±35	22±22	6±6	1.05±1.05
Senecio jacobaea	45±22	10±5	15±8	2±1	.73± .38
Stachys mexicana	11±4	10±4	81±13	2±1	3.93± .65
Misc. Forbs[4]	19±9	13±9	62±16	2±2	2.95± .72
Total Forbs	486±80	238±40	49±5	39±6	2.38± .26
Polystichum munitum	23±17	1±1	42±30	<1±<1	2.04±1.49
Pteridium aquilinum	8±8	0	0	0	0
Total Ferns	31±24	1±1	42±30	<1±<1	2.04±1.49
Acer circinatum	244±84	91±18	41±6	15±3	1.98± .27
Prunus emarginata	5±2	4±2	55±27	1±1	2.60±1.31
Rubus parviflorus	29±4	14±7	46±23	2±1	2.26±1.13
R. spectabilis	9±9	4±4	45±<1	1±1	2.12± .01
R. ursinus	23±4	10±3	51±18	2±<1	2.50± .91
Misc. Browse[4]	4±4	4±3	96±4	1±1	4.65± .20
Total Browse	314±99	127±19	45±8	21±4	2.18± .39
Total Forage	1596±47	586±8	37±1	97±2	1.77± .01
Pseudotsuga menziesii	1341±66	21±10	2±1	3±2	.08± .03
Total Phytomass	2937±112	607±15	21±<1	100	1.00

[1] Values derived form only those replications containing the species.
[2] Includes *Agrostis exarata* and *A. tenuis*.
[3] Includes *Aira careophyllea* and *A. praecox*.
[4] Species included in miscellaneous category listed in Appendix C.

Table C-8. Above ground phytomass on offer, amount and percent of phytomass utilized by sheep, percent of forage component in sheep diet, and the relative preference index (RPI) of plants in plantation YMy, 1981. Data are mean ± standard error.

	Phytomass (kg/ha)		Percent		
Plant species	On offer	Utilized	Utilization[1]	In diet	RPI[1]
Carex hendersonii	23±23	9±9	40±<1	1±1	.56±<1
Dactylis glomerata	1345±415	924±195	73±7	59±5	1.06±.07
Holcus lanatus	51±24	45±21	88±3	3±1	1.30±.10
Misc. Graminoids[2]	78±25	55±24	65±20	3±1	.97±.32
Total Graminoids	1497±381	1033±186	71±5	66±4	1.04±.03
Anaphalis margaritacea	19±10	15±9	76±3	1±<1	1.12±.11
Cirsium vulgare	26±15	23±14	84±4	2±1	1.24±.09
Scrophularia californica	417±47	206±53	48±9	13±3	.70±.13
Misc. Forbs[2]	36±17	33±16	93±2	3±2	1.36±.04
Total Forbs	498±29	277±24	56±5	18±1	.75±.13
Polystichum munitum	31±7	16±7	54±26	1±<1	.84±.43
Acer circinatum	95±27	89±24	94±2	6±2	1.38±.08
Prunus emarginata	6±2	6±2	90±3	<1±<1	1.32±.11
Rubus parviflorus	90±12	69±8	77±1	5±1	1.14±.07
R. spectabilis	12±6	9±5	55±20	1±<1	.84±.43
Sambucus callicarpa	25±11	24±11	96±2	2±1	1.41±.11
Misc. Browse[2]	10±5	10±5	99±1	1±<1	1.46±.07
Total Browse	238±20	207±14	87±2	14±2	1.28±.08
Total Forage	2263±389	1533±195	69±4	99±<1	1.01±<1
Psuedotsuga menziesii	34±1	14±2	40±4	1±<1	.60±.10
Total Phytomass	2298±390	1547±196	68±3	100	1.00

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[1] Values derived from only those replications containing the species.

[2] Species included in miscellaneous category listed in Appendix C.

Table C-9. Above ground phytomass on offer, amount and percent of phytomass utilized by sheep, percent of forage component in sheep diet, and the relative preference index (RPI) of plants in plantation YMy, 1982. Data are mean ± standard error.

Plant species	Phytomass (kg/ha)		Percent		
	On offer	Utilized	Utilization[1]	In diet	RPI[1]
Agrostis spp.[2]	23±12	15±13	49±25	2±1	1.25±.62
Dactylis glomerata	1809±118	747±78	41±3	78±6	1.07±.06
Elymus glaucus	27±9	8±4	41±21	1±<1	1.11±.57
Holcus lanata	162±41	76±36	50±19	8±4	1.28±.48
Luzula parviflora	1±<1	1±1	82±19	<1±<1	2.06±.35
Misc. Graminoids[3]	14±10	2±1	34±15	<1±<1	.88±.38
Total Graminoids	2035±78	848±49	42±1	90±1	1.09±.02
Anaphalis margaritacea	28±8	22±9	80±17	2±1	2.07±.42
Cirsium vulgare	75±20	2±2	3±3	<1±<1	.07±.07
Digitalis purpurea	33±30	19±19	20±20	2±2	.56±.56
Scrophularia californica	166±51	18±10	12±6	2±1	.29±.15
Senecio jacobaea	2±1	1±<1	42±10	<1±<1	1.11±.28
Misc. Forbs[3]	32±9	16±6	49±8	2±1	1.30±.26
Total Forbs	336±57	78±12	25±6	8±1	.63±.12
Polystichum munitum	5±4	<1±<1	32±32	<1±<1	.88±.88
Acer circinatum	9±6	1±1	6±6	<1±<1	.15±.15
Prunus emarginata	2±<1	1±4	80±6	<1±<1	2.08±.18
Rubus parviflorus	48±15	11±1	16±16	1±1	.44±.44
R. spectabilis	7±6	<1±<1	13±13	<1±<1	.32±.32
R. ursinus	3±3	1±1	5±5	<1±<1	.13±.13
Sambucus callicarpa	11±7	4±1	68±22	<1±<1	1.83±.62
Misc. Browse[3]	3±2	2±1	40±22	<1±<1	1.01±.53
Total Browse	83±20	19±10	21±7	2±1	.55±.20
Total Forage	2459±26	946±46	39±2	100±<1	1.00±.01
Pseudotsuga menziesii	10±1	4±<1	42±2	<1±<1	1.08±.04
Total Phytomass	2469±27	950±47	39±2	100	1.00

