Use of sheep to control weeds in a ryegrass-white clover pasture in which Knob Cone-Monterrey hybrid pine trees had been planted was investigated in Corvallis, Oregon during 1997-1998. Treatments consisted of an ungrazed control (C) and grazing applications to achieve 25 (L), 50 (M) or 75 (H) percent utilization of the understory vegetation. The treatments were applied three times between May and July of 1998 (T1, T2, and T3). Cover and phenological stage by plant group was measured after each treatment application. Two species of interest, Himalayan blackberry and bull thistle, were also studied independently of the other forbs. Their growth was measured at T1, T2, T3 and also in October of 1998 (T4). All yearling ewes were weighed at the beginning of the trial, before T1, and again after T3. Sheep used in the trial were also weighed after T2.

Initially understory vegetation covered about 90% of the ground, approximately 20% of which was perennial ryegrass (RYE). Incidence of other perennial grasses (OPG) remained constant at about 20% where ungrazed but declined from 20% to 10% during the study in all grazed treatments. Annual grasses (AG) performed similarly to OPG, remaining at 25% in C throughout the trial but declining to 8% or less in all grazed
treatments by T3. Forb cover was variable throughout the site, ranging from about 20 to 50% before initial grazing. Grazing at T1 reduced forb cover by 44% (L) to 80% (H) from initial levels. Forbs did not fully recover by T2 and constituted about 25% of the cover in C and L and <10% in M and H. Grazing at T2 reduced forb presence by 25% in L, with little change in M and H due to the low presence of forbs in those treatments. Late season forbs began to appear by T2 and were dominant by T3 when grazing reduced total forb cover to 15% in L and <10% in M and H.

Grazing also delayed maturation of all plant groups, with some affected more than others. All grazing treatments resulted in delayed RYE maturation compared to C (p<0.01). By T3 80% of RYE plants were reproductive in C, while less than 50% were scored as reproductive in grazed areas. Almost 90% of OPG in C had set seed by T2. By comparison, in the grazed treatments an average of 53% of OPG plants had set seed prior to T2 grazing and this was reduced to 13% post-grazing (p=0.0001). The more intensive grazing treatments reduced seed set compared to L (33% vs. 3%, p=0.001) but there was no difference in seed set between M and H. By T2 all AG sampled in ungrazed, control cells and 60% of AG plants in L had set seed. In M and H most were still flowering with nearly none having yet set seed (p<0.01). By T3 there was very little AG present in any of the grazed cells.

At T2 about 50% of the forbs had set seed in C while most of the remainder were still vegetative, reflecting a transition in species present from early season species to late season species. Late season forbs were actively growing at T3 and nearly all forbs in C were reproductive. In C the proportion of forbs having set seed was about 40% at T2 and T3, compared to 25% or less in any of the grazed treatments at either T2 or T3 (p<0.01). Grazing had no effect on the number of bull thistle flowers produced per plant but did reduce plant height. Thistles in C averaged 71 cm in October (T4) compared to 42 cm in L and 32 cm for M and H (p<0.01). Himalayan blackberry cane length was also
affected by grazing, reaching 81 cm in length in C by T3 but was reduced to 31 cm in L, 23 cm in M and 13 cm in H (p<0.01). No increases in cane length were observed after T3 in C. However, the canes continued to grow between T3 and T4 in the grazed treatments to achieve lengths of 37 cm (L), 41 cm (M) and 27 cm (H).

Intense grazing at T1 resulted in browsing of nearly all available pine branches in H compared to <30% browsed in L and M. Tree browsing in L was slightly higher at T2 than at T1 and was 25% higher in M. No additional browsing occurred at T3 in any treatment (p>0.3).

Sheep performance was not affected by the grazing treatments. There were no significant differences in weight gain among the three groups of yearling ewes used in the trial. Moderate levels of sheep grazing can be an effective tool to reduce competition from many undesirable species including Himalayan blackberry.
Effects of Sheep Grazing to Control Weeds in a Pine Plantation on Weed Reproductive Success, Trees and Sheep Performance

by

Lisa J. Milliman

A Thesis Submitted to Oregon State University

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Agricultural activities are being required to comply with more stringent environmental requirements, particularly with respect to surface water quality and management of riparian areas. In Oregon, passage of Senate Bill 1010 and listing of various salmon species under the Endangered Species Act is requiring reduction of water pollution from land use activities including agriculture. The Oregon Department of Agriculture has been working with farmers and ranchers to develop management plans specifically for their properties in an effort to implement procedures for effective protection of fish habitat and improvement of water quality while allowing continued use of their land for agricultural production.

Creation of a forested riparian buffer is one method that has merit for providing additional shade for streams and providing a transition between intensively used crop and pasture land and the riparian zone where sediment and nutrients can be filtered out before they reach surface waters. In addition to pollution control, forest buffers can benefit landowners economically. Timberbelts or shelterbelts have been used in New Zealand for many years (Knowles 1991), particularly in lowland areas by farmers to diversify the types of products taken from the land and to utilize lands not well suited for crops or other agricultural systems. Grazing in these shelterbelts has been used to get an early return from the land while minimizing weed growth under the growing trees. Treed buffers have also
been studied in the United States as a way of establishing a buffer zone adjacent to riparian areas, protecting these systems from runoff, nutrient transport (mostly nitrogen) and sedimentation from uplands while providing a source of income for the land owner.

Trees have been shown to remove nitrogen from subsurface water flows before reaching riparian areas and surface waters (Peterjohn and Correll 1984, Osborne and Kovacic 1993). Trees also: 1) provide shade to keep surface waters cool for fish; 2) screen out wind-borne pollutants such as aerially applied fertilizers and pesticides and 3) produce leaf litter which promotes higher infiltration rates to minimize surface runoff and soil erosion. Buffer widths of 15 to 80 meters have been suggested, depending on local soil conditions and slope (Phillips 1989). These forested strips of land can also provide a service to the landowner by providing a buffer to protect agricultural lands from weed invasions resulting from seeds carried downstream by surface waters.

Weeds are a major source of concern in both crops and pasture, both reducing land productivity and increasing production costs for weed control. While a riparian buffer intercepts water-borne weeds, they must still be controlled to prevent their invasion into agricultural lands. However, grazing in these riparian buffers is not currently a commonly accepted practice because of stream degradation observed as a result of unmanaged grazing. Overgrazing and unmanaged use of riparian areas by ranchers on public and private lands in the United States, particularly during the first half of the twentieth century, led to severe erosion, loss of habitat and degraded water quality that can still observed today in some places. As a result, many public and private agencies concerned with improving surface water quality and riparian habitat now advocate fencing riparian areas and
eliminating grazing altogether. While fencing riparian areas prevents further problems created by inappropriate grazing, it does not address the problems associated with weeds that become established in the buffer. Many of these weed species are very aggressively growing plants introduced from other parts of the world that outcompete the native plants that once grew in riparian areas and prevent re-establishment of the original plant communities.

For this study we investigated use of sheep as a weed control method. Their use under other conditions has proven comparable to use of herbicides in effectiveness, while being less expensive and potentially less damaging to water quality. Sheep can also be used in place of mechanical control of understory vegetation, especially inaccessible areas or where one has concerns about soil erosion or compaction.

Research to date provides a great deal of information on the effectiveness of livestock grazing in controlling various weeds in pastures to maintain high quality forage. Much research has also been reported concerning the use of livestock in agroforestry systems and forest plantations to keep understory vegetation from negatively affecting tree growth. The use of livestock to limit encroachment of undesirable herbaceous and woody plants into tree buffer areas and then into improved pasture and crop lands is more complicated. It encompasses a combination of objectives that may require grazing management tailored to the particular weed species present and consideration of their palatability relative to the trees. The goal of this research is to develop a better understanding of how managed livestock grazing can foster tree growth in riparian buffer areas while minimizing the influx of undesirable plants into and from this less intensively managed land. In other words, the goal is to develop sustainable grazing strategies
that balance needs for improved water quality and fish and wildlife habitat with productive uses of natural resources. The challenge is to manage the sheep to consume the ground vegetation in such a way as to maintain the desirable ryegrass and white clover and control the growth of weeds, while at the same time limiting damage to the trees by browsing, rubbing and debarking. There were three main objectives to this study. The first was to evaluate whether sheep would be effective in reducing reproductive success of an assemblage of desirable and undesirable forbs and grasses with different life cycles and palatabilities. The second objective was to determine the extent of damage to the trees that resulted from three intensities of grazing. The third objective was to evaluate the potential cost of this method of weed control in reduced productivity of the sheep measured as weight gain over the study period.
Chapter 2
Literature Review

Grazing Effects on Weed Establishment and Persistence

Invasive plants are successful in establishing themselves for a variety of reasons, but a common characteristic is that if they are allowed to mature they produce large numbers of seeds, creating soil seed banks (Wilson 1988, McDonald and Tappeiner 1986). Seeds can persist in the soil for many years, depending on the plant species, and production of new seed each year can build large seed reserves, enabling colonization of disturbed sites by quickly germinating and developing into new plants when favorable conditions arise. These conditions are most often met when large areas are disturbed such as when a forest is clearcut and the resulting logging slash is burned, leaving large areas of bare soil or when croplands are cultivated, particularly in seasons when weed seeds germinate with greatest survival rates. Grazing, particularly at high intensities, can also create patches of bare soil and hoof action, particularly when the soil is wet, can bring stored seeds to the surface where they can germinate.

While grazing is most commonly associated with contributing to conditions that favor plant invasions, cessation of grazing can also contribute to the establishment of plant species in areas where they did not dominate while grazing continued. Grazing limits the growth and seed production of grazed plants and the formation of litter. When grazing is discontinued, the plants are free to grow to their natural height, which favors the taller plants, and increased seed production provides for increased dominance of these plants in subsequent years. The accumulation of litter resulting from uncontrolled plant growth and senescence
protects the soil from drying out and reduces erosion but can also decrease the amount of light available at the soil surface needed by seedlings and low growing species (Green and Kauffman 1995). These conditions favor establishment and dominance of perennial plants that can reproduce by vegetative means (Foin and Hektner 1986). Cessation of grazing has also been found to lead to a decrease in species diversity, particularly where plants that produce chemicals or have growth habits that interfere with the establishment of other species (Anderson 1994).

Where opportunistic, well-adapted alien species have been introduced it is unlikely that native species can reestablish formerly existing plant communities, even though they are well adapted to each other and to the physical environment in which they evolved (Foin and Hektner 1986). Grazing, burning and mowing was discontinued in former sheep pastures in the northern California coastal prairie and successional changes in species composition was studied over a four year period. The authors found that while native species were present throughout the study period, they represented a low percentage of the cover and introduced perennial grasses dominated. Even though several native species known to be highly competitive in the coastal prairie were not well represented in the study area, the authors concluded that based on previous research, the introduced species were so opportunistic and well-adapted, they were likely to continue their dominance of the prairie community. Grazing has variable effects on plant reproductive success and species dominance depending on the season and intensity of grazing. In general, however, grazing gives an advantage to lower growing species and plants otherwise adapted to grazing that would decrease in abundance as succession proceeded under ungrazed conditions. Effects of season and grazing intensity on bull thistle (Cirsium vulgare) seed germination was studied by Michaux (1989) in an
area of New Zealand with wet winters and dry summers. The author found equal
germination between the current year's seeds and seeds stored in the soil seed
bank that were brought to the soil surface. He suggested that high intensity grazing
during the wet winter months brought seeds to the soil surface when conditions
promoted high levels of seed germination.

Grazing plants at certain stages of their life cycle can reduce the number of
seeds contributed to the soil seed bank. Repeated grazing has been found to
reduce seed production in many species, an effect that is most pronounced under
environmental conditions favoring high seed production (Bastrenta 1991). Bastrenta
studied the effects of short duration high intensity grazing compared to low intensity
grazing for the entire growing season and no grazing on *Anthyllis vulneraria*, a
rosette-forming legume growing in a Mediterranean climate in southern France.
Less than one seed per plant was produced during the first year of the study
regardless of treatment. During the second year of the study, when environmental
conditions were more favorable for seed production, over 250 seeds were produced
per plant in the ungrazed quadrats compared to fewer than 90 seeds per plant in
either grazed treatment. Repeated low intensity grazing resulted in fewer seeds
produced than for the single round of intense grazing.

A study of spotted knapweed (*Centaurea maculosa* Lam.) found that
repeated short duration, high intensity grazing for three years resulted in 75 to 95%
utilization of the spotted knapweed and about 75% fewer seeds recovered from the
soil seed bank compared to ungrazed areas (Olson et al. 1997). Grazed plants
produced an average of five flowering stems per plant compared to three per
ungrazed plant; such compensation increased the need for a long-term
commitment to timely, repeated grazing to keep spotted knapweed under control.
A study of exclosure of native herbivores from a British grassland composed of a variety of grasses and forbs demonstrated that grazing can reduce the number of seeds contributed to the soil seed bank. A five year exclosure of rabbits from plots in the grassland doubled the number of germinable seeds in the soil (Edwards and Crawley 1999). Compared to ungrazed conditions, seven of the nine most common plant species produced significantly fewer flowerheads when exposed to rabbit grazing. Reduced seed production was attributed to either removal of the flowerheads by the rabbits or lower availability of resources for plant reproduction.

Sharrow and Mosher (1982) found that intensive grazing of tansy ragwort (Senecio jacobaea), a biennial forb, by sheep is effective in reducing its ability to flower and produce seed. Cattle grazed a site in western Oregon in the spring to 20 percent utilization after which sheep were introduced in part of the area in the early summer, resulting in a total utilization of 80 percent by early August. While overall tansy ragwort mortality was similar in both treatments, the cattle-followed-by-sheep treatment resulted in the death of most ragwort plants before seeds were produced and reduced mortality resulting from completion of flowering and seed production (normal for biennials) to 3 percent compared to 55 percent in the cattle only treatment.

In some plant species, grazing apparently does not affect the total number of seeds produced but does affect seed size and viability. A study of defoliation on curly dock (Rumex crispus) found that while there was no change in the total number of seeds produced by grazed plants, there was a decrease in overall seed weight (Maun and Cavers 1971). Removal of cauline leaves soon after the plant bolted and the leaves had fully expanded (mid May) resulted in smaller seeds that germinated more rapidly and under more diverse conditions than larger seeds. As a
result, the new seedlings were less vigorous and fewer seeds were contributed to the seed bank.

