Sheep grazing as a poisoning control method on tall larkspur populated cattle range
by Jack Dudley Alexander

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Range Science
Montana State University
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Abstract:
Tall larkspur (Delphinium qlaucescens) seriously reduces the efficient use of mountain cattle range. Sheep are relatively resistant to poisoning in normal grazing situations. The use of sheep grazing as a method of reducing the risk of larkspur toxicosis among cattle was studied in southwest Montana in the summers of 1984 and 1985. It was found that sheep removed from 71% to 100% of plants from the "toxic window" of plants in stages dangerous to cattle. Further, we propose that the density of plants left in a toxic form was reduced to a level which greatly reduced the risk of toxicosis to cattle. From this we propose that sheep grazing is an effective alternative to deferring grazing as a method of reducing toxicosis risk to cattle.

SHEEP GRAZING AS A POISONING CONTROL METHOD

ON TALL LARKSPUR POPULATED CATTLE RANGE

by

Jack Dudley Alexander III

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

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APPROVAL

of a thesis submitted by

Jack Dudley Alexander III

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ACKNOWLEDGEMENTS

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

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the efficient use of mountain cattle range. Sheep are
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INTRODUCTION

Tall larkspurs are a group of perennial forbs that grow in foothills and mountains. Although they contain alkaloids which are toxic to cattle, they can usually be grazed safely by sheep. Every summer since 1981, a band of approximately 1,500 yearling ewes has been grazed in patches of tall larkspur, Delphinium glaucescens Rybd., immediately preceding summer grazing by cattle. The study was conducted along the Ruby River in southwest Montana's Beaverhead National Forest, approximately 70 km west of the northwest corner of Yellowstone National Park.

The purpose of this study was to test sheep as agents to reduce the incidence of cattle poisoning by tall larkspur on summer range allotments. Prior to 1981, deaths due to larkspur poisoning in the vicinity had been high. Reports exist of over 50 head dying the first day cattle were turned into the pastures. Livestock losses historically had created management problems for both the grazing association and US Forest Service (USFS). Cattle grazing in pastures with large larkspur patches was often delayed until the tall larkspur matured and became less dangerous. Thus, the grazing strategy dictated by tall larkspur resulted in more use on spring range.

In developing the present study, it was theorized that sheep would select for larkspur, slow or stop growth for the current year, and hasten the maturing (drying) of the plant to a less dangerous stage.

The study was funded by the Montana Agriculture Experiment Station in cooperation with the Upper Ruby River Grazing Association, USFS, US Department of Agriculture-Agricultural Research Service Poisonous Plants Laboratory (Logan, Utah), and Joe Helle, a sheep owner with sheep grazing in the Beaverhead National Forest. Cattle were owned by the Ruby Valley Livestock Association.

LITERATURE REVIEW

Definition of a Poisonous Plant

Cronin et al. (1978) offered the following definition: a poisonous plant contains some specific substance which causes injury when consumed by animals under specific circumstances. Mechanically injurious plants are usually exempted from such a definition because they lack an injurious chemical agent. The "specific circumstances" under which the poisonous plants must be consumed to cause problems pertain to the modifying role of variable environmental conditions in determining what plants are poisonous (Cronin et al 1978).

Tall larkspur fits this definition. It contains a number of complex diterpenoid alkaloids. Further, cattle are susceptible to injury or death when they ingest sufficient quantities of tall larkspur at most phenological stages.

The Plant Poisoning Problem

James (1978) stated that a large portion of the earth's land is devoted to the grazing of livestock and that the forage on these lands can best be harvested by grazing animals. However, poisonous plants often interfere with the proper harvesting of this forage. The fact that poisonous plants have a severe economic impact on the livestock industry on western rangelands has been well documented (Stoddart and Smith 1943, Keeler 1978, Gilkey 1958, James 1978, Durell and Newson 1939).