[1] Values derived form only those replications containing the species.
[2] Includes *Agrostis exarata* and *A. tenuis*.
[3] Species included in miscellaneous category listed in Appendix C.

Table C-10. Above ground phytomass on offer, amount and percent of phytomass utilized by sheep, percent of forage component in sheep diet, and the relative preference index (RPI) of plants in plantation YJy, 1981. Data are mean ± standard error.

Plant species	Phytomass (kg/ha)		Percent		RPI[1]
	On offer	Utilized	Utilization[1]	In diet	
Agrostis spp.[2]	187±82	52±47	17±13	6±6	.43±.34
Bromus sp.	36±14	12±11	31±19	2±1	.65±.36
Dactylis glomerata	764±124	243±28	35±11	29±5	.79±.14
Lolium perenne	199±23	88±34	42±12	10±4	1.00±.31
Misc. Graminoids[3]	103±54	76±35	84±9	9±4	1.94±.28
Total Graminoids	1290±236	471±90	39±7	56±10	.88±.11
Anaphalis margaritacea	19±11	12±7	45±22	1±1	1.03±.54
Cirsium vulgare	21±19	13±11	49±26	2±1	1.17±.68
Digitalis purpurea	27±13	11±11	24±24	1±1	.66±.66
Rumex acetosella	79±19	40±8	52±3	5±1	1.23±.09
Trifolium repens	9±5	7±4	85±6	1±<1	2.05±.32
Misc. Forbs[3]	102±30	76±18	78±6	9±2	1.83±.08
Total Forbs	256±53	160±36	62±2	19±4	1.49±.20
Polystichum munitum	135±14	39±32	25±20	5±4	.51±.36
Pteridium acquilinum	21±18	4±2	37±32	1±<1	.73±.58
Total Ferns	156±15	44±34	26±20	6±4	.51±.37
Rubus parviflorus	6±3	<1±<1	2±2	<1±<1	.04±.04
R. ursinus	217±74	139±69	59±13	16±8	1.40±.34
Misc Browse[3]	51±16	28±9	56±9	3±1	1.30±.12
Total Browse	274±81	167±71	57±11	20±8	1.34±.29
Total Forage	1976±292	841±34	44±5	100±<1	1.03±.01
Psuedotsuga menziesii	55±3	<1±<1	1±<1	<1±<	.03±.01
Total Phytomass	2031±291	842±34	43±5	100	1.00

[1] Values derived from only those replications containing the species.
[2] Includes *Agrostis exarata* and *A. tenuis*.
[3] Species listed in miscellaneous category listed in Appendix C.

Table C-11. Above ground phytomass on offer, amount and percent of phytomass utilized by sheep, percent of forage compontent in sheep diet, and the relative preference index (RPI) of plants in plantation YJy, 1982. Data are mean ± standard error.

	Phytomass (kg/ha)		Percent		
Plant species	On offer	Utilized	Utilization[1]	In diet	RPI[1]
Agrostis spp.[2]	156±51	85±32	52±5	8±1	1.29± .12
Bromus sp.	19±9	11±6	67±20	1±<1	1.83± .82
Carex hendersonii	8±3	7±4	66±33	1±<1	1.76± .99
Dactylis glomerata	668±70	315±78	47±10	34±6	1.10± .10
Festuca rubra	101±54	51±29	49±7	4±2	1.02± .04
Holcus lanata	120±97	78±64	44±22	7±5	1.16± .65
Lolium perenne	187±52	110±23	61±5	12±2	1.56± .30
Luzula parviflora	2±1	1±1	31±18	<1±<1	.95± .64
Misc. Graminoids[3]	8±8	7±7	31±31	1±1	.72± .72
Total Graminoids	1269±200	666±187	50±8	69±7	1.21± .01
Anaphalis margaritacea	13±6	5±3	58±26	1±<1	1.67± .90
Cirsium vulgare	17±14	1±<1	39±31	<1±<1	1.26±1.09
Digitalis purpurea	29±11	2±1	9±5	<1±<1	.18± .10
Rumex acetosella	232±84	97±6	37±13	9±4	.81± .23
Scrophularia californica	38±35	37±34	98±2	3±2	2.63± .66
Senecio jacobaea	9±4	7±2	84±12	1±<1	2.14± .53
S. vulgaris	40±22	27±16	46±23	4±3	1.32± .70
Trifolium repens	4±2	4±2	95±3	1±<1	2.43± .45
Misc. Forbs[3]	25±9	13±5	57±3	2±1	1.53± .31
Total Forbs	408±79	192±71	44±8	20±3	1.07± .08
Polystichum munitum	22±8	3±2	17±14	<1±<1	.41± .33
Pteridium aquilinum	4±4	<1±<1	6±6	<1±<1	.11± .11
Total Ferns	26±7	3±2	18±14	<1±<1	.43± .32
Rubus parviflorus	17±6	8±1	60±20	1±<1	1.54± .52
R. ursinus	349±104	67±32	17±4	10±6	.47± .18
Misc. Browse[3]	3±2	2±<1	81±19	<1±<1	2.18± .77
Total Browse	370±100	77±31	19±3	11±7	.52± .17
Total Forage	2073±158	938±217	44±7	100±<1	1.06± .01
Psuedotsuga menziesii	130±3	2±1	1±1	<1±<1	.04± .01
Total Phytomass	2203±161	940±218	42±7	100	1.00

[1] Values derived from only those replications containing the species.
[2] Includes *Agrostis exarata* and *A. tenuis*.
[3] Species included in the miscellaneous category listed in Appendix C.