Seed characteristics of primary, secondary and tertiary umbels produced by the biennial forb wild parsnip (*Pastinaca sativa*) were compared in a study of mature seed collected from 16 plants collected in an Iowa old field (Hendrix 1984). Removal of the primary inflorescence such as by grazing resulted in growth of more lower order inflorescences to compensate for loss of the primary inflorescence. While there was no change in number of seeds produced by lower order inflorescences compared to the primary inflorescence, lower germination rates and more incidences of fall germination resulted in higher rates of seedling mortality.

One drawback of grazing can be enhanced germination of weed seeds in response to additional light reaching the soil surface. Edwards and Crawley (1999) studied seedling emergence in artificially created gaps equivalent to those created by moles and rabbits in a grass/forb grassland. The authors compared gaps from which above ground vegetation had been removed to gaps where the soil had been removed and sterilized to kill any propagules present. Nearly 2,000 seedlings emerged in the gaps, 97 percent of which emerged in the fall, soon after creation of the gaps. Only five seedlings of the five species present only in the soil seed bank emerged. Of the 17 species present in both the vegetation and the seed bank, only one had greater seedling density in the treatment that allowed recruitment from both current year’s seed production and the seed bank. These results indicate that despite recruitment to the seed bank, the source of most seedlings recruited into the pasture was the current year’s seed production. Gaps in the cover created by grazing close to the time of seed dispersal by the plants present in the pasture and
The limited amount of soil disturbance occurring as a result of grazing provided little opportunity for seeds in the soil to come to the surface and germinate.

In some cases, the timing of gap creation has been found to be more critical to plant establishment than the reduction of competition from more dominant species. A study of species richness in a grassland in England comparing the effects of low intensity sheep grazing in winter and spring and two levels of short duration, moderate intensity grazing in summer found that gaps created by grazing in winter and spring seemed to favor establishment of forbs more than reduction of competition from dominant grasses by summer grazing (Watt et al. 1996). Winter grazing increased big chickweed (*Cerastium fontanum*), spring grazing decreased soft chess (*Bromus hordaceous*) and both winter and spring grazing or neither winter nor spring grazing increased crested dogtail (*Cynosurus cristatus*; Watt et al. 1996).

A study of the effects of season of grazing comparing low-intensity season-long sheep grazing in winter, spring and/or summer in a mixed grass pasture in England found similar results for bull thistle (*Cirsium vulgare*), a biennial forb. Intense summer or winter grazing favored establishment of bull thistle by increasing soil surface area with no canopy or litter, that, in turn, increased seedling survival (Bullock et al. 1994).

Gap size can also be a factor in successful establishment of invasive plants. Watt and Gibson (1988) found that small seeded forbs required larger gaps for successful establishment than larger seeded forbs and grasses. This difference was attributed to lower seed reserves in the small seeds, which limited ability of seedlings to grow through litter at the soil surface and become established and competitive with adjacent plants. By the spring sampling in the second year, high
intensity, short duration grazing in spring resulted in bare ground over about 2 percent of the area compared to 1 percent in the no grazing treatment. The season long autumn and summer treatment resulted in over 7 percent bare ground. Seedlings of Bromus species established in gaps less than or equal to 0.16 mm in diameter more often than the forbs, while the forbs, composed primarily of the small seeded species *Crepis capillaris* and *Prunella vulgaris*, established more readily in gaps greater than 3.2 mm in diameter. Almost no forb seedlings were recorded in the no grazing treatment, while 10 forb seedlings per square meter were recorded at each sampling period during the study in the short duration spring grazing and 10 to 80 per square meter in the summer and autumn season long grazing, depending on date of sampling. The treatments that included autumn grazing resulted in much more variability in the number of new seedlings recorded with the highest numbers recorded in March and April of the second year of the study.

Carefully managed grazing can improve pastures and minimize weed establishment if the preferred species are maintained so as to provide a dense cover of vegetation (Michael 1968a, Carter 1970, Sindel 1991). Variegated thistle (*Silybum marianum* L.) plants were removed from a site in Australia that was subsequently sown to various perennial and annual pasture species to study the effectiveness of these species in controlling germination of thistle seeds present in the soil seed bank (Michael 1968a). The author found that alfalfa (*Medicago sativa* L.) sown in the spring provided complete control of these annual thistles in the year following sowing and *Phalaris tuberosa* L. reduced the weight of dry matter produced by the thistles. Reduced thistle production was attributed to depressed thistle size rather than fewer plants. Two annual pasture species studied, annual ryegrass (*Lolium rigidum*) and subterranean clover (*Trifolium subterraneum* L.),
were not effective in reducing thistle numbers or size. The success of spring-sown alfalfa was attributed in part to the fact that variegated thistles germinate primarily in the fall and do not compete with crops sown the following spring. The alfalfa would be expected to have been well established by fall and provided a dense, vigorous and competitive pasture when the thistles would normally have germinated and seedlings become established (Sindel 1991).

Timing of grazing can be important in affecting the species composition of the grazed site by reducing competition from other species at critical stages of a plant's life cycle. Bullock et al. (1994) found no significant effect of grazing on number of flowerheads, but the season of grazing affected different parts of the lifecycle. Seedling emergence and rosette survival and the percentage of large rosettes that flowered increased under winter but not spring. There was no difference in the number of flowers per flowering plant (except winter 1992), percent viable seeds, or number of seeds per flowerhead. Grazing apparently affects the number of plants that become established rather than seed production or viability by a single plant.

Timing of grazing to benefit desirable plant species, increasing competition from grasses, can have an affect on both weed survival and seed production. A four year study of the effects of sheep grazing on a bull thistle (Cirsium vulgare) infestation in an annual ryegrass/subterranean clover pasture found that the season of grazing was important to establishment of a dense cover of ryegrass in the fall which provided competition at the seedling to rosette stage (Forcella and Wood 1986). Sheep grazed in part of the site at 10 animals per hectare whenever forage was available for a three-year period. After the first year grazing had no effect on the number of flowerheads produced per plant, however in the subsequent three
years an average of 34 flowerheads per plant were found in the grazed treatment compared to 19 in the control. When seed production was compared there was a difference (26,371, grazed vs. 1,833, ungrazed, measured in seeds per square meter) only in a wet year.

Grazing can give a competitive advantage to plant species that are tolerant of grazing or are avoided by the herbivore. Grazing can also affect plant growth characteristics that can, in turn, affect the plant’s palatability to the herbivore. During a two-year study of low intensity sheep grazing a weedy ryegrass-subterranean clover pasture in southern Tasmania, Bendall (1973) found spring grazing favorably altered species composition in pastures. The grazing treatment increased the frequency of perennial ryegrass and subterranean clover and reduced the frequency of weed grasses and slender thistles (*Carduus pycnocephalus* L. and *C. tenuiflorus* Curt.). All combinations of autumn, winter and/or spring grazing were studied. Spring grazing increased the ryegrass and forbs while decreasing annual grasses. Absence of autumn grazing resulted in reduction of the number of slender thistles present, which was attributed to etiolation of the thistles in response to competition with the other species, which were then consumed by the sheep. This reduction did not carry over to the following year, indicating that a long-term commitment to grazing would be required to control the thistles.

Plant response to grazing is extremely variable, depending on the timing of herbivory with respect to plant growth stage, environmental conditions at time of grazing and the life cycle of the plant. Life-form has an effect on plant response to herbivory; annual and short-lived perennials are usually less tolerant of grazing than perennials. Annual grasses and, to a lesser extent, short-lived perennial forbs also
declined in response to 10 days of spring grazing by sheep in an old field in England, the annual grasses comprising less than one tenth the abundance measured in control cells after fall growth had resumed (Gibson et al. 1987). Conversely, most perennial grasses, even though they are highly palatable to sheep, increased in abundance in response to grazing.

Plants can usually respond favorably to grazing that occurs early in the growing season, often growing larger or producing more seeds than if they hadn't been grazed, while plants grazed later in the season often produce fewer seeds (Briske 1990). Maschinski and Witham (1989) studied response of *Ipomopsis arizonica*, a native monocarpic forb that usually fruits in the second year, to grazing at different stages in its lifecycle. The study included comparison of simulated grazing (clipping of 95 percent of the above ground biomass) on May 2, May 30 and June 12 in different years. The authors found that clipping before May 30 had no effect on subsequent fruit set while later clipping significantly reduced fruit set.

Grazing intensity can interact with the timing of grazing, resulting in more pronounced effects on plant growth early in the growing season and less effect late in the season, even at higher grazing intensities. Reduced plant production among some plant species in a community can change the species composition, at least temporarily. Response of grazing-intolerant tussock grasses *Themeda triandra* and *Chrysopogon fallax* to season of defoliation and preferential selection by herbivores was studied in a monsoon grassland in northern Australia over a two year period (Ash and McIvor 1998). Cattle grazed the study area for three eight week periods in summer (early wet), late summer (late wet) and spring (dry) to achieve utilization rates of 15, 30 and 45 percent. Moderate and high utilization grazing early in the wet season resulted in undercompensation by the perennial
grasses (reduced tillering and seed production) and increasing the abundance of annual grasses and non-leguminous forbs. Standing biomass production in the medium and high utilization treatments occurring during the early wet season were 80 and 60 percent of that measured in the low utilization treatment. High utilization late in the wet season had a smaller negative effect at 70 percent of the production measured in the low utilization treatment. The grazing treatments occurring during the wet season affected species composition of the grassland for two years after grazing event, but there was no effect when grazing occurred during the dry season.

When seeds of *Geranium dissectum*, a plant that is palatable to sheep, were sown into an old field and subjected to the grazing treatments described by Watt et al. (1996) and Silvertown and Smith (1989), the effects of grazing on plant reproductive success depended on the intensity of grazing and the life stage at which the plants were grazed. Absence of grazing in the winter favored establishment of seedlings, while in the spring the small plants were out-competed by other species. Intense grazing during all seasons allowed seeds to germinate but didn’t allow completion of the life cycle.

The relative palatability of weeds compared to desired species in a mixed sward can be very important in the effectiveness of grazing for weed control. Many weeds have spines or thorns or have chemical defenses against herbivory and specialized grazing management is needed to ensure that these plants are grazed sufficiently to control them. Hartley et al. (1984) studied the effects of different sheep grazing treatments on Californian thistle (*Cirsium arvense*) numbers in an established pasture in Australia. The authors found that sheep would graze soft, new shoots under moderate stocking pressure but extreme pressure was required
to induce sheep to consume mature plants. Hard rotational grazing at 66 sheep per hectare for four days at a time throughout the spring and summer resulted in a reduction in thistle numbers of 95 percent. Medium rotational grazing at 50 sheep per hectare for three days at a time throughout the spring and summer reduced thistle numbers by 46 percent. Light rotational grazing at 33 sheep per hectare for two days at a time increased thistle numbers by 69 percent. Hard set stocking had an effect on thistle numbers similar to moderate rotational grazing.

A study of sheep and goat effectiveness in controlling *Rubus* species and *Smilax rotundifolia* L. in an old field in West Virginia found that goats stocked at 20 animals per hectare reduced brush cover from 45 percent to 15 percent after one year while sheep stocked at the same rate provided the same level of control after three years (Dabaan et al. 1997). Grazing effectiveness was maximized when the rotations were started early in the growing season and the stocking rate was high enough to force the animals to remove most of the vegetation present in the grazed area.

Grazing can be managed to encourage under- or over-compensation by the forage plants, depending on whether the plant species are desirable or undesirable, however frequent grazings may be required to affect the survival of some grazing-tolerant undesirable species such as cheatgrass (*Bromus tectorum*; Pyke 1987). The author studied the effects of small mammal grazing on cheatgrass, an annual grass and bluebunch wheatgrass (*Agropyron spicatum* L.), a native perennial, in eastern Washington State. Plants were grazed to the soil surface at each grazing. Initial grazing at a plant age of 7 days lowered survival for cheatgrass but older plants were not as clearly affected. Initial grazing before 30 days reduced survival for bluebunch wheatgrass. When cheatgrass was grazed weekly during the autumn
and winter survival declined to 53 percent, while less frequent grazing increased survival to 65 to 75 percent. Weekly and biweekly grazing of bluebunch wheatgrass during this period resulted in 11 percent survival and less frequent grazing increased survival to 40 percent.

Developing a grazing plan which favors desirable species while putting undesirable species at a disadvantage can be complicated when a wide variety of species coexist and mature over an extended period. For instance, in the California annual grasslands, some species including filaree (*Erodium botrys*) and wild oat (*Avena barbata*) set seed over an extended period throughout the spring, while others, including some undesirable species such as medusa head (*Elymus caput-medusae*) and tarweed (*Madia spp.*), mature late in the growing season (Heady 1961). Grazing is most effective in limiting reproductive success of undesirable plants when it coincides with vulnerable plant growth stages prior to seed set; therefore, multiple grazing bouts may be required to control individual species that mature over an extended period or where there are several undesirable species maturing at different times.

**Grazing in Tree Plantations**

Tree seedlings planted after a tree harvest compete with understory vegetation that regrows from roots remaining in the soil after site preparation or sprouts from seeds brought to the soil surface. Many of the understory species are woody plants that grow very quickly and can retard tree growth or even lead to tree seedling mortality. Aerial seeding of pasture grasses in clearcuts is sometimes used to control brush growth with the formation of a dense grass cover that inhibits establishment of brush while reducing competition with the trees. Trees are also
planted in established pasture as a means to increase income from the land (Knowles 1991). Whether trees are grown as the only product with understory vegetation consisting of native or introduced shrubs, brush, forbs and grasses or are planted as an added product in improved pastures, the trees compete with the understory vegetation for nutrients, moisture and light particularly for the first few years after planting (Coates et al. 1991).

Various methods of vegetation control have been studied, including mechanical removal, application of herbicides and livestock grazing. The use of livestock grazing in tree plantations has been found to be a very promising alternative providing adequate weed control to reduce competition with trees and reduce fire hazard from dry underbrush, while often costing less than other alternatives. A comparison of costs of weed control by herbicides and sheep grazing in a coastal Oregon Douglas fir plantation found that herbicide control of brush was estimated at $143 per acre, herbicide control of grass was $110 per acre, while grazing costs were only $10 per acre per year when all operational costs are included (Krueger 1985).