In the traditional view of the ecology of poisonous plants, the occurrence of poisonous plants is equated with poor range condition. Stoddart et al (1975) wrote that areas with poisonous plants should be managed in such a manner as to reduce the invasion, spread or relative abundance of toxic species in relation to favorable species. Livestock should be managed to allow the animals to select forage other than poisonous species. Areas with desirable forage should be grazed and animals should not be stressed to the point that their natural forage selection patterns are altered.

Unfortunately, these practices do not apply to tall larkspur. Rather than increasing in density and/or relative abundance in the animal's diet as the resource declines, larkspur is present in the climax community, is consumed on excellent condition rangeland in a disproportionate amount to its abundance, and is dangerous to healthy cattle (Cronin et al 1978). As reported by Cronin et al (1978) the larkspurs are readily grazed by cattle, which makes prevention of poisoning more difficult than with most poisonous plants. However, as with many other poisonous plants, cattle may graze and utilize small amounts of the plant over prolonged periods without apparent effect while rapid consumption of larger amounts in short periods of time may result in death (Anonymous 1968).

Stoddart et al (1975) reported that since little progress has been made toward elimination of poisonous plants, a

producer must manage grazing to avoid toxicity problems. In order to reduce risk it is important that the range manager (1) recognize the poisonous plants which are present on the range, (2) know at what times they are most dangerous and for which animals, and (3) maintain a good cover of suitable forage plants. Although tall larkspur toxicosis cannot be avoided simply by providing for a good cover of forage plants, a suitable management plan for grazing larkspur populated pastures can be developed.

The Delphinium Poisoning Problem

Olsen (1977a) stated that larkspur poisoning of cattle in North America was reported as early as 1760. Cronin and Nielsen (1981) noted that larkspurs have been a major cause of livestock losses since the industry migrated west of the 100th meridian in the 1800's. Species of Delphinium occur throughout the northern hemisphere; however, they have caused the most damage in western North America. One or more species of larkspur are listed as poisonous plants for each of the Western States and western provinces of Canada (Cronin and Nielsen 1981). The importance of the genus Delphinium as livestock hazard is demonstrated by the following statements which typify many of those in the literature. "The larkspurs cause more cattle deaths than any other plant species grazed on the ranges of the western United States and Canada (Kingsbury 1964)." This statement occurred in literature as

early as 1900 (Chestnut). Platt (1959a,1959b) developed a list of the most important herbaceous range weeds and undesirable shrubs based on a questionnaire survey. <u>Delphinium</u> species ranked 9th among herbaceous species and covered 2 million ha of area (Heady 1975). Contemporary reports and comments reaching the Poisonous Plant Research Laboratory indicate that more cattle deaths are attributed to larkspurs than to all other poisonous plants combined (Cronin and Nielsen 1981). Cattle losses are still excessively high. Over 1,000 cattle reportedly died from larkspur poisoning on the Intermountain Forest Service Region in 1986 (Nielsen and Ralphs 1987).

Three to five percent of the cattle on larkspur populated range die each year, though cattle losses have been as high as 20 percent on some ranges (Torrel and Higgins 1963). Cronin et al (1976) cited annual mortality losses on certain cattle allotments as high as 12%. Cronin and Nielsen (1981) remarked that, unfortunately, not enough data are available to quantify economic loss. Stockmen appear willing to accept small losses (less than 2 percent) as normal for rangeland conditions and do not report them. In addition, other poisonous plants exist on many grazing areas, sometimes making it difficult to determine the cause of deaths of animals found. Ranchers may also be reluctant to report or discuss

their losses because they believe that would be an admission they had failed to manage their stock properly (Cronin and Nielsen 1981).

Reports of cattle poisoning due to tall larkspur in Montana were published as early as 1899 in the Montana Agricultural Experiment Station Bulletin (Wilcox 1899). Beath (1919) first described the toxicity of D. glaucescens (DEGL). He reported that DEGL was not as toxic and did not grow in as dense stands as other tall larkspurs and that cattle did not often consume enough to receive a lethal dose.