Table C-12. Above ground phytomass on offer, amount and percent of phytomass utilized by sheep, percent of forage component in sheep diet, and the relative preference index (RPI) of plants in plantation YMy/Ag 1982. Data are mean ± standard error.

	Phytomass (kg/ha)		Percent		
Plant species	On offer	Utilized	Utilization[1]	In diet	RPI[1]
Agropyron sp.	6±2	2±1	27±7	<1±<1	.95± .23
Agrostis spp.[2]	15±7	10±6	57±30	2±1	2.10±1.06
Dactylis glomerata	1075±218	330±74	33±2	56±11	1.09± .10
Elymus glaucus	16±9	5±2	54±24	1±<1	2.03±1.00
Holcus lanata	143±45	22±22	9±9	4±4	.38± .38
Misc. Graminoids[3]	20±19	0	0	0	0
Total Graminoids	1276±183	368±72	29±2	63±11	1.01± .12
Anaphalis margaritacea	14±3	12±4	81±10	2±1	2.81± .18
Cirsium vulgare	153±74	13±13	13±13	2±2	.41± .41
Conyza canadensis	24±10	12±7	35±21	2±1	1.19± .67
Digitalis purpurea	48±28	3±3	12±12	<1±<1	.38± .38
Scrophularia californica	124±17	23±12	17±9	4±2	.59± .29
Senecio jacobaea	7±6	4±4	25±25	1±1	.80± .80
S. vulgaris	10±8	8±6	51±26	1±1	1.68± .84
Stachys mexicana	44±6	12±3	27±8	2±1	.94± .26
Misc. Forbs[3]	4±2	1±1	15±8	<1±<1	.54± .31
Total Forbs	428±117	88±45	22±10	15±8	.72± .31
Polystichum munitum	2±2	0	0	0	0
Prunus emarginata	5±1	4±1	82±13	1±<1	2.92± .49
Rubus parviflorus	126±37	43±25	29±14	7±4	.95± .46
R. spectabilis	20±9	13±7	67±9	2±1	2.31± .29
R. ursinus	40±35	8±7	28±19	1±1	1.01± .66
Sambucus callicarpa	47±24	40±21	82±3	7±4	2.92± .29
Misc. Browse[3]	8±5	3±2	47±29	<1±<1	1.70±1.00
Total Browse	245±56	111±20	47±5	19±4	1.64± .08
Total Forage	1951±125	567±21	29±2	97±1	1.03± .02
Psuedotsuga menziesii	118±11	18±6	15±6	3±1	.57± .26
Total Phytomass	2069±161	585±16	29±2	100	1.00

[1] Values derived from only those replications containing the species.

[2] Includes *Agrostis exarata* and *A. tenuis*.

[3] Species included in the miscellaneous category listed in Appendix C.

APPENDIX D. Plant species included in miscellaneous category of the phytomass summaries (Appendix C).

Table D-1. Plant species included in the miscellaneous category of the phytomass summaries (Appendix C), 1981 (1) and 1982 (2).

	Plantation										
	OMy		OJy		OAg		YMy		YJy		YMy/Ag
Plant species	81	82	81	82	81	82	81	82	81	82	82
Graminoids											
Agrostis exarata							1				
A. tenuis							1				
Aira caryophyllea							1		1		2
A. praecox							1		1		2
Arrhenatherum elliatus									1		
Bromus sp.		2	1	2	1	2					
Carex sp.				2							2
C. hendersonii					1			2	1		2
Dactylis glomerata			1			2					
Elymus glaucus		2	1		1		1				
Festuca arundinacea	1	2	1								
F. rubra			1			2		2	1		2
Holcus lanatus									1		
Luzula parviflora					1		1		1		2
Phleum pratense	1							2	1		
Poa pratensis	1										
Trisetum cernuum		2		2	1				1		
Vulpia sp.						2		2		2	
Forbs											
Cardamine sp.		2			1	2		2			
Cerastium arvense		2	1	2		2		2			
Cirsium vulgare	1	2	1	2							
Conyza canadensis			1		1	2		2	1	2	
Crepis capillaris			1	2				2	1		
Dicentra formosa	1	2		2				2	1	2	2
Digitalis purpurea	1						1				
Epilobium angustifolium	1	2	1	2	1	2		2	1	2	2
Gallium sp.	1	2	1	2	1	2		2	1	2	2
Hypochaeris radicata	1	2		2					1	2	
Iris tenax											2
Lotus crassifolius							1		1		2
Lupinus sp.									1	2	
Maianthemum dilatum	1	2	1	2		2				2	
Mimulus sp.	1										
Montia sibirica		2	1		1						
Oxalis oregana	1								1	2	
Ranunculus sp.								2			
Rumex acetosella			1	2							
Scrophularia californica	1	2	1						1		
Senecio sp.				2		2					
S. jacobaea							1		1		
S. sylvaticus									1		