Understory vegetation control has been found to significantly improve tree growth. Eight levels of manual cutting and chemical control of shrub and forb cover on survival and growth of Engelmann spruce (Picea engelmannii Parry), lodgepole pine (Pinus contorta Dougl.) and subalpine fir (Abies lasiocarpa (Hook.) Nutt.) were studied in south central British Columbia to observe the effects of competition in a harsh environment (Coates et al. 1991). The authors found that after three years, mean seedling diameter was 44 and 84 percent greater for spruce and pine trees, respectively, when understory vegetation was controlled than for seedlings grown under unmanaged conditions. Spruce height was significantly increased (22
percent) only when the understory vegetation was completely removed. Pine height was significantly affected by either partial removal or complete control of understory vegetation, with complete control resulting in a 38 percent increase in height.

Sheep grazing has also been found to increase tree growth. Growth in height and diameter of Douglas fir (*Pseudostuga menziesii*) seedlings planted in a burned clearcut in western Oregon was studied in plots grazed by a herded flock of sheep for three to four days in spring and again in summer (Sharrow et al. 1992). The understory vegetation was a vine maple (*Acer circinatum*) - sword fern (*Polystichum munitum*) community which also included various native blackberries (*Rubus* spp.) and alder (*Alnus rubra*) into which orchardgrass (*Dactylis glomerata*) was aerially seeded to impede growth of unwanted woody vegetation and improve wildlife habitat. After 10 years of grazing, average tree diameter was increased by 22 percent in the grazed plots compared to the ungrazed plots, while tree height increased by 6 percent.

Concerns about the use of livestock in tree plantations center mainly on damage to the trees by the livestock through browsing, bark stripping, trampling and rubbing (Adams 1975, Krueger 1985, Knowles 1991). Sheep are often selected as the preferred species for several reasons. Their small size limits how high they can browse should they develop a preference for trees (about 1.0 meters; Pearson 1931). Sheep also prefer a variety of grasses and forbs in their diets and will consume many weed species that cattle will not, but sheep are less likely to develop a preference for the trees than are goats (Wood 1987). Use of sheep to control ground cover in pine plantations may result in some damage to the trees by the sheep, however, it has been found that the trees can tolerate the removal of up to 50 percent of foliage before growth is appreciably reduced (Sharrow et al., 1992).
Even at understory utilization levels of up to 68% the authors found that fewer than 5% of the terminal leaders were browsed and the trees that were damaged tended to be the smallest ones. Such trees would most likely be removed at pre-commercial thinning, regardless of damage caused by livestock.

An early study of a young southwestern United States forest plantation subjected to severe overgrazing by both sheep and cattle found that few of the injured trees died as a result of browsing and these were mainly smaller trees that suffered complete defoliation (Pearson 1931). The western yellow pine seedlings had been previously subjected to more than five years of browsing damage by cattle and sheep. The authors found that once the trees reached three feet in height, they were seldom defoliated in excess of 50 percent, but trees less than three feet in height were sometimes defoliated up to 90 percent. Of 87 trees originally identified in 1914, 57 were classed as being moderately or severely injured. Heavy stocking of cattle and sheep continued through 1926. The trees were observed again in 1928 when only 71 were found, with the remaining 16 lost presumably to logging operations that had occurred in the interim. Seven trees died as a result of grazing and all seven were in the lowest height class of trees classified as severely injured. The remaining trees grew at average rates of 0.18, 0.63 and 0.47 feet annually for severely injured, moderately injured and uninjured trees, respectively. The author recommended that pine seedlings be protected from browsing until they are three years old, after which only repeated severe browsing is likely to kill the trees.

Lewis (1980) reported similar results in a study of the effects of simulated grazing damage on slash pine (Pinus elliottii Engelm.) seedlings in Georgia at 6,18 and 30 months after planting. Treatments included clipping needles to 0, 50 or 100
percent of the length, removing new shoot growth to 0, 50 or 100 percent, bending
stems, and combinations of the above. Only the highest levels of the treatment
resulted in mortality that was significantly greater than the control, even for
seedlings treated as early as six months after planting. Only complete defoliation of
the seedlings at six months after planting resulted in permanent effects; the
combination of all treatments at the highest intensity resulted in trees that were 50
percent as tall as the untreated trees six years after treatment. When applied at 18
months, the harshest combination of treatments reduced tree height by 1.5 meters
(30 percent) after six years. The harshest combination of treatments applied at 30
months reduced tree height by 1.2 meters (19 percent) after six years.

Pine needle consumption and bark stripping by sheep grazing in a pasture
into which pine trees were planted were studied to measure effects of tree planting
density and season of grazing on amount of tree damage (Anderson et al. 1985).
*Pinus radiata* and *P. pinaster* were planted in an unfertilized and ungrazed
Australian pasture at densities of 250, 500 and 750 trees per hectare (*P. radiata*)
and 440 trees per hectare (*P. pinaster*) and then stocked at six to ten sheep per
hectare to study the incidence of sheep consumption of needles or bark stripping.
Consumption of *P. radiata* needles, estimated from fecal samples, was highest at
266 grams per sheep per day declining to 125 grams during the spring and 77
grams in summer. Needle consumption was higher at low tree densities (250 per
hectare) and in the *P. pinaster* treatment than at higher tree densities or in the *P.
radiata* treatment. Bark stripping was observed at low levels beginning in the spring
in the low density *P. radiata* treatment and increased to affect about 10 percent of
the trees in the low density *P. radiata* treatment in the summer. Forty percent of the
trees shorter than four to five meters were affected compared to less than 25
percent of the taller trees. Tree damage was found more often near areas where sheep congregated than elsewhere. The authors suggested that rotational grazing could result in less damage to trees than set stocking as indicated by observations of sheep behavior during sheep management activities that were not part of this study.

The probability that trees will be browsed depends in part on the relative palatability of the trees compared to the understory vegetation. Leininger and Sharrow (1987) studied seasonal sheep diets in four-to-six-year-old Douglas fir plantations with a vine maple-sword fern (Acer circinatum-Polystichum munitum) understory compared to two-year-old Douglas fir plantations that were seeded with orchardgrass (Dactylis glomerata) and perennial ryegrass (Lolium perenne). Ewes and lambs grazed the plantations, spending a few days in each once per year during May, July or August in the older plantations and the July-grazed younger plantation and twice per year (May and August) in the remaining younger plantation. Relative preference indices for forbs and grasses were higher than for ferns, browse or Douglas fir in all treatments and were usually above 1.0, indicating the sheep actively selected forbs and grasses. The relative preference index of Douglas fir (0.60 in 1981 and 1.08 in 1982) was highest in the early-grazed plantation with the younger trees, although sheep diets never contained more than three percent Douglas fir.

Different tree species also range in palatability to sheep with deciduous trees normally more palatable than conifers. Among conifers, spruce (Picea spp.) is relatively unpalatable to sheep, followed by Douglas fir, and pine (Pinus spp.) being most palatable (Newsome 1996). Browsing damage can be minimized when relatively unpalatable tree species are grown with highly palatable understory
vegetation and grazing occurs during seasons when the understory is not yet mature but the new growth on the trees has hardened off. Use of an alternative grazing area to which to move the sheep should they begin to browse the trees excessively can further decrease the probability of browsing damage to trees (Newsome 1996, Sharrow 1994, Thomas 1989).

**Effects of Weed Grazing on Sheep Performance**

Use of sheep to control weeds can be expected to have an adverse effect on sheep performance. One reason for this is that weeds are usually less palatable than improved forages due to lower nutritional value or more rapid declines in nutritional value as the plants mature. The presence of toxic compounds or thorns or other mechanical anti-herbivory defenses can also result in avoidance by grazing animals.

Landgraf et al. (1984) found that ewes grazing in leafy spurge-infested pastures in Montana initially consumed low amounts of the weed but increased consumption to 40-50% of their daily dry matter intake. No significant differences in weight gain were found when ewes on leafy spurge-infested pastures were compared to ewes on weed free pasture.

Percival and Knowles (1983) found that when radiata pines are planted in New Zealand ryegrass/white clover pastures, pasture productivity declined as the tree canopy reduced light available to the understory vegetation. Pruning debris also killed underlying pasture species. Annual grasses including Poa species, sweet vernal (*Anthoxanthum odoratum*) and goose grass (*Bromis mollis*) increased in abundance and weeds such as thistles (*Cirsium arvense, Carduus nutans*), inkweed (*Phytolacca octandra*) and blackberries (*Rubus spp.*) invaded in areas
were pruning debris prevented grazing. Ewes which grazed for 12 months in pastures planted with pines at a density of 200 trees per hectare averaged seven kilograms lighter than ewes grazed on open pasture. The researchers speculated that the difference in weight gain may have been due to: 1) ingestion of sufficient pine needles to affect weight gain, 2) the decline in the portion of white clover in the ryegrass/white clover pasture because of tree shading, or 3) thinning and pruning debris left on pasture may have decreased the density of forage present.

When weight gains among sheep grazing in forest plantations is compared to gains for sheep grazing pasture sheep usually gained more weight on improved pasture (Hall et al. 1959, Black and Vladimiroff 1963, McKinnell 1975, Leininger et al. 1989). Hall et al. (1959) had mixed results where occasionally sheep gained more weight in forest plantations than on pasture. The authors attributed this to the presence of more legumes in an open-canopied forest regeneration than in the pasture.

Lactating ewes grazing from late spring to late summer in clearcuts in a Douglas fir plantation in Oregon's Coast Range lost weight while their lambs gained an average of 14.2 kg (Sharrow and Leininger 1983). Ewe weight loss was attributed to both the high energy demands of lactation and the declining forage nutritional value as the undergrowth matured. However, ewes with lambs grazing in a Douglas fir plantation in southwestern Oregon made average daily gains of almost 0.6 pounds during the late spring (Black and Vladimiroff 1963). Merino wethers grazing in an Australian radiata pine agroforest gained more than 18 kg per head from June to December then lost about 5 kg per head during the dry summer months when most forages were not actively growing (Anderson et al. 1985). This performance pattern was similar to sheep grazing pasture with no trees.
Sheep performance is influenced by nutritional needs that are affected by the age of the animal and its reproductive status. While some classes, including young lambs and lactating ewes have high nutritional demands, other classes may not need high quality feed if weight gain is not important (National Research Council 1985). Sheep with low nutritional needs might be expected to maintain weight while grazing weeds unless the weeds are of such low palatability that the sheep refuse them.

Weed species vary considerably in nutritional value, with many species approaching that of cultivated forage species (Marten et al. 1987, Landgraf et al. 1984, Leininger et al. 1989, Bell et al. 1996, Ralphs and Pfister 1992). Weeds like leafy spurge often have nutritional levels and palatability comparable to cultivated forages and are readily consumed by sheep with no negative effect on sheep performance (Landgraf et al. 1984). One major difference between weeds with high nutritional value and improved forages is the rapid decline in digestibility often seen in maturing weeds (Bosworth et al. 1985). Some species, such as Canada thistle have higher in vitro digestible dry matter (IVDMD) concentrations than alfalfa (Marten et al. 1987) but are of little value to sheep because they are not palatable.

Grazing management could also be expected to have an impact on sheep performance because the sheep are managed to decrease their selectivity and prevent less palatable species from having a competitive advantage. A study comparing continuous to rotational grazing on a fertilized ryegrass (Lolium perenne)/subterranean clover (Trifolium subterraneum) pasture with about 14 percent annual grasses and forbs found no difference in sheep performance between the two systems of grazing management at moderate stocking rates during the spring green feed period (Sharrow and Krueger 1979, Sharrow 1983).
Control of weeds can be very complex when there are many species of weeds of varying palatability and maturing at different times of the year. The situation is further complicated when weed control is planned for an area where trees are planted because the trees may become more palatable than the target weeds. However, the risk of damage to trees can be lessened if precautions are taken to match grazing management to site conditions.

If possible, trees should be selected that are the least palatable to the grazing animal and best suited for site conditions. Grazing should resume soon after tree establishment to limit ingress of weeds. If possible, grazing should be timed to avoid tree bud break and when new growth is soft and green, but also when weeds are most palatable. Sheep bedding areas, sources of water and fencelines should be located away from the trees. Sheep behavior should be watched, and individuals particularly prone to damaging trees should be removed from the area as soon as sustained tree browsing is noticed. Multiple rounds of grazing may be required to provide best control of weeds and prevent many of them from setting seed, particularly if early, middle and late season species are present or if the species present are grazing-tolerant. Several rounds of short duration grazing can minimize potential effects on sheep performance if the sheep are put on good pasture when they are not controlling weeds. Use of animals with relatively low nutritional needs (dry ewes or wethers) will also minimize the potential for poor sheep performance.
Chapter 3
Materials and Methods

Site Characteristics

This study was composed of several elements including: 1) pasture species composition changes as a result of sheep grazing, 2) effects of sheep grazing on two particular weed species (bull thistle and Himalayan blackberry), 3) amount of browsing by the sheep of the KMX pine trees growing in the study area and 4) effects of the grazing treatments on sheep performance. The study site was located at the edge of a ryegrass (*Lolium perenne*) pasture along Oak Creek in Corvallis, Oregon. This location has a Mediterranean climate with warm, dry summers and cool, wet winters. Mean monthly temperatures range from 4°C in January to 19°C in August. Monthly precipitation averages range from 19.6 cm in December to 1.3 cm in July, with an annual average of 108.5 cm. January through May of 1998, the year of the study, was wetter and warmer than average, June was average in both temperature and precipitation and July was warmer and slightly drier than normal. The site is comprised of Bashaw clay and Waldo silty clay loam, two poorly drained alluvial soils commonly found along streams and drainages of foothill valleys (Knezevich 1975).

The site was fenced off from the rest of the pasture around 1990 and planted with Knob Cone-Monterey cross (KMX) pine trees. No cultivation, grazing or other management of the understory herbaceous plants occurred after this area was fenced from the rest of the pasture. The ground cover in the study area initially consisted of ryegrass and small proportion of other grasses and forbs similar to the portion of the pasture that remained in use for grazing and hay production. During
the period between tree planting and the start of this study a variety of herbaceous and woody plants became established in the pine plantation. Ryegrass was the dominant species on the southern quarter of the grazing cells, adjacent to the pasture, composing 50 to 90% of the cover at the initial sampling, prior to first grazing. Ryegrass cover decreased with proximity to Oak Creek to compose only 0 to 10% of the cover in the northern quarter of the grazing cells. Canada thistle, bull thistle and Himalayan blackberry, as well as over 20 other forb and grass species, were scattered throughout the study area. The pasture continued to be grazed by sheep and cattle, mown for hay and fertilized during this time and the pasture species composition was mainly ryegrass with some meadow foxtail and white clover. The only thistles apparent in the pasture grew along the fence lines at the perimeter of the pasture. The area between the trees was cut in late October 1997 to reduce standing dry matter. Vegetation was allowed to regrow without further manipulation until sheep were introduced for the first grazing in early May.