Poisonous Plant Effects

Losses from poisonous plants affect the economic returns of ranching in several ways. The most obvious is from animals that are killed directly from the consumption of these plants. Death is the loss most often associated with poisonous plants and is probably the easiest loss to evaluate (Nielsen 1978). There are, however, many ways in addition to death that poisonous plants exert their detrimental effects on livestock. Some of these include chronic illness and debilitation, decreased weight gains, abortion, birth defects, and photosensitization (James 1978). Some poisonous plants do not kill the animal but severely reduce the production from that animal and/or its offspring. This loss is reflected in reduced weaning weights and percent calf or lamb crops, orphaned animals, unmarketable animals due to birth

deformities, and reduced longevity of the breeding herd. There are other indirect but costly effects, including such things as altered grazing programs, additional fencing, loss of forage, increased labor costs of herding and caring for livestock, and the use of supplemental feeding programs (James 1983). Probably the least obvious economic loss caused by poisonous plants on rangelands is that the presence of poisonous plants causes the range resource to be used and developed at less than its optimum. For example, the decision on class of animal to graze (sheep or cattle) could be the result of trying to avoid poisonous plant problems rather than being determined by which class of animal is best suited to utilize the rangeland on the basis of available forage and topography. Poisonous plant problems often dictate the season of use of rangelands, not allowing these lands to be used as efficiently as they could without this potential danger.

Livestock management measures which avoid grazing larkspur areas during dangerous periods do not allow the forage that grows in tall larkspur areas to be used at a time when it is most palatable and nutritious. Deferred use of mountain ranges can contribute to over-use of lower elevation ranges. Such practices do nothing to eliminate the fundamental problem, since the larkspur remains (Torrell and Higgins 1963). As an example, Cronin et al (1977) reported that in the mountains east of Cedar City, Utah, stockmen face a serious economic handicap because, except for the fortunate

few owning summer range free of larkspur, they are restricted to grazing sheep since the abundant tall larkspur (D. barbeyi) precludes safe grazing of cattle.

Ralphs et al (1988) report that tall larkspur can dictate when and how lush mountain rangelands are used. Larkspur-populated cattle allotments at higher elevations are deferred until after flowering, when the risk of poisoning is reduced. This practice wastes much of the production and nutritive content as the forage matures. Gains by calves grazing these allotments probably could be increased 9 kg by grazing these ranges 15 to 30 days earlier (Nielsen and Ralphs 1987).

Kingsbury (1964) notes that additional danger to cattle is created by the fact that grazing cattle are attracted by the particularly palatable vegetation on sites where late melting snowdrifts produce water for luxuriant growth. These are the sites which are likely to support large, dense patches of larkspur. These sites are extremely dangerous for two reasons. First, the abundant tall larkspur contains the highest concentrations of poisonous alkaloids during this early growth (Marsh et al 1916, Williams and Cronin 1963). Second, relatively small amounts of tall larkspur can be lethal if eaten rapidly (Kingsbury 1964).

Tall vs. Low Larkspurs

There are numerous species classified as "tall" larkspurs and "low" larkspurs, based on their height at maturity. Tall larkspur is not a single species, but an entire group of species having a similar appearance. Low larkspurs are smaller plants (less than 30 cm in height at maturity) that inhabit the drier plains and foothill areas, while the tall larkspurs (>30 cm) are larger, more robust plants growing in the higher mountains or sites with abundant soil moisture (Dayton 1960). Low larkspurs begin growing in early spring, and poisonings often occur in the spring prior to hot weather (James and Johnson 1976).

Tall larkspurs grow at higher elevations on deep soils where moisture is readily available over most of the growing season. Typical sites are mountain meadows where deep snowdrifts persist well into the growing season, under aspens on north facing slopes, along streams, or around seeps and springs where they are frequently the dominant forb (James et al 1980). They are climax species and tend to increase with improving range conditions. They remain green and may be palatable to livestock throughout the growing season (Cronin and Nielsen 1981). Since tall larkspurs are found at higher elevations and grow later in the year, poisonings occur primarily in the summer and fall (James and Johnson 1976).

Description of Delphinium glaucescens

Hitchcock et al (1964) offer the following description.