Table D-1. (Continued)

	Plantation										
	OMy		OJy		OAg		YMy		YJy		YMy/Ag
Plant species	81	82	81	82	81	82	81	82	81	82	82
S. vulgaris		2						2	1		
Smilacena sp.		2							1	2	
Stachys mexicana									1	2	
Taraxicum officinale				2							
Trientalis latifolia	1	2	1	2					1	2	
Trifolium repens										2	2
T. subterraneum										2	
Trillium sp.								2			
Viola sp.	1	2	1					2	1		
Browse											
Acer circinatum											2
Alnus rubra				2							
Baccharis pilularis							1				
Corylus cornuta californica							1	2	1		2
Gaultheria shallon	1	2	1	2					1	2	
Holodiscus discolor		2	1		1	2	1	2			2
Prunus emarginata		2	1	2			1		1	2	
Rubus laciniatus							1				2
R. leucodermis	1		1		1	2	1				2
R. spectabilis					1				1		
R. ursinus							1				
Sambucus spp.				2	1						
Vaccinium parvifolium					1	2					

APPENDIX E. Ocular estimates of percent utilization and relative preference indices based on ocular estimates for plant species in 5 Douglas-fir plantations grazed by sheep, 1981 and 1982.

Table E-1. Ocular estimates of percent utilization (%U) and relative preference indices (RPI) based on ocular estimates for plant species in 5 Douglas-fir plantations grazed by sheep in 1981.

	Plantation											
	OMy		OJy		OAg		YMy		YJy		YMy/Ag	
Plant species	%U	RPI	%U	RPI	%U	RPI	%U	RPI	%U	RPI	%U	RPI
Graminoids												
Agrostis spp.^{1}	83	1.53	67	1.67	28	.91	80	1.45	20	.69	13	.66
Aira spp.			3	.06	20	.64						
Anthoxanthum odoratum											12	.61
Bromus sp.									32	1.10	60	3.06
Carex hendersonii	80	1.49	70	1.75	78	2.52	80	1.45	65	2.25	35	1.79
Dactylis glomerata	82	1.52			13	.40	73	1.33	40	1.38	57	2.91
Elymus glaucus											30	1.53
Festuca arundinacea	80	1.49										
F. rubra					16	.52			27	.92		
Holcus lanatus	90	1.67	57	1.42	33	1.07	80	1.45	20	.69	50	2.55
Lolium perenne									28	.98		
Luzula parviflora			25	.63	22	.70	80	1.45				
Forbs												
Anaphalis margaritacea	83	1.55	63	1.58	40	1.29			25	.86	10	.51
Cirsium vulgare	67	1.24	25	.63	30	.97	20	.36	20	.69	5	.26
Crepis capillaris					48	1.55						
Digitalis purpurea	1	.02	1	.03	1	.03	0	0	1	.03	0	0
Epilobium angustifolium			43	1.08					27	.92	28	1.43
Hypochaeris radicata					48	1.55						
Iris tenax	80	1.45			83	2.67						
Lotus crassifolius	90	1.67	77	1.92	70	2.25			50	1.73		
Lupinus sp.									70	2.42		
Rumex acetosella									53	1.84		
Senecio jacobaea	65	1.21	68	1.71	57	1.84	40	.73	60	2.07		

Table E-1. (Continued)

	Plantation											
	OMy		OJy		OAg		YMy		YJy		YMy/Ag	
Plant species	%U	RPI	%U	RPI	%U	RPI	%U	RPI	%U	RPI	%U	RPI
Forbs (continued)												
S. vulgaris									25	.86	2	.10
Scrophularia californica					20	.64	35	.64	38	1.32	40	2.04
Stachys mexicana											0	0
Trifolium repens									25	.87		
Polystichum munitum	28	.53	15	.38	3	.08	30	.54	5	.17	1	.05
Pteridium aquilinum					3	.08			5	.17		
Browse												
Acer circinatum	57	1.05	53	1.33	27	.87	57	1.03			20	1.02
Alnus rubra			33	.81	25	.81						
Berberis nervosa	30	.56										
Corylus cornuta californica					40	1.29	80	1.45			2	.10
Gaultheria shallon	10	.19			5	.16			1	.03		
Holodiscus discolor	35	.65	37	.92	40	1.29					7	.36
Prunus emarginata	75	1.39	67	1.67	47	1.51	60	1.09			30	1.53
Rosa spp.					20	.64						
Rubus leucodermis	33	.62	35	.88	22	.71	50	.91			2	.10
R. parviflorus	62	1.15	30	.75	26	.84	33	.60	10	.35	2	.10
R. spectabilis	60	1.11	47	1.17	33	1.06	37	.67	23	.81	2	.10
R. ursinus	57	1.05	27	.67	20	.64	62	1.13	12	.40	2	.10
Sambucus spp.							90	1.63			60	3.06
Vaccinium parvifolium	60	1.11	37	.92	45	1.45						
Pseudotsuga menziesii	11	.20	2	.05	1	.02	35	.64	1	.03		

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[1] Includes *Agrostis exarata* and *A. tenuis*.
[2] Includes *Aira caryophyllea* and *A. praecox*.

Table E-2. Ocular estimates of percent utilization (%U) and relative preference indices (RPI) based on ocular estimates for plant species in 5 Douglas-fir plantations grazed by sheep, in 1982.