Methods

The study site was subdivided with three strands of electrified polywire into 12 adjacent rectangular grazing cells, each measuring 13.6 m by 33.3 m (slightly less than 0.04 ha) and extending from the pasture boundary toward Oak Creek (see figure below).
The cells were grouped into three blocks of four cells each. Four grazing treatments were allocated to cells within each block in a randomized complete block design. The four treatments consisted of an ungrazed control (C), and low (L), moderate (M) and high (H) intensity grazing intended to utilize 25%, 50% and 75% of the available forage, respectively. Actual average grazing intensity for the High treatment was lower (53%) than intended because the sheep had to be removed from the cells before target utilization was achieved when they began browsing trees. Grazing treatments were applied in early May (T1), late June (T2), and late...
July (T3) using two groups of ten yearling ewes. Grazing bouts lasted from one to four days per cell depending on treatment; sampling was conducted immediately post-grazing.

Prior to the grazing of each cell, ten paired 0.1 m$^2$ quadrats were identified in each cell and one of each pair was protected from grazing by a wire exclosure cage. Following grazing, canopy cover and plant phenological stage were recorded in all 20 quadrats using an inclined (45°) 10-point frame (Levy and Madden, 1933). The first plants contacted as the pins were lowered in the 10 channels of the frame were recorded as to species (or non-living material (NLM) if bare ground or no living plant part was hit by the pin) and phenological stage (vegetative, flowering, or set seed). Both grazed and ungrazed quadrats were then clipped, and the plant matter was dried and weighed to estimate forage utilization for the cell. Cover and phenology were measured in control cells but the quadrats were not clipped. A list of plant species encountered and group to which they were assigned is provided in the Appendix.

Prior to first introduction of the sheep, ten thistle plants were randomly selected in each cell for study. A transect with permanent endpoints was established in each cell, and the location of plants was recorded as distance from the north end of the transect and lateral distance and direction from the transect line. Plant height and number of flowerheads were measured for each thistle plant after each of the three grazing bouts and again on October 11, 1998 (T4). No grazing occurred between T3 and T4, a time when most plants were not actively growing.

With one exception, ten Himalayan blackberry plants were identified in each cell prior to first introduction of the sheep; Cell 12 had only six plants - all were
included in the study. A transect with permanent endpoints was established in each cell, and the location of plants was recorded as distance from the north end of the transect and lateral distance and direction from the transect line. Length of the longest cane present on each blackberry plant was measured after each of the three grazing bouts and at T4.

There was an average of 37 KMX hybrid pine trees (*Pinus attenuata* × *P. radiata*) in each grazed cell. The trees were planted approximately eight years prior to this study, however most of the trees did not prosper due to unknown factors which may include competition with the ground cover, extremely wet soils in the winter and spring or location of the site in a low spot that is colder than the surrounding area. Tree height ranged from 45.7 cm to 276.9 cm. Tree height was greatest in the western third of the study area and blocking was used in the experimental design to account for the difference in tree height. Comparisons of the proportion of branches within reach of the sheep (about 1.0 m, Pearson 1931) that were browsed were used to determine the effect of grazing intensity on level of tree browsing. A branch was considered browsed if any needles or portions of needles were removed or tips of branches had been removed. In some cases, particularly in the High treatment, all needles and green growing tips of branches were removed by browsing. The number of branches that were browsed was counted after each of the three grazing bouts for each of the trees present in each grazed cell. Only new branches browsed or branches rebrowsed were counted at T2 and T3.

Thirty yearling ewes were randomly selected from 90 yearling ewes available from the Oregon State University (OSU) flock. Five white face and five black face cross ewes were randomly selected for each of three trial groups to equalize the potential effects of beginning weight and genotypic differences in rate
of gain on weight change over the trial. The three groups were randomly assigned to graze the low and moderate treatments, the high intensity treatment and control. The ewes used in the trial were managed separately from the remaining yearling ewes to avoid having to sort a large number of ewes prior to each round of grazing. Two groups of ten ewes grazed the pine plantation in early May, late June, and late July for seven to 14 days each time, depending on the amount of forage present and the length of time required to achieve the specified level of utilization in each grazing cell. One group of ewes was used in the low and moderate intensity treatments and the other group was used in the high intensity treatment. The third group of ten ewes was kept in the areas used to hold the other two groups of sheep in between rounds of grazing as the control. This control group also was used as a comparison to the remainder of the OSU yearling ewes not used in the trial to determine the effect of management differences on weight gain.

**Statistical Analysis**

All analyses were by analysis of variance using a randomized complete block design (General Linear Model, SAS, 1989). Block effects and interactions involving block were dropped from the final models if found to be non-significant in initial analyses.

For the pasture species composition analyses plant species were grouped for analysis as perennial ryegrass (RYE), other perennial grasses (OPG), annual grasses (AG) or forbs (FORB). RYE was analyzed separately from the other grasses because it was the primary desirable pasture species and composed a large proportion of the cover. The plants defined as FORB were analyzed collectively because no single species of the 18 identified made up more than a
small proportion of the total vegetative cover and many were not sampled in all cells. Models including all first and second order interactions were initially fit for each plant group and reduced by removing random terms and interactions that were found to be not significant at the 0.1 level. The reduced models were then analyzed using orthogonal single degree of freedom contrasts among treatments and grazing times. RYE, OPG, and AG were analyzed using percent cover represented by the group as the dependent variable. FORB was analyzed differently from the other groups because there was a significant difference in the amount of forb cover among treatments at the outset of the study. FORB was analyzed using percent forb cover removed by grazing (ungrazed forb cover minus grazed forb cover divided by ungrazed forb cover) as the dependent variable.

Reproductive success of the various plant groups was estimated as the proportion of plants that set seed from data on phenological stage collected with the ten-point frame as described for pasture species composition. The full model included treatment, time and block and all two-way interactions. Block effects and two-way interactions involving block were dropped from final models after being found non-significant in initial analysis. Single degree of freedom orthogonal contrasts were run for treatment (C vs. L, M, & H; L vs. M & H; M vs. H), time (1 vs. 2, 3, & 4; 2 vs. 3 & 4; 3 vs. 4) and interactions of treatment and time.

For bull thistle height and number of flowerheads per plant and blackberry cane length, the full model included treatment, grazing time, block and all two-way interactions. Reduced models were used in the final analyses. Single degree of freedom orthogonal contrasts were run for treatment (C vs. grazed; L vs. M & H; and M vs. H) and time (1 vs. 2, 3, & 4; 2 vs. 3 & 4; 3 vs. 4). The treatment by block interaction was used as the error term for contrasts comparing treatment effects,
while the time by block interaction was used as the error term for contrasts comparing time effects.

For tree browsing the full model included treatment, time, block and all two-way interactions. All terms were significant and the full model was used for analysis. Single degree of freedom orthogonal contrasts were run for treatment (L vs. M & H; M vs. H), time (1 vs. 2 & 3; 2 vs. 3) and interactions of treatment and time. The treatment by block interaction was used as the error term for contrasts comparing treatment effects. The time by block interaction was used as the error term for contrasts comparing time effects.

For sheep weight change the full model included sheep group, genotype, beginning weight (covariate) and all interactions. None of the interaction terms approached significance so all were dropped from the final model. Logical group comparisons were made using single degree of freedom orthogonal contrasts. The contrasts included: ewes not in the trial (Group 0) vs. trial ewes (Groups 1, 2 and 3); Control (Group 1) vs. trial ewes (Groups 2 and 3) and the group grazing low and moderate intensity treatments (Group 2) vs. the group grazing the high intensity treatment (Group 3).
Chapter 4
Effect of Sheep Grazing Intensity on a Streamside Pine Plantation

Introduction

Invasive plants are successful in establishing themselves for a variety of reasons, but a common characteristic is that if they are allowed to mature they produce large numbers of seeds, creating soil seed banks (Wilson 1988, McDonald and Tappeiner 1986) or immediately germinate in gaps in the vegetation. Seed banks provide the means by which invasive plants can capitalize on chance favorable conditions to quickly germinate and develop into new plants where gaps in cover have been created.

One means of limiting weed proliferation is using livestock grazing to reduce seed production. Sharrow and Mosher (1982) found that intensive grazing of tansy ragwort (Senecio jacobaea) by sheep is effective in reducing its ability to flower and produce seed and eventually leads to the death of established plants. Similarly, rotational grazing has been recommended for control of leafy spurge by preventing the plants from going to seed (Brock, 1988). This method did not eradicate established leafy spurge, but continued use of the grazing program kept the invasion from spreading. Species such as Imopsis arizonica, a biennial forb native to the southwestern United States are affected by defoliation at later stages of maturity, which results in reduced seed set, while early defoliation has no effect (Maschinski and Witham 1989).

When the undesirable species are less palatable than desired ones, low intensity, continuous grazing has been found to be ineffective in their control

Development of a grazing plan which favors desirable species while putting undesirable species at a disadvantage can be complex when a wide variety of species coexist and mature over an extended period. For instance, in California annual grasslands, species including filaree (Erodium botrys) and wild oat (Avena barbata) set seed throughout the spring while medusa head (Elymus caput-medusae) and tarweed (Madia spp.) mature in the summer (Heady 1961). Grazing is most effective in limiting plant reproductive success when it coincides with vulnerable plant growth stages prior to seed set; therefore, multiple grazing bouts may be required to control individual species that mature over an extended period or where several undesirable species mature at different times.

The purpose of this study was to assess the effects of repeated grazing by sheep at three intensities on a weed infested pine plantation planted in a former ryegrass pasture.

Materials and Methods

The study site was located at the edge of a ryegrass (Lolium perenne) pasture along Oak Creek in Corvallis, Oregon. This location has a Mediterranean climate with warm, dry summers and cool, wet winters. Mean monthly temperatures range from 4°C in January to 19°C in August. Monthly precipitation averages range from 19.6 cm in December to 1.3 cm in July, with an annual average of 108.5 cm. January through May of 1998, the year of the study, was wetter and warmer than
average, June was average in both temperature and precipitation and July was warmer and slightly drier than normal. The site is comprised of Bashaw clay and Waldo silty clay loam, two poorly drained alluvial soils commonly found along streams and drainages of foothill valleys (Knezevich 1975).

The site was fenced off from the rest of the pasture around 1990 and planted with Knob Cone-Monterey cross (KMX) pine trees. No cultivation, grazing or other management of the understory herbaceous plants occurred after this area was fenced from the rest of the pasture. The ground cover in the study area consisted of a variety of herbaceous and woody plants. Ryegrass was the dominant species on the southern quarter of the grazing cells, adjacent to the pasture, composing 50 to 90% of the cover at the initial sampling, prior to first grazing. Ryegrass cover decreased with proximity to Oak Creek to compose only 0 to 10% of the cover in the northern quarter of the grazing cells. Canada thistle, bull thistle and Himalayan blackberry were scattered throughout the study area. The area between the trees was cut in late October 1997 to reduce standing dry matter. Vegetation was allowed to regrow without further manipulation until sheep were introduced for the first grazing in early May.

The study site was subdivided with three strands of electrified polywire into 12 adjacent rectangular grazing cells, each measuring 13.6 m by 33.3 m (slightly less than 0.04 ha) and extending from the pasture boundary toward Oak (see figure in Chapter 3). The cells were grouped into three blocks of four cells each. Four grazing treatments were allocated to cells within each block in a randomized complete block design. The four treatments consisted of an ungrazed control (C), and low (L), moderate (M) and high (H) intensity grazing intended to utilize 25%, 50% and 75% of the available forage, respectively. Actual average grazing intensity
for the High treatment was lower (53%) than intended because the sheep had to be removed from the cells before target utilization was achieved when they began browsing trees. Grazing treatments were applied in early May (T1), late June (T2), and late July (T3) using two groups of ten yearling ewes. Grazing bouts lasted from one to four days per cell depending on treatment; sampling was conducted immediately post-grazing.

Prior to the grazing of each cell, ten paired 0.1 m² quadrats were identified in each cell and one of each pair was protected from grazing by a wire exclosure cage. Following grazing, canopy cover and plant phenological stage were recorded in all 20 quadrats using an inclined (45°) 10-point frame (Levy and Madden, 1933). The first plants contacted as the pins were lowered in the 10 channels of the frame were recorded as to species, or non-living material (NLM) if bare ground or no living plant part was hit by the pin, and phenological stage (vegetative, flowering, or set seed). Both grazed and ungrazed quadrats were then clipped, and the plant matter was dried and weighed to estimate forage utilization for the cell. Cover and phenological stage were measured in control cells but the quadrats were not clipped.

Plant species were grouped for analysis as perennial ryegrass (RYE), other perennial grasses (OPG), annual grasses (AG) or forbs (FORB). A list of plant species encountered and group to which they were assigned is provided in the Appendix. RYE was analyzed separately from the other grasses because it was the primary desirable pasture species and composed a large proportion of the cover. The plants defined as FORB were analyzed collectively because no single species of the 18 identified made up more than a small proportion of the total vegetative
cover and many were not sampled in all cells. Area not covered by living plant matter (including bare ground) was recorded as NLM.

Vegetative cover measured after each of the three grazing bouts was analyzed with analysis of variance as a randomized complete block design using the average of each grazed cell for each of the three sample times (n=27; General Linear Model; SAS 1989). Models including all first and second order interactions were initially fit for each plant group and reduced by removing random terms and interactions that were found to be not significant at the 0.1 level. The reduced models were then analyzed using orthogonal single degree of freedom contrasts among treatments and grazing times. RYE, OPG, and AG were analyzed using percent cover represented by the group as the dependent variable. FORB was analyzed differently from the other groups because there was a significant difference in the amount of forb cover among treatments at the outset of the study. FORB was analyzed using percent forb cover removed by grazing (ungrazed forb cover minus grazed forb cover divided by ungrazed forb cover) as the dependent variable.