Delphinium glaucescens Rybd. Mem. N.Y. Bot Gard.
1:155. 1900. (Rydberg & Bessey 4078, Electric
Peak, Yellowstone Park, Aug 18, 1897)

D. glaucescens var multicaule Rybd. Mem. N.Y. Bot.
Gard. 1:156. 1900. (Rydberg & Bessey 4071, Cedar
Mt. Mont., July 16,1897)

A rather stout perennial from a large,
branched, woody root; stems usually several, from
slender to (more commonly) stout and fistulose,
glabrous throughout or only below the
inflorescence, often purplish, (2) 3-10 dm tall;
leaves chiefly on the lower 1/2-2/3 of the stem,
the basal and lower cauline ones long-petioled and
forming large clumps that tend to persist until
after anthesis, the upper portion of the stems with
much-reduced bracts; main leaf blades (4) 6-13 cm
broad, usually more or less finely crisp-pubescent,
not clearly marked into primary divisions, but
about (2) 3 times dissected, the ultimate segments
linear or (more commonly) oblong-lanceolate, mostly
acute or acuminate, (1) 2-10 mm broad;
inflorescence glabrous, crisp-puberulent, or
somewhat glandular-pilose, simple to compound, the
main raceme up to 2.5 dm long but generally rather
closely 15- to 30 (40) -flowered and somewhat
spikelike, the pedicels (except the lowest) usually
shorter than the spur and more nearly spreading
than ascending; sepals commonly deep clear blue,
(6) 10-15 mm long, narrowly oblong-lanceolate,
spreading but the tips somewhat cupped forward,
usually sparsely crisp-pubescent with soft hairs,
the spur about equalling the upper sepal blade;
petals colored as the calyx, the lower ones deeply
bilobed, the upper whitish-margined; follicles
mostly 9-13 (17) mm long, usually heavily veined or
mottled with purple, spreading slightly at
maturity, usually thickly pubescent with fine,
straight mostly glandular hairs, rarely glabrous
except along the sutures; seeds about 2 mm long,
the margins prominent.

Plants primarily of sagebrush slopes, less
commonly in bunchgrass areas or in open montane
forests; c. Ida. (Custer Co.) n. to Madison Co.,
Mont, e. to Yellowstone Nat. Park. July-Aug.

Although never found in wet areas, <u>D. glaucescens</u> is unusually responsive to local edaphic conditions. Plants growing on open, exposed, gravelly slopes are often dwarfed in all parts, and as low as 2 dm in height; these depauperate individuals are easily mistaken for <u>D. andersonii</u>. In contrast, plants occurring in areas where snow persists until late in the season and where the soil is more favorable to lush growth usually attain several times this stature and have correspondingly larger leaves and somewhat larger flowers. Although the species is notable for its lack of glandular pubescence, plants from Custer Co. Ida., occasionally are slightly glandular.

<u>Toxicity of the Genus Delphinium</u>

The entire genus <u>Delphinium</u> is toxic and animal responses to poisoning are similar among species (James and Johnson 1976). Several of the species cause severe stock losses, chiefly to cattle. Sheep are unaffected by the poison under ordinary range conditions (Hitchcock et al 1964). Differences are observed among species, years, and growth stages.

The toxic compounds in larkspurs are complex diterpenoid alkaloids (James 1983). Apparently there is a large number of these compounds in species of the genus <u>Delphinium</u> and each species probably contains its own characteristic complement of alkaloids. Thus, species vary in toxicity. Furthermore, the relative concentration of a particular alkaloid may change with the stage of growth (Kreps 1969). Little is known, however, concerning concentrations, toxicity, or mode of action of individual alkaloids (Cronin and Nielsen 1981).

Variations in concentrations of alkaloids in the plants and the tolerances of animals to the plant toxins interact

to confuse the relationships between larkspur and livestock losses. These factors may interact one year to keep losses low, while the following year they may interact to generate heavy losses. These sharp fluctuations in losses on the same grazing area require long-term records of losses to evaluate the impacts of larkspurs and to measure the effects of efforts to reduce losses (Cronin and Nielsen 1981).