	Plantation											
	OMy		OJy		OAg		YMy		YJy		YMy/Ag	
Plant species	%U	RPI	%U	RPI	%U	RPI	%U	RPI	%U	RPI	%U	RPI
Graminoids												
Agropyron sp.											30	.94
Agrostis spp.[1]	80	2.43	30	1.29	40	1.59	60	1.95	35	1.14	50	1.57
Aira spp.[2]			15	.64	5	.20			2.5	.08		
Bromus spp.									35	1.14		
Carex hendersonii	70	2.12	30	1.29	40	1.59	50	1.62	50	1.62	50	1.57
Dactylis glomerata	80	2.43					50	1.62	50	1.62	55	1.73
Elymus glaucus					10	.40	60	1.95			30	.94
Festuca rubra			20	.86	20	.80			30	.97		
Holcus lanatus	80	2.43	25	1.07	30	1.20	60	1.95			50	1.57
Lolium perenne									40	1.30		
Luzula parviflora	75	2.28	15	.64	10	.40	60	1.95	25	.81	25	.79
Forbs												
Anaphalis margaritacea	80	2.43	60	2.57	50	1.99	70	2.27	60	1.95	70	2.20
Cirsium vulgare	10	.30			5	.20	5	.16	2.5	.08	2.5	.08
Conyza canadensis											30	.94
Crepis capillaris					40	1.59						
Digitalis purpurea	0	0	0	0	0	0	0	0	0	0	0	0
Hypochaeris radicata					40	1.59						
Iris tenax					20	.80						
Lotus crassifolius	80	2.43	60	2.57	70	2.79	70	2.27	75	2.44	70	2.20
Rumex acetosella					35	1.39			50	1.62		
Senecio jacobaea	20	.61	15	.64	10	.40	10	.32	35	1.14	25	.79
S. vulgaris									40	1.30	25	.79
Scrophularia californica					10	.40	20	.65	30	.97	30	.94

Table E-2. (Continued)

	Plantation											
	OMy		OJy		OAg		YMy		YJy		YMy/Ag	
Plant species	%U	RPI	%U	RPI	%U	RPI	%U	RPI	%U	RPI	%U	RPI
Forbs (continued)												
Stachys mexicana					60	2.39			20	.65	25	.79
Trifolium repens									70	2.27		
Viola spp.			50	2.14								
Ferns												
Polystichum munitum	0	0	2.5	.11	2.5	.10	2.5	.08	2.5	.08	2.5	.08
Pteridium aquilinum					0	0			0	0		
Browse												
Acer circinatum	5	.15	35	1.50	30	1.20	2.5	.08	25	.81	50	1.57
Alnus rubra	20	.61	5	.21	40	1.59	70	2.27	2.5	.08	10	.31
Baccharis pilularis			60	2.57								
Berberis nervosa	0	0										
Corylus cornuta californica					40	1.59	35	1.14			50	1.57
Gaultheria shallon	0	0			2.5	.10			0	0		
Holodiscus discolor	25	.76			35	1.39	20	.65	40	1.30	40	1.26
Prunus emarginata					50	1.99	40	1.30			50	1.57
Rubus leucodermis	2.5	.08			15	.60	2.5	.08			10	.31
R. parviflorus	2.5	.08	2.5	.11	10	.40	5	.16			2.5	.08
R. spectabilis	2.5	.08	15	.64	25	1.00	2.5	.08			20	.63
R. ursinus	10	.30	2.5	.11	20	.80	5	.16			10	.31
Sambucus spp.							20	.65	60	1.95	60	1.88
Vaccinium parvifolium	65	1.97	60	2.57	40	1.59						
Pseudotsuga menziesii	18	.55	1	.04	3	.12	44	1.43	2	.06	19	.60

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[1] Includes *Agrostis exarata* and *A. tenuis*.
[2] Includes *Aira caryophyllea* and *A. praecox*.

APPENDIX F. Ocular estimates of percent utilization of forage plants and percent of Douglas-fir trees impacted for different levels of sheep grazing.

Table F-1. Ocular estimates of percent utilization of forage plants and percent of Douglas-fir trees impacted for different levels of sheep grazing in OMy, 1982.

Plant species	Days of Grazing 1	 2
Graminoids		
Agrostis spp.	70	80
Carex hendersonii	65	70
Dactylis glomerata	70	80
Holcus lanatus	70	80
Luzula parviflora	65	75
Forbs		
Anaphalis margaritacea		80
Cirsium vulgare		10
Digitalis purpurea	0	0
Lotus crassifolius		80
Senecio jacobaea		20
Ferns		
Polystichum munitum		0
Browse		
Acer circinatum	3	5
Alnus rubra		20
Berberis nervosa		0
Gaultheria shallon		0
Holodiscus discolor		25
Rubus leucodermis		3
R. parviflorus	2	3
R. spectabilis	2	3
R. ursinus		10
Vaccinium parvifolium		65
Pseudotsuga menziesii[1]		
Terminals browsed (%)	0	0
Laterals browsed (%)	72	86
Current year's growth consumed (%)	7.1	9.6

[1] Data include only replication #1.

Table F-2. Ocular estimates of percent utilization of forage plants and percent of Douglas-fir trees impacted for different levels of sheep grazing in OAg, 1981.