Reproductive success of the various plant groups was estimated as the proportion of plants that set seed from data on phenological stage collected with the ten-point frame as described for pasture species composition. Cell means for samples taken in the grazed part of the treatment cells and for the control cells were compared in analysis of variance as a randomized complete block design (n=36, GLM, SAS 1989). The full model included treatment, time and block and all two-way interactions. Block effects and two-way interactions involving block were dropped from final models after being found non-significant in initial analysis. Single degree of freedom orthogonal contrasts were run for treatment (C vs. L, M, & H; L
Results

Pasture Species Composition

The proportional area covered by each of the four plant groups as a percent of the total area is shown in Table 4.1. This information is also presented graphically in the Appendix. The portion of each cell covered by vegetation averaged 90% at the start of the trial. By the end of the study it had declined to around 80% in C and dropped to 40% in L, M and H at the conclusion of the third grazing.

In the absence of any grazing (Control), RYE occurrence was quite stable and covered about 15% of the pasture area throughout the study. Under light grazing (L) proportional ryegrass removal increased slightly with each grazing bout. As shown in Table 3.2, in M and H the proportional removal was greatest during the second bout when about one half of RYE was removed. The overall effect of the three grazing bouts was that among the grazing treatments there was a net gain in ryegrass cover in L but M and H remained at the same level or decreased. The difference between L and M and H approached significance (p>0.07). There was a significant time effect with respect to change in amount of ryegrass present. All treatments showed an increase in ryegrass when T1 was compared to T2 and T3 (p<0.01) and a decrease when T2 was compared to T3 (p=0.02).
Table 4.1 Inclined Point Quadrat Pasture Composition (Mean No. of Hits/100 Points)

<table>
<thead>
<tr>
<th>Time Treatment</th>
<th>RYE U</th>
<th>OPG U</th>
<th>AG U</th>
<th>FORB U</th>
<th>NLM U</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 Control</td>
<td>15</td>
<td>19</td>
<td>30</td>
<td>27</td>
<td>9</td>
</tr>
<tr>
<td>Low</td>
<td>12</td>
<td>16</td>
<td>19</td>
<td>17</td>
<td>50</td>
</tr>
<tr>
<td>Moderate</td>
<td>20</td>
<td>14</td>
<td>20</td>
<td>25</td>
<td>16</td>
</tr>
<tr>
<td>High</td>
<td>33</td>
<td>17</td>
<td>12</td>
<td>19</td>
<td>7</td>
</tr>
<tr>
<td>T2 Control</td>
<td>16</td>
<td>21</td>
<td>33</td>
<td>18</td>
<td>11</td>
</tr>
<tr>
<td>Low</td>
<td>24</td>
<td>22</td>
<td>15</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>Moderate</td>
<td>44</td>
<td>23</td>
<td>14</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>High</td>
<td>50</td>
<td>25</td>
<td>28</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td>T3 Control</td>
<td>13</td>
<td>26</td>
<td>25</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Low</td>
<td>20</td>
<td>16</td>
<td>8</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Moderate</td>
<td>31</td>
<td>20</td>
<td>10</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>High</td>
<td>36</td>
<td>22</td>
<td>4</td>
<td>8</td>
<td>12</td>
</tr>
</tbody>
</table>

Note: U=ungrazed, G=grazed

Like RYE, OPG was stable throughout the study in the absence of grazing (Control), making up approximately 20% of the cover. In all grazed treatments, OPG represented a higher percentage of the canopy cover at T1 and T2, when grazed samples were compared to ungrazed samples. Nevertheless, OPG failed to recover following the second grazing and declined significantly (p<0.01) by the third sampling, making up 10% or less of the cover present.

Annual grasses initially made up about 25% of the cover and held steady throughout the study in the ungrazed Control cells. Annual grass cover also held steady in the grazed treatments through T2, but by T3 the proportion of vegetation as annual grass showed a dramatic decline to 8% or less in all grazed treatments (p=0.0001). Graminoid cover measured as a proportion of total cover remained steady in ungrazed cells during the study but was reduced by half in all of the
grazed treatments. Graminoids made up approximately 80% of the vegetative cover by the end of the study period in all treatments, including Control.

In all treatments, FORB canopy cover was at its highest level at T1 before any grazing. In the control, FORB cover had declined by one third at T2 and then remained at that level for the remainder of the study. The first round of grazing removed a substantial amount of the FORB cover in the other treatments. Forb removal was consistent with grazing pressure, ranging from 44% removal in L to 80% in H. Vetch (Vicia spp.) and wild geranium (Geranium dissectum) were the primary forbs present at T1.

FORB cover did not completely recover after the first grazing bout, achieving approximately one half or less of the initial amount by T2. The most common forb species at T2 were vetch, tarweed (Madia sativa Molina) and eyebright (Parentucellia viscosa), along with some white clover (Trifolium repens L). The wild geranium was a minor constituent of the T2 forb plant group, having been grazed heavily at T1, and tarweed and eyebright were in early growth stages, indicating a shift in species comprising the group FORB. Grazing at T2 removed about 25% of the FORB cover in L, 50% in M and 75% in H.

Following the second grazing, T3 FORB cover recovered to ungrazed T2 levels. However, tarweed and bull thistle (Cirsium vulgare Savi) were now the dominant forb species present. Grazing at T3 reduced percent forb cover in L less than in M and H (p=0.0001). Among the grazed treatments, T1 had a greater amount of forb cover removed by grazing than T2 and T3 (p=0.0001).
Phenology

Nearly all RYE plants recorded in May (T1) were classified as vegetative (Table 4.2). All grazing treatments resulted in delayed RYE maturation (p<0.01). The low grazing intensity treatment showed a delayed rate of maturity in comparison to C, with less than 50% having set seed at T2. Grazing removed some of the reproductive stems so that less than 25% of plants sampled were classified as being reproductive. By T3 most RYE (80%) was again reproductive in the ungrazed area, while less than 50% remained reproductive following grazing.

No RYE that had set seed was recorded in M or H. In the ungrazed area less than 20% had set seed at that time and 75% or more was flowering. T3 grazing resulted in only 25% of M RYE and 10% of H RYE recorded as flowering and no plants were recorded as having set seed.

OPG plants were just beginning to flower in all cells at T1. In the absence of grazing (C) almost 90% had set seed by T2. The first round of grazing did not appear to remove OPG reproductive stems in the L treatment, but at T2 only 30% of OPG plants had set seed, well below the control. The second grazing again failed to remove reproductive stems but at T3 only a small proportion of OPG plants sampled had set seed. Grazing in the M and H treatments did result in removal of the majority of reproductive stems at T1, but subsequent effects on OPG incidence of flowering and seed set was only slightly greater than for L. Compared to the control, all grazed treatments reduced the proportion of OPG plants that set seed from 53% to an average of 13% (p=0.0001). The more intensive grazing reduced seed set compared to L (33% vs. 3%, p=0.001); there was no difference in seed set between M and H.
About 25% of AG plants observed at T1 were flowering, but none was recorded as having set seed. By T2 all annual grasses sampled in ungrazed, control cells had set seed. While the first grazing in the L cells did not remove the reproductive stems, it reduced the proportion of AG that set seed to about 60% in L, versus 100% in the control. Grazing at T2 likewise appeared not to remove reproductive stems but by T3 AG plants had virtually disappeared from the sample. More intense grazing retarded AG maturation even further. Most AG in M and H at T2 were flowering but nearly none had set seed; a dramatic decrease from levels found in L (p<0.01). Grazing at T2 did substantially reduce AG occurrence, and by T3 there was very little AG present in any of the grazed cells. The proportion of AG plants that managed to set seed in the grazed treatments was approximately half that of C (p<0.01) and occurred almost entirely under light grazing. The annual grasses that were able to set seed in the grazed treatments were shorter and less lignified, and made up less of the total vegetation than those in C. The effect of the first grazing was to slow maturation of the plants when compared to C. Annual grasses were able to continue growing after the first grazing, with some plants successfully setting seed by T2.

FORB plants observed at T1 were nearly all vegetative or in early stages of flowering and consisted mainly of vetch and geranium. At T2 about 50% of FORB had set seed and most of the remainder was vegetative in the control. Warm season forbs were actively growing at T3. Nearly all forbs in control were reproductive. The primary forb was hairy catsear (*Hypochaeris radicata*) which was nearly all flowering or had set seed. Tarweed was also present and was beginning to flower.
Table 4.2  Inclined Point Quadrat Pasture Composition by Phenological Stage (Mean No. of Hits/100 Points)

<table>
<thead>
<tr>
<th></th>
<th>Ryegrass</th>
<th>Other Perennial Grass</th>
<th>Annual Grass</th>
<th>FORB</th>
<th>Litter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ungrazed</td>
<td>Grazed</td>
<td>Ungrazed</td>
<td>Grazed</td>
<td>Ungrazed</td>
</tr>
<tr>
<td>Time</td>
<td>V</td>
<td>F</td>
<td>S</td>
<td>V</td>
<td>F</td>
</tr>
<tr>
<td>T1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>5</td>
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<tr>
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<td>0</td>
<td>14</td>
<td>0</td>
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<tr>
<td>High</td>
<td>30</td>
<td>3</td>
<td>0</td>
<td>17</td>
<td>0</td>
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<tr>
<td>T2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>1</td>
<td>0</td>
<td>15</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Low</td>
<td>11</td>
<td>3</td>
<td>10</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>Moderate</td>
<td>16</td>
<td>28</td>
<td>0</td>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td>High</td>
<td>26</td>
<td>24</td>
<td>0</td>
<td>24</td>
<td>1</td>
</tr>
<tr>
<td>T3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>Low</td>
<td>3</td>
<td>9</td>
<td>9</td>
<td>5</td>
<td>2</td>
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<tr>
<td>Moderate</td>
<td>3</td>
<td>26</td>
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<td>5</td>
<td>0</td>
</tr>
<tr>
<td>High</td>
<td>3</td>
<td>26</td>
<td>19</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Notes: V=vegetative, F=flowering, S=set seed, U=ungrazed, G=grazed
At T2 grazing had removed the vetch and geranium, leaving less palatable species such as tarweed and eyebright the most common forbs. In L most of the eyebright was in the process of setting seed (about 50% of FORB), while the tarweed was still in early growth and remained vegetative. Few forbs in M and H were flowering and none had set seed.

At T3 approximately two thirds of the forbs were reproductive in samples protected from the third grazing in L and H, which was reduced slightly by the third grazing. However, forbs that had set seed were reduced from 40% to 13%, comparing ungrazed to grazed samples in both L and H at T3. Fewer forbs had set seed in M (9%) where protected from the third grazing and none had set seed where subjected to grazing. This difference could be due to different and more palatable forb species present in M cells.

In C the proportion of forbs having set seed was about 40% at T2 and T3, compared to 25% or less in any of the grazed treatments at either T2 or T3 (p<0.01). Seeding rates were higher in L than under more intensive grazing but the difference was not significant.

Discussion and Conclusions

The forbs and grasses other than the species that occurred in the part of the pasture that continued to be grazed, hayed and fertilized likely became established as a result of the discontinued management of the understory. Successional changes in the species present were able to proceed, as has been observed by Foin and Hektner (1986) and others as a common occurrence when grazing or other management is curtailed, leaving the plants to grow, mature and reproduce without constraint. If sheep grazing had been continued in the pine
plantation it is likely that the ryegrass would have comprised a larger proportion of
the cover while many of the forbs and annual grasses may not have been able to
become established. A denser sward of ryegrass may have also prevented thistles
from becoming established because fewer gaps would limit the number of
seedlings that could survive. The results of this study indicate that the seedlings
that did survive would probably not have been controlled by sheep grazing alone.

The primary effects of grazing were an increase in gaps in the pasture
(recorded as NLM in this study) due to the disappearance of annual grasses and
forbs and a reduction in the proportion of plants that successfully reproduced,
particularly among the annual grasses. All grazing levels reduced the number of
annual grasses and forbs that successfully set seed. Similar grazing effects on
seed set were reported for a legume (*Anthyllis vulneraria* L.) by Bastrenta (1991).
Grazed annual grasses that did succeed in reproducing were visibly much less
vigorous than plants of the same species growing in the control cells and probably
produced fewer seeds as a result. Annual grasses virtually disappeared between
the second and third grazing bouts in all grazed treatments while continuing to
make up 25% of the canopy cover in the ungrazed control. The cumulative effect of
the three rounds of grazing was to reduce both canopy coverage by annual grass
and the proportion of annual grass that was able to set seed. It is expected that
effective annual grazing will reduce the proportion of plants setting seed and
gradually deplete the soil seed bank.

Although forbs collectively made up a small portion of the total vegetative
cover, there was a large number of species in the study area. They were very
diverse in form, life cycle and palatability to the sheep; thus it is difficult to draw
specific conclusions from this study as to the effectiveness of grazing on controlling
individual forb species. However, grazing was found to generally delay forb maturity and reduce the proportion of plants that successfully set seed. As a result, many species set fewer seeds. During the study, overall forb cover declined by approximately 50% in all treatments, including the control, indicating that grazing was not the major factor affecting forb incidence. This finding contradicts Ash and McIvor (1998) who found that high rates of grazing occurring early in the wet season increased the proportion of forbs at a northern Australia site. The difference in results may be due to any of several factors, but most probably are due to differences in moisture conditions and the growth potential of the different forb species that were present.

The wide range in timing and rate of maturity of the different plant species necessitated multiple grazing bouts to insure grazing of the various forbs and annual grasses late in their development. Grazing at that stage has been found to result in undercompensation by many plants because they are unable to completely recover and replace lost tissue, decreasing seed production, particularly under conditions of nutrient-poor soils and competition, while early grazing can trigger overcompensation in many species resulting in greater seed production than would have occurred without grazing (Maschinski and Whitham 1989). However, the strategy of applying all grazing at later growth stages is not possible in diverse plant communities with overlapping life cycles. Restricting grazing to late development may likewise not provide adequate control for some species such as wild carrot (*Daucus carota* L.) which was observed in this study to be considerably more palatable to the sheep during early growth stages than when approaching reproductive stage. Other species, such as tarweed, were not present until late in the study and were just becoming a significant component of the vegetation at the
time of the third grazing. Discontinuation of grazing early in the life cycle of such late season plants may give them a competitive advantage due to reduced competition from earlier growing species that have been weakened or killed by previous grazing. However, this may be relatively unimportant in a Mediterranean climate where early season plants go dormant as the late season plants begin growth, thereby providing little competition whether they have been grazed or not.