	Days of Grazing		
Plant species	4	6	7
Graminoids			
Agrostis spp.	12	23	28
Aira spp.	3	5	20
Carex hendersonii	65	77	78
Dactylis glomerata	3	3	13
Holcus lanatus	18	28	33
Forbs			
Anaphalis margaritacea	23	35	40
Cirsium vulgare	13	25	30
Digitalis purpurea	0	0	1
Iris tenax	60	77	83
Senecio jacobaea	32	48	57
Scrophularia californica	10	18	20
Ferns			
Polystichum munitum	0	1	3
Pteridium aquilinum	1	3	3
Browse			
Acer circinatum	10	23	27
Alnus rubra	22	22	25
Corylus cornuta californica	30	37	40
Gaultheria shallon	0	1	5
Holodiscus discolor	35	40	40
Prunus emarginata	25	30	47
Rosa spp.	12		20
Rubus leucodermis	12	20	22
R. parviflorus	3	21	26
R. spectabilis	18	32	33
R. ursinus	5	10	20
Vaccinium parvifolium	40	43	45
Pseudotsuga menziesii			
Terminals browsed (%)	0	0	0
Laterals browsed (%)	7	13	18
Current year's growth consumed (%)	<1	<1	<1

Table F-3. Ocular estimates of percent utilization of forage plants and percent of Douglas-fir trees impacted for different levels of sheep grazing in YMy, 1982.

Plant species	Days of Grazing 2	 6
Graminoids		
Agrostis spp.	35	60
Carex hendersonii	15	50
Dactylis glomerata	30	50
Holcus lanatus	25	60
Luzula parviflora	20	60
Forbs		
Anaphalis margaritacea	40	70
Cirsium vulgare	3	5
Digitalis purpurea	0	0
Lotus crassifolius	40	70
Senecio jacobaea	3	10
Scrophularia californica	10	20
Ferns		
Polystichum munitum	0	3
Browse		
Acer circinatum	2	3
Alnus rubra	35	65
Corylus cornuta californica	15	35
Holodicus discolor	15	20
Prunus emarginata	25	40
Rubus leucodermis	2	3
R. parviflora	0	5
R. spectabilis	2	3
R. ursinus	3	5
Sambucus sp.	15	20
Pseudotsuga menziesii		
Terminals browsed (%)	55	69
Laterals browsed (%)	91	100
Current year's growth consumed (%)	29	44

Table F-4. Ocular estimates of percent utilization of forage plants and percent of Douglas-fir trees impacted for different levels of sheep grazing in YJy, 1981.

	Days of Grazing			
Plant species	1	2	3	4
Graminoids				
Agrostis spp.	2	13	15	20
Bromus sp.	7	23	27	32
Carex hendersonii	33	40		65
Dactylis glomerata	15	27	35	40
Festuca rubra	7	15	18	27
Holcus lanatus	4	8	10	20
Lolium perenne	3	17	22	28
Forbs				
Anaphalis margaritacea	5	8	20	25
Cirsium vulgare	4	12		20
Digitalis purpurea	0	0	0	1
Epilobium spp.	0		27	27
Lotus crassifolius	35	40	50	50
Lupinus sp.	50	70	70	70
Rumex acetosella	1	4	33	53
Senecio jacobaea	50	60	60	60
S. vulgare	13	17	25	25
Scrophularia california	17	23	30	38
Ferns				
Polystichum munitum	0	0	0	5
Pteridium aquilinum	0	1	3	5
Browse				
Acer circinatum	2	22	27	47
Gaultheria shallon	0	0	1	1
Prunus emarginata	8	15	18	23
Rubus parviflorus	0	2	5	10
R. spectabilis	1	4	18	23
R. ursinus	0	2	5	12
Sambucus sp.		50	55	58
Pseudotsuga menziesii				
Terminals browsed (%)	0	0	0	1
Laterals browsed (%)	0	1	1	9
Current year's growth consumed (%)	<1	<1	<1	1

APPENDIX G. Preference displayed by sheep for important plant species in 5 Douglas-fir plantations, 1981 and 1982.

Table G-1. Preference displayed by sheep for important plant species in 5 Douglas-fir plantations, 1981 and 1982.[1]

	Plantation[2]										
	OMy		OJy		OAg		YMy		YJy		YMy/Ag
Plant species	81	82	81	82	81	82	81	82	81	82	82
Graminoids											
Agrostis spp.	HP	HP	P	P	N	P	P	HP	N	N	N
Aira spp.			NP	N	NP	N				NP	
Carex hendersonii	HP	P	P	N	HP	P	P	P	HP	P	N
Dactylis glomerata	HP	HP			NP		P	P	N	N	N
Festuca rubra				N	NP				N	N	
Holcus lanatus	HP	HP	P	N	N	N	HP	P	N	N	N
Lolium perenne									N	N	
Luzula parviflora	P	P	N	N	N	N	P	HP	N	N	N
Forbs											
Anaphalis margaritacea	HP	HP	HP	HP	P	HP	HP	HP	N	P	HP
Cirsium vulgare	N	NP	NP	N	N		NP	A	N	A	A
Crepis capillaris					P	P					
Digitalis purpurea	A	A	A	A	A	A	A	A	A	A	
Hypochaeris radicata					P	P					
Iris tenax	P				HP		N				
Lotus crassifolius	HP	HP	HP	HP	HP	HP	P	HP	P	HP	HP
Rumex acetosella					P	N			P	P	
Senecio jacobaea	N	NP	HP	NP	HP	NP	N	NP	HP	N	N
Scrophularia californica					N	NP	NP	NP	P	N	N
Trifolium repens									P	HP	
Polystichum munitum	NP	A	NP	A	A	A	NP	A	A	A	A
Pteridium aquilinum					A	A	NP		A	A	

Table G-1. (Continued)

	Plantation[2]										
	OMy		OJy		OAg		YMy		YJy		YMy/Ag
Plant species	81	82	81	82	81	82	81	82	81	82	82
Browse											
Acer circinatum	N	NP	P	P	N	N	N	A	N	N	P
Alnus rubra	P		N	NP	N	N		HP	N	NP	NP
Corylus cornuta californica					P	P	P	N			P
Gaultheria shallon	NP	A			A	A	A		A	A	
Holodiscus discolor	NP	N	N			N	N	NP		N	N
Prunus emarginata	P		P		P	P	N	P	P		HP
Rubus leucodermis	N	A	N	NP	N	NP	N	A			NP
R. parviflorus	N	A	N	NP	N	NP	N	NP	NP	NP	NP
R. spectabilis	N	A	N	N	N	N	N	A	N	NP	N
R. ursinus	N	NP	N	NP	N	N	N	NP	NP	NP	NP
Sambucus spp.							HP	N		P	HP
Vaccinium parvifolium	N	P	P	HP	P	P					
Pseudotsuga menziesii	NP	NP	A	A	A	A	NP	N	A	A	NP

[1] Preference ratings for plant species determined from field notes and relative preference indices (Appendix C and D).

[2] HP,P,N,NP, and A refer to highly preferred, preferred, neutral, not preferred, and avoided, respectively.

APPENDIX H. Phenology scorecard and phenological growth stages of important plant species at time of sheep grazing, 1981 and 1982.

Table H-1. Phenology scorecard.[1]

Code	Growth Stage
1	First growth
2	First leaves fully expanded
3	Active vegetative growth
4	Boot stage, first floral buds
6	Exsertion of grass infloresence, earliest flowers
7	Reproductive culms fully extended
8	Anthesis, full flower
9	Fruit developing
10	Fruit ripe
11	Dehiscence
12	Vegetative maturity, summer or winter dormancy, leaf drop, annuals dead

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[1] After Taylor and Leininger 1979.

Table H-2. Phenological growth stages of important plant species at time of sheep grazing, 1981 and 1982.[1]

Plant species	OMy 81	OMy 82	OJy 81	OJy 82	OAg 81	OAg 82	YMy 81	YMy 82	YJy 81	YJy 82	YMy/Ag 82
Graminoids											
Agrostis spp.	4	4	8	8	10	9	5	4	8	11	8
Aira spp.			11	11	11	11					
Arrhenatherum eliatus									11	10	
Bromus spp.					11	11			8	9	
Carex hendersonii	7	7	12	12	12	12	8	9	12		
Dactylis glomerata	5	6			11	11	6	7	10	10	8
Elymus glaucus					11	11		4			
Festuca rubra	7	5	8	8	11	11	11			11	
Holcus lanatus	5	4	8	10	11	11	6	7	10	9	8
Lolium perenne									9	9	
Luzula parviflora	8	8	11	11	12	12	8	9	11		
Phleum pratense	4	4									
Forbs											
Anaphalis margaritacea	4	3	7	6	8	8	4	4	8	6	8
Cirsium vulgare		3	6		7	7	3	3	5	6	6
Conyza canadensis									5	5	5
Crepis capillaris					10	9				7	9
Dicentra formosa	8	8	11								
Digitalis purpurea	5	4	8	9	11	11	7	5	9	10	9
Epilobium spp.			8		8	9		8	6		9
Galium spp.						11	6		11	9	
Hypochaeris radicata					11	11					
Iris tenax					12	12	7	8			
Lotus crassifolius	7	6	9	9	11	10	7	7	9		11
Lupinus spp.									10	9	
Montia siberica	8	9	10				9			10	
Rumex acetosella				9		10			9	9	

Table H-2. (Continued)

	Plantation										
	OMy		OJy		OAg		YMy		YJy		YMy/Ag
Plant species	81	82	81	82	81	82	81	82	81	82	82
Forbs (continued)											
Scrophularia californica			9	9	11	11	8	5		9	9
Senecio jacobaea	1	2	6	6	8	9	3	2	7	6	
S. vulgaris									9	6	7
Stachys mexicana						11			8	9	10
Trientalis latifolia	8	8	9	10							
Trifolium repens									9	8	
Viola spp.	9	9		10							
Polystichum munitum	2	1	6	6	9	9	3	3	6	6	
Pteridium aquilinum					10	9			4	4	
Browse											
Acer circinatum	3	1	9	9	10	9	3	2	9	9	
Alnus rubra	3	1			4	4	3	3	4		
Corylus cornuta californica					4	4	3	3			
Gaultheria shallon		5			10	9			9	9	
Holodiscus discolor		3			4	4		3	4	6	4
Prunus emarginata			3		4	4	3	3	4		4
Rubus leucodermis	5	5	9			9	8	8			
R. parviflorus	8	5	9	9	12	12	8	8	9		12
R. spectabilis	9	9	10	10	12	12		9	10	10	12
R. ursinus	8	5	9	9	11	11	9	8	9	9	
Sambucus spp.						9	3	3	9		4
Vaccinium parvifolium		3	9	9	12				10		

[1] Codes are given in table F-1.

Table H-3. Phenological growth stages of Douglas-fir at time of sheep grazing, 1981 and 1982.

Plantation	Growth Stage
OMy	
1981	Bud break to 10 cm new growth; average 7.5 cm new growth
1982	Bud swell to 7.5 cm new growth; average 4 cm new growth
OJy	
1981	Bud set
1982	Average 15 cm new growth; buds swelling for second flush of growth
OAg	
1981	Second flush of growth
1982	Bud set
YMy	
1981	Bud break to 8 cm new growth; average 6 cm new growth
1982	Bud swell to 5 cm new growth; average 2.5 cm new growth
YJy	
1981	Buds swelling for second flush of growth
1982	Buds swelling for second flush of growth
YMy/Ag	
1982	Second flush of growth

APPENDIX I. Analysis of variance tables for botanical composition of sheep diets, above ground phytomass on offer, relative preference indices, Douglas-fir trees damaged by sheep, soil moisture, and percent nitrogen of Douglas-fir needles.