Some researchers (e.g. Watt and Gibson 1988) have reported that grazing actually benefits annual forbs by providing gaps needed for seedling establishment. While the present study was limited to one growing season and no sampling was done after late July, it was observed that annual grass and ryegrass (but few forbs) were actively growing at the beginning of the fall rains. In this study, ryegrass did not decrease in proportion to the other species, and it was removal of annual grasses and forbs that created the gaps in cover created by grazing. The annuals that sprouted with the fall rain merely occupied space that had been vacated by other annuals. In fertile soils, ryegrass would be expected to spread to fill gaps left by the annuals. Silvertown et al. (1991) suggest that heavy grazing that produces the gaps necessary for seedling establishment also prohibits successful reproduction of the same plants. The results provided here indicate that it is possible to time grazing to decrease reproduction of undesirable plants without causing declines in pasture productivity through soil compaction, erosion and other effects associated with continuous grazing.

The results of this study indicate that short duration, intensive sheep grazing is a promising method of reducing seed set in a variety of grasses and forbs while not significantly impacting more desirable pasture species such as ryegrass. Such grazing repeated yearly is expected to decrease the number of viable seeds in the
soil seed bank and also contribute fewer seeds available for immediate germination. Further studies designed to measure actual numbers of seeds produced by plants subjected to different grazing intensities would allow more accurate estimates of the rate of depletion of soil seed banks. In addition, since the study was over a single season and follow-up studies of open niches and plant re-establishment were not made, further study would be useful to follow potential secondary responses and the long-term effects of the three grazing intensities. Given the continual recruitment of seeds into pastures via the wind, surface water and animals, continued grazing management and maintenance of healthy desired pasture species may be required in order to limit the influx of weedy plants once they have become established in the vicinity of pasture lands (Sheley et al. 1996).

References


Chapter 5
Sheep Grazing Effects on Bull Thistle (*Cirsium vulgare* Savi)

Introduction

Overgrazing of pastures has been linked to creating conditions suitable for the invasion of weeds due to creation of gaps in the pasture canopy, allowing emergence of seedlings (Bullock et al. 1994, Klinkhamer and DeJong 1993, Forcella and Wood 1986, Silvertown and Smith 1989). While overgrazing may lead to conditions that favor weed establishment, good grazing management inhibits weed proliferation in perennial grass pastures of by encouraging development of more tillers resulting in denser swards. It can also reduce the contribution of seeds to the soil seed bank by annual grasses and forbs. Furthermore, high intensity, short duration grazing can achieve more even defoliation of forage plants varying in palatability (Briske 1990).

The primary contribution of grazing to persistence of thistle populations is apparently reduction of competition from neighboring plants (Forcella & Wood 1986). While it has been reported that thistle invasion is unlikely in ungrazed vegetation (Forcella & Wood 1986), pastures that have been invaded by weeds that do not provide the dense ground cover of grasses such as ryegrass can provide conditions suitable for thistle establishment. The site of this study had been ungrazed for at least six years and contained a high population of forbs including bull thistle (*Cirsium vulgare* Savi). This species was not present in adjacent pasture that is grazed in the spring by sheep, mown for hay production in the summer and grazed thereafter by cattle.
Bull thistle is a biennial forb that forms a rosette during the first year and normally flowers in the second year, although flowering can be delayed beyond the second year if growing conditions are not favorable (De Jong and Klinkhamer 1988). Reproductive thistles typically range between 30 and 200 cm in height (De Jong and Klinkhamer 1988).

One objective of this study was to assess the effects of sheep grazing on the growth and reproductive success of bull thistle. Individual bull thistle plants were studied to determine if any of three levels of grazing intensity repeated three times over the growing season affected thistle growth or reproductive success.

Materials and Methods

The study site and experimental design were described in Chapter 3. Prior to first introduction of the sheep, ten thistle plants were randomly selected in each cell for study. A transect with permanent endpoints was established in each cell, and the location of plants was recorded as distance from the north end of the transect and lateral distance and direction from the transect line.

Grazing treatments were applied in early May (T1), late June (T2), and late July (T3) using two groups of ten yearling ewes. The four treatments consisted of an ungrazed Control (C), and low (L), moderate (M), and high (H) intensity grazing intended to utilize 25%, 50% and 75% of the available forage, respectively. Actual average grazing intensity for the High treatment was lower (53%) than intended because the sheep were removed from the cells when they began browsing trees.

Plant height and number of flowerheads were measured for each thistle plant after each of the three grazing bouts and again on October 11, 1998 (T4). No grazing occurred between T3 and T4, a time when most plants were not actively
growing. Treatment means were compared by analysis of variance of a randomized complete block design using the average of each cell (n=48; GLM; SAS 1989). The full model included treatment, grazing time, block and all two-way interactions. Block effects and interactions involving block were dropped from the final models if found to be non-significant in initial analyses. Single degree of freedom orthogonal contrasts were run for treatment (C vs. grazed; L vs. M & H; and M vs. H) and time (1 vs. 2, 3, & 4; 2 vs. 3 & 4; 3 vs. 4). The treatment by block interaction was used as the error term for contrasts comparing treatment effects, while the time by block interaction was used as the error term for contrasts comparing time effects.

Results

Mean thistle height measured after each grazing bout and then again at the end of summer is shown in Table 4.1. Where protected from grazing, bull thistle height averaged 20 cm at T1 and increased by more than threefold by T3. Height did not change between T3 and T4. There was no difference in thistle height among the grazed treatments at any time, but all were greatly reduced compared to the control (p<0.01). At T1, thistle height in the grazed treatments was less than 25% of C. While initially retarded, thistles in the grazed cells continued growing for a longer period of time than those in C and achieved heights averaging 40% of the C mean at T2 and T3. No obvious animal effects through trampling or consumption were noted at any of the observations, however, the prostrate nature of the thistles at the rosette stage may have concealed evidence of any trampling that did occur. Thistles continued to grow beyond T3 in the grazed cells, eventually reaching 60% of mean C plant height by T4. No grazing occurred between T3 and T4, a time when most plants, particularly the grasses, were not actively growing.
Bull thistles began flowering after T2 and continued flowering through T4 in all treatments; mean number of flowerheads per plant at each observation is shown in Table 4.2. Control cell plants had the greatest number of flowerheads at T3 but treatment differences were not significant at either T3 or T4.

Table 5.1  Bull Thistle Average Height (cm)

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
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<tr>
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<td>19.7a</td>
<td>45.6a</td>
<td>71.7a</td>
<td>71.0a</td>
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<tr>
<td>Low</td>
<td>4.7a</td>
<td>18.3a</td>
<td>28.4a</td>
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<tr>
<td>Moderate</td>
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<td>25.9a</td>
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<tr>
<td>High</td>
<td>3.6a</td>
<td>17.1a</td>
<td>26.3a</td>
<td>32.2a</td>
</tr>
</tbody>
</table>

Note: Numbers within columns with different superscripts differ at 0.05 level of significance

Table 5.2  Bull Thistle Average Number of Flowerheads per Plant

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
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<th>T3</th>
<th>T4</th>
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<td>Control</td>
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<td>7.4</td>
<td>10.2</td>
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<tr>
<td>Low</td>
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<td>0</td>
<td>3.2</td>
<td>10.4</td>
</tr>
<tr>
<td>Moderate</td>
<td>0</td>
<td>0</td>
<td>3.5</td>
<td>10.6</td>
</tr>
<tr>
<td>High</td>
<td>0</td>
<td>0</td>
<td>5.3</td>
<td>11.1</td>
</tr>
</tbody>
</table>

Discussion and Conclusions

While studies (Bullock et al. 1994, Klinkhamer and DeJong 1993, Forcella and Wood 1986, Silvertown and Smith 1989) have indicated that grazing by sheep is not effective in controlling bull thistle this study indicates that grazing in the spring does not give thistles a competitive advantage during the reproduction phase. The number of flowerheads produced per plant was not significantly influenced by grazing. While there was an indication that time of flowerhead production may be delayed slightly early in the season, the plants in the grazed treatments caught up
to the plants in the control by the end of flowering. Previous reports differ regarding the influence of sheep grazing on the number of flowerheads produced per plant with Bullock et al. (1994) finding no effect and Forcella and Wood (1986) finding an increase in the number of flowerheads produced per plant in areas that had been subjected to season long sheep grazing. Bullock et al. (1994) compared winter, spring and summer grazing in a British pasture planted with an agricultural grass mix, where bull thistle is native. Forcella and Wood (1986) studied the effects of sheep grazing whenever there was sufficient forage available on an annual pasture that had been ploughed and sown with oats two years prior to initiation of the study. The latter study took place in Australia where bull thistle is an introduced species. The differences in results may be attributed to different grazing management that affected how the grazed plants competed with the thistles and resulting numbers of thistle seedlings that survived and became rosettes. The current study initiated grazing treatments after thistle rosettes had formed and used intermittent sheep grazing more similar to Bullock et al. (1994) than Forcella and Wood (1986), that allowed competition during thistle life stages that apparently have a significant influence on subsequent flowerhead production.

The intensity of grazing did not affect thistle height and the sheep did not apparently affect the thistle plants by browsing or trampling to any significant degree. Bull thistles spread their achenes (seed) mainly by the wind, but seeds usually fall within a radius of 1.5 times the height of the source plant (Michaux 1989). Thistles in the grazed treatments were approximately one half the height of those in the control, reducing the distance seeds would be expected to be spread; however, the relative importance of dispersal distance to persistence of thistle populations is not known (Michaux 1989, Augsberger 1986).
While inappropriate grazing has been demonstrated to give a competitive advantage to aggressive plants such as thistles through the formation of gaps in the pasture where seedlings can become established, grazing does not appear to influence production of seed by established plants. Grazing subsequent to thistle seedling emergence and transition to rosette stage should not have an effect on flowerhead and seed production.

References


Chapter 6
Sheep Grazing Effects on Himalayan Blackberry (*Rubus discolor* Weihe & Nees)

Introduction

*Rubus* species are aggressive invaders of disturbed areas because their growth habits allow them to quickly acquire available resources including nutrients, space, light and moisture (Oleskevich et al. 1995, Hancock et al., 1996). Blackberries reproduce principally by vegetative means from root suckers and rooting of canes when they come into contact with the ground (Oleskevich et al. 1995), allowing them to rapidly establish themselves and shade out shorter competitors. A secondary means of reproduction is by seed, which may remain viable in the soil seed bank for over 50 years, and dispersed by birds and mammals that consume the fruit (Oleskevich et al. 1995). Attempts to control blackberries by burning and cutting can actually benefit them through stimulation of seed germination and regrowth from rhizomes (Oleskevich et al. 1995).

Both sheep and goats have been used to study of the effectiveness of grazing in blackberry control. Comparisons of sheep and goats for control of well-established blackberry plants found that sheep could be as effective as goats but took longer to achieve the same level of control (Dabaan et al. 1997). Goats may be preferred in reclaiming abandoned pastures because they prefer brush to grass and thus control woody species (Wood 1987). On the other hand, sheep are often preferred to goats in grazing situations such as conifer plantations because they are less likely to damage the trees through browsing and bark stripping. Sheep are
also more readily available. Use of rotational grazing rather than the season long
grazing used in many studies may increase the effectiveness of sheep in controlling
blackberries by encouraging higher utilization of the blackberries by providing
multiple opportunities for the sheep to browse new cane growth before it has
hardened off and become unpalatable. Much of the research that has been done on
blackberry growth characteristics and to assess the effectiveness of grazing in
controlling blackberries has been on blackberry species other than Himalayan
blackberry (*Rubus discolor*). Himalayan blackberry is commonly known as a quickly
growing, aggressive invader that can quickly overcome established herbaceous
plants, shrubs and young trees. Its stout canes are protected from herbivory by
large, sharp thorns that become unpalatable as the new cane growth becomes
woody during the growing season. Sheep find the leaves palatable throughout the
summer when little else is green in western Oregon’s Mediterranean climate.

The purpose of this study was to assess the effects of repeated short
duration sheep grazing at three intensities on a weed-infested pine plantation
planted in a former ryegrass pasture. In this paper we report grazing effects on the
growth and reproductive success of Himalayan blackberry that had been cut back in
the fall prior to introduction of sheep the following spring.

**Materials and Methods**

The study site and experimental design were described in Chapter 3. With
one exception, ten Himalayan blackberry plants were identified in each cell prior to
first introduction of the sheep; Cell 12 had only six plants - all were included in the
study. A transect with permanent endpoints was established in each cell, and the
location of plants was recorded as distance from the north end of the transect and lateral distance and direction from the transect line.

Grazing treatments were applied in early May (T1), late June (T2), and late July (T3) using two groups of ten yearling ewes. The four treatments consisted of an ungrazed Control (C), and low (L), moderate (M) and high (H) intensity grazing intended to utilize 25%, 50% and 75% of the available forage, respectively. Actual average grazing intensity for the High treatment was lower (53%) than intended because the sheep had to be removed from the when they began browsing trees.

Length of the longest cane present on each blackberry plant was measured after each of the three grazing bouts and on October 11, 1998 (T4). No grazing occurred between T3 and T4, a time when most plants were not actively growing. Treatment means were compared with analysis of variance of a randomized complete block design (n=48; GLM; SAS 1989). The full model included treatment, grazing time, block and all two-way interactions. Block effects and interactions involving block were dropped from the final models if found to be non-significant in initial analyses. Single degree of freedom orthogonal contrasts were run for treatment (C vs. grazed; L vs. M & H; and M vs. H), time (1 vs. 2, 3, & 4; 2 vs. 3 & 4; 3 vs. 4) and interactions of treatment and time. The treatment by block interaction was used as the error term for contrasts comparing treatment effects, while the time by block interaction was used as the error term for contrasts comparing time effects.

**Results**

At T1 blackberry canes averaged 28 cm where there had been no grazing (Table 5.1). In the absence of grazing (Control) the canes grew steadily through T3
when the canes had attained a mean length of 86 cm. Control plants showed no further growth between T3 and T4. None of the control cell plants produced flowers, presumably a response to site preparation the previous fall, so effects of sheep grazing on flowering and seed set could not be determined.

All grazing treatments reduced blackberry growth compared to the Control through T3 (p<0.01). Light grazing held cane length to half that of C throughout the trial, while M and H reduced length nearly 10 cm more than did L (p<0.01). Cane length under moderate grazing was only 16% of C at T1, about 25% of C at T2 and T3, and had increased to about half C at T4. Cane length in H was maintained at about 15% of C through T3 but increased to 33% of C at T4. The first grazing greatly reduced cane length in both M and H; thereafter, H plants were consistently 30-40% shorter than M plants (p<0.05).

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>27.8°</td>
<td>50.0°</td>
<td>86.0°</td>
<td>81.1°</td>
</tr>
<tr>
<td>Low</td>
<td>13.0b</td>
<td>21.5b</td>
<td>31.4a</td>
<td>36.9a</td>
</tr>
<tr>
<td>Moderate</td>
<td>4.5a</td>
<td>10.6ab</td>
<td>23.3a</td>
<td>41.1a</td>
</tr>
<tr>
<td>High</td>
<td>4.1a</td>
<td>6.7a</td>
<td>12.9a</td>
<td>27.0a</td>
</tr>
</tbody>
</table>

Note: Numbers within columns with different superscripts differ at 0.05 level of significance

### Discussion and Conclusions

The study site had been protected from grazing for at least eight years, during which bull thistles, Himalayan blackberries and a variety of other forbs and annual grasses became established. These weeds were not present to a significant degree in the adjacent pasture that is grazed in winter/spring by sheep,
mechanically harvested in mid-summer and grazed thereafter by cattle. Despite a variety of other forage available, even the lowest intensity grazing treatment had a significant effect on blackberry cane length, indicating that sheep find Himalayan blackberry palatable. Elevating grazing intensity increased the effectiveness of grazing in reducing the growth of blackberries, although growth was not completely arrested at even the highest grazing intensity. By the time of the final grazing (late July), ungrazed blackberries had completed cane elongation while grazed plants showed evidence of compensatory growth thereafter. The amount of recovery between T3 and T4 increased with grazing intensity, although the grazed plants were not able to attain more than half the length of ungrazed plants (in C). While sheep did not completely suppress blackberry growth, they removed most of the leaves from the plants, thereby reducing the amount of energy the plants could store for future growth. The observed dramatic reduction in blackberry growth by periodic sheep grazing supports the conclusions of previous researchers (Wood 1987, Sharrow 1994, Dabaan et al. 1997). Sharrow and Leininger (1983) reported that two native blackberry species could be controlled with a single round of grazing per year, however, these species do not grow as aggressively as Himalayan blackberry. Himalayan blackberry grows very rapidly and the canes soon become stout and woody, protecting new growth and leaves from grazing by growing taller than the sheep can reach or by encircling the new growth with an impenetrable barrier of woody, thorned canes. The results of this study indicate that a single grazing would not significantly slow growth and repeated grazings are needed to keep Himalayan blackberry canes from becoming woody within a growing season. It is likely that even with grazing continued over several years, if the canes are allowed to lengthen and become woody within a grazing season, the following
year's growth would branch out from the existing woody growth, gradually covering more area. The woody cane growth would likely protect enough new growth and leaves to provide adequate photosynthetic material for the plant to sustain itself. Annually repeated grazing will also probably be necessary to maintain control of both seedlings that sprout from seeds stored in the soil and new sprouts from the rhizomes of established plants.

References


Chapter 7

Browsing Effects on a KMX Hybrid Pine Plantation When Sheep are Used to Control Weeds

Introduction

When trees are planted in existing pasture there is normally no effect on weed populations in the pasture unless grazing is discontinued, resulting in major ingress of weeds (Percival and Knowles 1983). Weed invasions into and from tree plantations located adjacent to pastures and croplands can be a significant problem, increasing the time, effort and expense needed to control weeds that become established in the plantations and spread into adjacent lands.

When grazing is used to control understory vegetation in tree plantations, damage to trees by the grazing animals is a concern. While most studies have found that browsing of the trees does not usually occur at levels great enough to cause significant damage to the trees, and in fact usually increases tree growth, the animals must be carefully managed to minimize browsing damage (Sharrow and Leininger 1983, Thomas 1984, Monfore 1983, Fulgham 1985). The timing of grazing is important, particularly when the forage is not highly palatable. The potential for tree damage is lowest if grazing can be accomplished before bud break in the spring or when the herbaceous forage is green and succulent (Krueger 1985). Grazing management is simplified when the plantations have been seeded with a palatable forage species (McLean 1983), or when conifer species that are least palatable to the grazing animals are used (Newsome 1996). Grazing management becomes more complicated when the forage species include a variety
of grasses, forbs and woody species with a wide range of palatability (Sharrow 1994) and differing life cycles. Grazing management is further complicated with small trees below 1.0 m in height (Pearson 1931) and pines which are thought to be among the more palatable conifers (Newsome 1996).

The goals of this study were to assess the effectiveness of repeated short duration grazing by sheep at reducing the reproductive success of weeds growing in the conifer plantation, thereby reducing the potential for infestation of adjacent pasture lands, as well as assess the damage the sheep imposed on the trees and effects on sheep performance. This paper assesses the level of browsing of the pines by the sheep.

Materials and Methods

The study site and experimental design were described in Chapter 3. Grazing treatments were applied in early May (T1), late June (T2), and late July (T3) using two groups of ten yearling ewes. The four treatments consisted of an ungrazed control (C), and low (L), moderate (M) high (H) intensity grazing intended to utilize 25%, 50% and 75% of the available forage, respectively. One group of ewes was used in the Low (L) and Moderate (M) treatments and the other group was used in the High (H) treatment. Actual average grazing intensity for the High treatment was 53% lower than intended because the sheep had to be removed from the cells when they began heavily browsing trees.

There was an average of 37 KMX hybrid pine trees (Pinus attenuata \times P. radiata) in each grazed cell. The trees were planted approximately eight years prior to this study, however most of the trees did not prosper due to unknown factors which may include competition with the ground cover, extremely wet soils in the
winter and spring or location of the site in a low spot that is colder than the surrounding area. Tree height ranged from 45.7 cm to 276.9 cm. Tree height was greatest in the western third of the study area and blocking was used in the experimental design to account for the difference in tree height. Comparisons of the proportion of branches within reach of the sheep (about 1.0 m, Pearson 1931) that were browsed were used to determine the effect of grazing intensity on level of tree browsing. A branch was considered browsed if any needles or portions of needles were removed or tips of branches had been removed. In some cases, particularly in the High treatment, all needles and green growing tips of branches were removed by browsing. The number of branches that were browsed was counted after each of the three grazing bouts for each of the trees present in each grazed cell. Only new branches browsed or branches rebrowsed were counted at T2 and T3. Cell means were compared in analysis of variance as a randomized complete block design using the average of each grazed cell (n=36; GLM; SAS 1989). The full model included treatment, time, block and all two-way interactions. All terms were significant and the full model was used for analysis. Single degree of freedom orthogonal contrasts were run for treatment (L vs. M & H; M vs. H), time (1 vs. 2 & 3; 2 vs. 3) and interactions of treatment and time. The treatment by block interaction was used as the error term for contrasts comparing treatment effects. The time by block interaction was used as the error term for contrasts comparing time effects.

Results

The Low and Moderate treatments resulted in light browsing of the trees at T1, at less than 30% of the available branches (see Table 7.1). Many of the branches
counted as browsed had lost only parts of some of the needles or the tips of a few branchlets. In contrast, the High treatment resulted in nearly all of the branches browsed, many of which suffered near complete defoliation. Tree buds had broken prior to T1 and new growth on the trees was soft and lush. The forage was lush and green and consisted mainly of grasses, few of which had progressed to reproductive stages, and small forbs.

The current year’s growth on the trees was hardening off at T2, however there was also some soft new regrowth that was stimulated by the browsing that occurred at T1. During the T2 grazing browsing had increased slightly in the low intensity treatment and increased by 25% in the moderate intensity treatment, presumably due to a decrease in palatability of the grasses and forbs that were present. Additional browsing in the high intensity treatment was low because there was little current year’s growth left after the previous round of grazing.

By T3, browsing in all treatments decreased and the cumulative level of browsing was not significantly different from T2 (p>0.3). Although the forage had become much less palatable than at earlier grazings, the current year’s tree growth had also hardened off and apparently decreased in palatability.

Table 7.1 Branches Browsed (Cumulative Percent of Available)

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>23a</td>
<td>52a</td>
<td>64a</td>
</tr>
<tr>
<td>Mod</td>
<td>29a</td>
<td>71ab</td>
<td>75a</td>
</tr>
<tr>
<td>High</td>
<td>92b</td>
<td>95b</td>
<td>98a</td>
</tr>
</tbody>
</table>

Notes: Available means branches less than 1.5 meters above the ground.
Numbers within columns with different superscripts differ at 0.05 level of significance.
Overall, the Low treatment resulted in less cumulative browsing of the trees than the more intensive treatments (p<0.05), and the Moderate treatment resulted in less tree browsing than High (p<0.05). While measured utilization of the forage in the Moderate and High treatments was similar at 50% and 53%, respectively, sheep grazing the High treatment were present about 25% longer at T1 and T3 and about the same amount of time at T2.

Discussion and Conclusions

Grazing management was complicated in this study by the presence of plants targeted for grazing that were highly variable in timing of maturation and relative palatability and the small size of many of the trees. Success in controlling the various forage species was therefore mixed due to differences in palatability that changed over time between the understory vegetation and the trees. Rotational grazing has been proposed as a better grazing strategy for utilizing pastures under young pines than season long grazing (Anderson et al 1985). For this study multiple rounds of short duration grazing was identified as the best way to control the variety of forage species present when they were at early growth stages and most palatable. The low intensity grazing treatment resulted in the least damage to the trees while providing some control of many of the forage species. The sheep browsed the trees to a greater extent at T2 than T1 in all treatments, even though the new growth was starting to harden off. This may be due to maturation of the early season forage species while late season species were just beginning to grow, with a resulting decrease in the difference in palatability between the pines and the forage species. Several studies have found that little damage to trees from sheep
browsing occurs as long as the understory vegetation is more palatable than the trees (Fulgham 1985, Sharrow and Leininger 1983, Monfore 1983, Thomas 1985).

The first grazing resulted in high levels of browsing damage in the high intensity treatment that left little growth on the trees available for browsing at later times. The high intensity treatment resulted in unacceptably high levels of damage to the trees, although no bark stripping was noted. The low and moderate intensity treatments resulted in increased browsing damage to accessible branches at T2 but browsing decreased by the third round of grazing. The extent of browsing was much less than at the highest intensity grazing with less photosynthetic material observed to have been consumed and fewer available terminal leaders removed (25% in L vs. 80% in H). These results appear to disagree with a previous study that found that browsing levels were lower at the end of the growing season than at the beginning (Sharrow and Leininger 1983) however, the earlier study included only an early spring and a late summer grazing.

Some behavioral differences among the individual sheep were observed but not quantified during the study regarding preference for tree browse over the forage that was present. Other members of the group often joined the individual that preferred trees in browsing a single tree in the grazing cell. This behavior sometimes occurred as soon as the sheep were introduced to the cell, a phenomenon that was also observed by Sharrow and Leininger (1983). If the sheep performance had not been studied, the individuals showing a preference for the trees would have been removed from the situation and lower levels of damage to the trees may have occurred. Additionally, if properly managed grazing had been initiated in the plantation at the time the trees were planted, the less palatable weeds may not have invaded the area to the degree that occurred in the absence of grazing. Maintenance of highly palatable
pasture species under the trees would have resulted in a greater difference in relative palatability between the understory vegetation and the trees, reducing the potential for the trees to be browsed.

References


Chapter 8

Use of Sheep to Control Weeds in a Pine Plantation: Effect on Sheep Performance

Introduction

Sheep have been studied for many years as a means of reducing competition from native and introduced understory vegetation in forest regeneration and tree plantations. They have been used both as an alternative to herbicides and, more recently, as a means of increasing the productivity of the land (Leininger 1984). Much of the research has taken place in timber lands consisting of large acreages where the sheep are herded in large bands from one timber cut to another.

Weeds are also a problem on rangelands and in crops. Plants such as cheatgrass, leafy spurge and yellow starthistle have become well known as noxious weeds on rangelands. In many places they have grown so well that they outcompete the native vegetation because they are less palatable or even toxic to livestock and/or wildlife. Weed plants are also a concern in agricultural and silvicultural areas where they use light, nutrients and moisture to the disadvantage of the desired species.

Although weeds are by definition undesirable in the location in which they have become established, such plants are not necessarily poor sources of nutrition for grazing animals. In fact, several studies have reported some weed species equal in nutritive value to cultivated forages (Marten et al. 1987, Landgraf et al. 1984, Leininger et al. 1989, Bell et al. 1996). However, nutritive value is tempered
by palatability which may be reduced by the presence of mechanical or chemical plant defenses and usually declines as the plants mature (Marten et al. 1987).

Most studies of sheep grazing for weed control that recorded performance found that body weight was maintained or increased whether animals grazed forested areas (Hall et al. 1959, Black and Vladimiroff 1963, McKinnell 1975, Leininger et al. 1989) or weed infested pastures (Landgraf et al. 1984, Cassida et al. 1995), although performance was usually less than for animals grazing local improved pastures. Studies reporting weight losses identified other factors such as use of sheep with high nutritional demands as the primary cause (McKinnell 1975, Cassida et al 1995, Sharrow and Leininger 1983).

Applying multiple rounds of short duration grazing is a way to control multiple species of weeds with different times of maturation before they set seed and decline in palatability and nutritional value, while minimizing the time the sheep are grazing sub-optimal forage. Another way to minimize adverse effects on sheep performance is to use sheep with relatively low nutritional requirements. Yearling replacement ewes were selected for this trial because their nutritional demands are lower than that of either lactating ewes or young growing lambs. This paper assesses the performance of yearling replacement ewes used for weed control in a weed infested pine plantation.