Table I-1. Analysis of variance for botanical composition (%) of sheep diets for 5 forage classes in 5 Douglas-fir plantations, 1981 and 1982.

Source	dF	Mean Square	Probability
Total	149	527.944	
Between subjects			
Plantation (P)	4	25.716	<.001
Error	10	.756	
Within subjects			
Forage class (FC)	4	13087.828	<.001
P x FC	16	907.488	<.001
Error	40	101.871	
Year (Y)	1	27.563	<.001
P x Y	4	25.881	<.001
Error	10	.746	
FC x Y	4	895.589	<.001
P x FC x Y	16	105.196	.049
Error	40	55.082	

Table I-2. Analysis of variance for above ground phytomass (kg/ha) within 1.5 m of ground for 5 forage classes in 5 Douglas-fir plantations, 1981 and 1982.

Source	dF	Mean Square	Probability
Total	149	218706.73	
Between subjects			
Plantation (P)	4	570964.198	<.001
Error	10	16537.188	
Within subjects			
Forage class (FC)	4	3349979.848	<.001
P x FC	16	691168.116	<.001
Error	40	36026.840	
Year (Y)	1	34113.703	.337
P x Y	4	50526.606	.270
Error	10	33415.700	
FC x Y	4	255006.182	<.001
P x FC x Y	16	98580.609	<.001
Error	40	26767.498	

Table I-3. Analysis of variance for relative preference indices for 5 forage classes in 5 Douglas-fir plantations grazed by sheep, 1981 and 1982.

Source	dF	Mean Square	Probability
Total	149	.602	
Between subjects			
Plantation (P)	4	1.766	.006
Error	10	.256	
Within subjects			
Forage class (FC)	4	6.090	<.001
P x FC	16	.828	.008
Error	40	.326	
Year (Y)	1	1.427	.037
P x Y	4	.896	.047
Error	10	.253	
FC x Y	4	.966	.036
P x FC x Y	16	.270	
Error	40	.341	

Table I-4. Analysis of variance for percent of Douglas-fir trees with lateral browsing for 5 plantations, 1981 and 1982.

Source	dF	Mean Square	Probability
Total	35	1486.343	
Between subjects			
Plantation (P)	5	6643.667	<.001
Error	12	328.222	
Within subjects			
Year (Y)	1	3364.000	<.001
P x Y	5	2033.800	<.001
Error	12	111.000	

Table I-5. Analysis of variance for percent of Douglas-fir trees with terminals browsed for 5 plantations, 1981 and 1982.

Source	dF	Mean Square	Probability
Total	35	97.711	
Between subjects			
Plantation (P)	5	3960.111	<.001
Error	12	53.944	
Within subjects			
Year (Y)	1	498.778	.001
P x Y	5	431.044	<.001
Error	12	26.500	

Table I-6. Analysis of variance for percent of Douglas-fir trees with mechanical damage for 5 plantations, 1981 and 1982.

Source	dF	Mean Square	Probability
Total	35	2.473	
Between subjects			
Plantation (P)	5	1.978	
Error	12	2.222	
Within subjects			
Year (Y)	1	13.444	.022
P x Y	5	2.511	.343
Error	12	2.000	

Table I-7. Analysis of variance for percent of current year's growth of Douglas-fir trees browsed by sheep for 5 plantations, 1981 and 1982.

Source	dF	Mean Square	Probability
Total	35	233	
Between subjects			
Plantation (P)	5	1378.817	<.001
Error	12	28.550	
Within subjects			
Year (Y)	1	278.834	.002
P x Y	5	87.698	.010
Error	12	17.508	

TableI-8. Analysis of variance for percent soil moisture at 6 depths in grazed and ungrazed areas of OMy in August, 1981 and 1982.

Source	dF	Mean Square	Probability
Total	599	17.217	
Between subjects			
Grazing (G)	1	32.591	.244
Error	48	23.573	
Within subjects			
Depth (D)	5	12.627	.032
G x D	5	21.313	.001
Error	240	5.084	
Year (Y)	1	18.601	
G x Y	1	3.473	
Error	48	35.663	
D x Y	5	113.371	<.001
G x D x Y	5	33.286	<.001
Error	240	6.624	

Table I-9. Analysis of variance for percent soil moisture at 6 depths in grazed and ungrazed areas of YMy in August, 1981 and 1982.

Source	dF	Mean Square	Probability
Total	599	17.214	
Between subjects			
Grazing (G)	1	48.377	
Error	48	49.353	
Within subjects			
Depth (D)	5	38.291	.003
G x D	5	134.260	<.001
Error	240	10.182	
Year (Y)	1	62.447	.183
G x Y	1	121.476	.064
Error	48	34.687	
D x Y	5	36.454	.003
G x D x Y	5	3.694	
Error	240	9.898	

Table I-10. Analysis of variance for percent nitrogen in Douglas-fir needles from grazed and ungrazed areas of 5 plantations.

Source	dF	Mean Square	Probability
Total	49	.028	
Between subjects			
Plantation (P)	4	.279	<.001
Error	20	.007	
Within subjects			
Grazing (G)	1	.049	<.001
P x G	4	.002	
Error	20	.003	