Materials and Methods

The study site and experimental design were described in Chapter 3. Thirty yearling ewes were randomly selected from 90 yearling ewes available from the Oregon State University (OSU) flock. Five white face and five black face cross ewes were randomly selected for each of three trial groups to equalize the potential
effects of beginning weight and genotypic differences in rate of gain on weight change over the trial. The three groups were randomly assigned to graze the low and moderate treatments, the high intensity treatment and control. The ewes used in the trial were managed separately from the remaining yearling ewes to avoid having to sort a large number of ewes prior to each round of grazing. Two groups of ten ewes grazed the pine plantation in early May, late June, and late July for seven to 14 days each time, depending on the amount of forage present and the length of time required to achieve the specified level of utilization in each grazing cell. Low, moderate and high intensity grazing treatments intended to utilize 25%, 50% and 75% of the available forage, respectively, were studied. One group of ewes was used in the low and moderate intensity treatments and the other group was used in the high intensity treatment. The third group of ten ewes was kept in the areas used to hold the other two groups of sheep in between rounds of grazing as the control. This control group also was used as a comparison to the remainder of the OSU yearling ewes not used in the trial to determine the effect of management differences on weight gain.

The sheep were weighed at several intervals during the study. All sheep were weighed within the same, approximate two-hour period using the same scale to avoid effects on weight due to management. The time of day the sheep were weighed varied slightly over the study but weights were normally taken during the morning. The sheep used in the grazing treatments were removed from the grazing treatments and held in pastures with the control group for a few days prior to weighing to allow weight differences due to gut fill to equalize. Initial weights of all OSU yearling ewes were taken in mid-April, prior to start of the grazing study. The treatment ewes were weighed prior to the second grazing and about three days
after the last group was removed from the treatment cells after the second grazing. The final weighing of all yearling ewes occurred in late July, several days after the third round of grazing was complete and the treatment ewes had been combined with the larger flock.

Sheep weight change by group (control, low/moderate, high, ewes not in trial) was compared by Analysis of Variance (SAS 1989). The full model included sheep group, genotype, beginning weight (covariate) and all interactions. None of the interaction terms approached significance so were dropped from the final model. Logical group comparisons were made using single degree of freedom orthogonal contrasts. The contrasts included: ewes not in the trial (Group 0) vs. trial ewes (Groups 1, 2 and 3); Control (Group 1) vs. trial ewes (Groups 2 and 3) and the group grazing low and moderate intensity treatments (Group 2) vs. the group grazing the high intensity treatment (Group 3).

Results

Least squares means for ewe starting weights and weight changes are shown in Table 8.1. All groups of ewes gained weight during the trial, including the sheep used in the grazing treatments. Among the trial ewes, the control group gained more weight than the treatment ewes but this difference was not significant. A greater, significant difference was found when the trial ewes were compared to the yearling ewes not used in the trial. All three groups used in the trial gained more weight than the yearling ewes not in the trial ($p < 0.001$). This difference is apparently due to differences in management of the ewes and not a result of the treatments that were studied.
Genotype had a significant effect on weight gain ($p < 0.05$), with black face ewes consistently gaining more weight than the white face ewes in all groups. No interactions of the main effects were found to be significant. Beginning weight had no effect on weight gain among the non-trial ewes and was not significant when weight gain for all yearling ewes was analyzed. When only the trial ewes were analyzed, beginning weight approached significance as a covariate ($p = 0.06$) with a modest positive effect on final weight.

Table 8.1 Mean Starting Weights and Weight Change for Yearling Ewes (Kg.)

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>No.</th>
<th>Starting Weight</th>
<th>Weight Change$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low/Moderate Intensity</td>
<td>10</td>
<td>60</td>
<td>4.36$^b$</td>
</tr>
<tr>
<td>High Intensity</td>
<td>10</td>
<td>62</td>
<td>4.32$^b$</td>
</tr>
<tr>
<td>Control</td>
<td>10</td>
<td>61</td>
<td>5.45$^b$</td>
</tr>
<tr>
<td>Yearling ewes not in trial</td>
<td>60</td>
<td>60</td>
<td>2.08$^a$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Genotype</th>
<th>No.</th>
<th>Starting Weight</th>
<th>Weight Change$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Face</td>
<td>45</td>
<td>63$^b$</td>
<td>3.95$^d$</td>
</tr>
<tr>
<td>White Face</td>
<td>45</td>
<td>59$^a$</td>
<td>2.41$^c$</td>
</tr>
</tbody>
</table>

Notes: $^1$ Weight change over 90 days. Means within columns and classification with different superscripts differ at 0.05 level of significance.

Discussion and Conclusions

Studies that compared sheep performance when used to control understory vegetation in forested areas with performance on improved pasture predictably reported lower weight gains in the former situation under season long grazing
management using young sheep or ewes with lambs (McKinnell 1975, Leininger et al. 1989). However, Leininger et al. (1989) found that dry ewes that grazed in forests performed similarly to those on nonirrigated local pastures in western Oregon where forages normally decline in nutritional value during the hot dry summer.

The lack of significant differences in weight gain among the different groups of sheep in this trial may be due to the limited length of time the sheep grazed weeds (about 14 days for the first grazing declining to about 7 days by the third round, with 30 days rest between grazings) and that the sheep were dry yearling ewes with lower nutritional demands than either young lambs or lactating ewes. These results indicate that sheep can be used to control weeds without sacrificing growth performance. Performance can be optimized if the sheep graze weeds only to the degree necessary to provide adequate weed control and enough sheep are used to provide a relatively high stocking density to minimize the duration of each round of grazing. Best control of diverse weeds may include multiple grazings, and the sheep should have improved pasture available when they are not controlling weeds. Sheep with relatively low nutritional demands are less likely to be adversely affected by the pressure required to control less palatable weeds than sheep with high nutritional demands.

References


Chapter 9
Summary

This study provided evidence that short duration rotational grazing by sheep can be effective in controlling many undesirable plants common in the Pacific Northwest, even in a diverse community of non-native species with different life cycles. However, some of the species present, particularly the perennial thistles including bull thistle and Canada thistle (Cirsium arvense) were not directly controlled by grazing. Other plants, such as Himalayan blackberry are tolerant of grazing, continuing to grow after defoliation and become woody and thus unpalatable to sheep with maturity. These species may need to be grazed more than once during the growing season so sheep can remove new green growing shoots before the shoots get tough and unpalatable. Comparison of grazing blackberries one time per year to multiple grazings repeated for several growing seasons would provide useful information on the effectiveness of different grazing regimes and how many years of grazing would be required to eradicate the plants.

Sheep performance was not adversely affected by the grazing management used in this study and, in fact, the yearling ewes used in the study gained more weight during the study period than their cohorts that were managed by routine procedures. The major reason for superior gains may be that when not in the grazing treatment cells the study ewes were kept in areas that had lusher forage in many cases than the other sheep. When not grazing in treatment cells, the study sheep were also rotated through smaller grazing areas more frequently than the ewes not in this study which were kept in large pastures. These differences in management may have resulted in more efficient use of the forage. The weed-
infested treatment cells also often offered greener forage than was available to the contemporary ewes grazed separately on pasture that was not actively growing during the dry summer months. The sheep that were used in the grazing treatments gained slightly less weight than the group of controls that were kept on good pasture the entire time, and on average the trial ewes gained more weight than their cohorts. The slightly lower weight gain among the sheep used in the grazing treatments compared to the control group was likely due to the level of forage utilization that the sheep were required to attain while grazing treatment cells rather than a difference in the overall nutritional value of the available forage.

The trees growing onsite had been subjected to stresses that varied over the site, as indicated by the great differences in tree height over the study area. Some of the stress was probably due to competition from the understory vegetation, but other conditions including standing water during much of the spring and other unidentified stresses probably also contributed to poor tree growth. Tree height ranged from 46 centimeters to nearly three meters tall. The variability in tree height affected the proportion of branches that were within range of the sheep. This was accounted for in data analysis by using the branches browsed as a proportion of the branches within range of the sheep. However, if browsing occurred on only a small proportion of the total branches, a tree would have more reserves available for growing new needles and branch tips than smaller trees, providing more new growth that would then become available for subsequent browsing.

Grazing can successfully control weeds in tree plantations provided the weeds are more palatable than the trees. Incidences of tree browsing can be minimized if fences, water sources and other attractions are not too close to the trees and sheep lounging and bedding areas are located some distance from the
trees. It is likely that fewer trees would have been browsed during the first grazing bout in early May if grazing had occurred prior to tree bud break. The level of browsing observed in this study was higher than that recorded in some other studies as a result. However, the understory vegetation was also at its peak of palatability and extensive browsing did not occur at low and moderate levels of utilization. The tree browsing observed may be confounded with the sheep groups used to graze in the study plots: one group of sheep was used in the low and moderate treatments and the second group was used exclusively in the high intensity treatment. One or two individuals among the latter group appeared to have a preference for browsing trees. They often sampled the trees immediately upon being introduced to a grazing plot. Other ewes joined in, and the whole group would then consume much of the green growth on the same tree. If collection of sheep performance data was not intended, ewes with a preference for trees would have been replaced and the level of browsing in the high intensity treatment may have dropped considerably.

More complete control of the weeds could probably have been achieved if other methods (mechanical or chemical) were focused on the less palatable species in combination with grazing. The thistles could have been controlled effectively by cutting off the reproductive spikes shortly before the flowers opened. Reseeding the study area with improved forage species that were tolerant of some shade and standing water in early spring, with initiation of grazing soon after would have resulted in better ground coverage, and the resulting fewer gaps would have prevented much of the weed invasion observed onsite. Maintaining a ryegrass pasture under the trees is also likely to have reduced the amount of tree browsing that occurred by increasing the palatability of the forage relative to the trees.
Longer-term studies of the effects of grazing on botanical composition of the understory vegetation in tree plantations would provide information on how grazing affects seedling recruitment into gaps in the cover created by grazing or poor growing conditions. Studies of the effects of grazing on botanical composition over time would provide additional information on the effectiveness of grazing as a tool to control weed invasions. Several years of additional data would be necessary to determine how continuation of the grazing initiated with this study would affect the plant species present, given continual influx of seeds from off-site. Studies designed to determine the effects of this type of grazing on soil compaction and stormwater runoff from the site would also provide valuable information on effects on water quality for sites located in or adjacent to riparian areas.


Appendix
## Appendix

### Species List

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
<th>Lifeform</th>
<th>Origin</th>
<th>Plant Group</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Lolium perenne</em> L.</td>
<td>perennial ryegrass</td>
<td>Perennial</td>
<td>Introduced</td>
<td>RYE</td>
</tr>
<tr>
<td><em>Festuca arundinacea</em> Schreb.</td>
<td>tall fescue</td>
<td>Perennial</td>
<td>Introduced</td>
<td>OPG</td>
</tr>
<tr>
<td><em>Alopecurus pratensis</em> L.</td>
<td>meadow foxtail</td>
<td>Perennial</td>
<td>Introduced</td>
<td>OPG</td>
</tr>
<tr>
<td><em>Bromus species</em></td>
<td>brome</td>
<td>Annual</td>
<td>Introduced</td>
<td>AG</td>
</tr>
<tr>
<td><em>Poa trivialis</em> L.</td>
<td>roughstalk bluegrass</td>
<td>Perennial</td>
<td>Introduced</td>
<td>OPG</td>
</tr>
<tr>
<td><em>Cynosurus echinatus</em> L.</td>
<td>dogtail</td>
<td>Annual</td>
<td>Introduced</td>
<td>AG</td>
</tr>
<tr>
<td><em>Holcus lanatus</em> L.</td>
<td>velvetgrass</td>
<td>Perennial</td>
<td>Introduced</td>
<td>OPG</td>
</tr>
<tr>
<td><em>Phalaris arundinacea</em> L.</td>
<td>reed canarygrass</td>
<td>Perennial</td>
<td>Native</td>
<td>OPG</td>
</tr>
<tr>
<td><em>Juncus</em> Spp.</td>
<td>rush</td>
<td>Perennial</td>
<td>Native</td>
<td>OPG</td>
</tr>
<tr>
<td><em>Vicia villosa</em> Roth</td>
<td>hairy vetch</td>
<td>Annual</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Valerianella locusta</em> (L.) Betcke</td>
<td>lamb’s lettuce</td>
<td>Annual</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Montia linearis</em> (Hook) E. Greene</td>
<td>narrow leaved montia</td>
<td>Annual</td>
<td>Native</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Cerastium vulgatum</em> L.</td>
<td>chickweed</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Myosotis discolor</em> Pers.</td>
<td>forget me not</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Daucus carota</em> L.</td>
<td>wild carrot</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Parentucellia viscosa</em> (L.) Caruel</td>
<td>eyebright</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Trifolium repens</em> L.</td>
<td>white clover</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Trifolium pratense</em> L.</td>
<td>red clover</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Madia sativa</em> Molina</td>
<td>Coast tarweed</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Ranunculus parviflorus</em> L.</td>
<td>buttercup</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Dipsacus fullonum</em> L.</td>
<td>common teasel</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Geranium dissectum</em> L.</td>
<td>wild geranium</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Hypochaeris radicata</em> L.</td>
<td>hairy catsear</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Rubus discolor</em> Weihe &amp; Nees</td>
<td>Himalayan blackberry</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Sonchus oleraceus</em> L.</td>
<td>sow thistle</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Cirsium arvense</em> (L.) Scop.</td>
<td>Canada thistle</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
<tr>
<td><em>Cirsium vulgare</em> (Savi) Tenore</td>
<td>bull thistle</td>
<td>Perennial</td>
<td>Introduced</td>
<td>FORB</td>
</tr>
</tbody>
</table>
Grass and Forb Phenology

Control

Sample Time

Percent Cover

0 20 40 60 80 100

T1 T2 T3

RYE veg  RYE bloom  RYE seed  OPG veg  OPG bloom
OPG seed  AG veg  AG bloom  AG seed  FORB veg
FORB bloom  FORB seed  LITTER
Figure A.3: Grass and Forb Phenology: Low Intensity Treatment
Grass and Forb Phenology

Moderate Intensity Treatment

Percent Cover

Sample Time

T1U  T1O  T2U  T2O  T3U  T3O

- RYE veg
- RYE bloom
- RYE seed
- OPG veg
- OPG bloom
- OPG seed
- AG veg
- AG bloom
- AG seed
- FORB veg
- FORB bloom
- FORB seed
- LITTER
Grass and Forb Phenology
High Intensity Treatment

Percent Cover

T1U  T10  T2U  T20  T3U  T30
Sample Time

RYE veg  RYE bloom  RYE seed  OPG veg  OPG bloom
OPG seed  AG veg  AG bloom  AG seed  FORB veg
FORB bloom  FORB seed  LITTER