Alkaloids do not accumulate in grazing animals and are metabolized, perhaps by the animal itself, perhaps by the rumen microflora. Alkaloids are also excreted. The rate at which larkspur is ingested also affects its toxicity to animals. A moderate amount ingested within an hour or less may prove lethal, while the same amount ingested over a period of a day or more may produce no evidence of toxicity (Cronin and Nielsen 1981).

Toxicity Determination by Rat Bioassay

A bioassay technique has been developed to estimate toxicity for rats, using an alcoholic extraction product from larkspur (Olsen 1977b). A saline extract is subcutaneously injected into rats and the LD_{50} is calculated from the mortality rate at 24 hours after injection, according to the method of Weil (1952). From this, the toxicity can be expressed in terms of the equivalent amount of dried plant material.

The bioassay method has been used to estimate differences in toxicity of larkspurs during various stages of plant growth and among different years of growth, and to determine the effects on toxicity of geographical site of growth and other environmental factors.

Olsen (1979) reported that the extrapolation of larkspur toxicity as measured by the mouse bioassay to that of larkspur toxicity for cattle is subject to reservation but some reasonable correlation can be expected. He found the LD_{50} of DEGL to be 16.2 mg/g in a rat bioassay (Olsen 1977b).

Signs of Larkspur Toxicosis

As reported in a review article by Olsen (1978a) the clinical signs of larkspur toxicosis were documented in 1916 by Marsh et al. These signs, in order of appearance, include uneasiness, stiff gait, and a characteristic straddled stance with the hind legs held far apart. Olsen (1978b) further described poisoning of both sheep and cattle fed larkspur extract. The clinical signs were similar for poisoning by either ground plant or extract. The first signs of poisoning were cervical muscle tremors in sheep and femoral muscle tremors in cattle. Generalized tremors and ataxia occurred until the animal could not stand. Usually a sequence of standing, tremors, and lying down was repeated. The time of standing became shorter, and eventually most animals went to lateral recumbency. Prognosis could be made based on the rate

of progression of muscular weakness. Respiratory movement became labored and shallow, with death by asphyxiation. One-half of the cattle, but none of the sheep, regurgitated before death.

Poisoned cattle are most often found dead, occasionally resting on their sternum with hind legs partially extended behind the animal (Olsen 1983). Radeleff (1970) reported that the severity of the poisoning may be gauged by the position of the animal when prostrated. Slightly poisoned animals rest on the sternum with the head erect. In more acute cases, the head rests on the ground, and in severe poisoning the animal lies on its side. Induced excitement will bring on seizures: therefore, treatment and its potential should be carefully evaluated against the disturbances always attendant upon range treatment of cattle (Radeleff 1970).

Toxicosis Treatment

As with most poisonous plants there are no known treatments for animals poisoned by larkspurs. Were treatment available, affected animals are usually in remote places and could not be reached in time to apply the treatment (James et al 1980).

Although treatments are included in the literature (Radeleff 1970, Anonymous 1974) they tend to provide nonspecific relief of symptoms rather than providing an antidote to the toxic alkaloids. Radeleff (1970) outlined

treatment for a 600-pound bovine suffering from larkspur poisoning as follows: 1 grain of physostigmine, 2 grains of pilocarpine hydrochloride, and 1/2 grain of strychnine sulfate injected subcutaneously to relieve constipation and stimulate respiration but cautions that this must be considered a nonspecific antidotal procedure.

Due to the speed with which the toxins in <u>Delphiniums</u> act it is much better to prevent the problem than to try to afford treatment, since the animals usually die before detected. Those animals in which treatment appears to be effective may have not received a toxic dose and so would have recovered on their own (James et al 1980).

Toxicosis Prevention

James et al (1980) offered the following preventative measures. Keep cattle off larkspur ranges until the grasses are producing abundant forage. Utilize sheep to graze heavily infested areas or control the larkspur with herbicides before allowing cattle to graze. Do not graze cattle on tall larkspur plants that have been treated with herbicides until the frost has dried the plants in the fall. Applications of herbicides to tall larkspur appear to increase their palatability, and treated plants do not lose their toxicity as untreated plants do. This may be a result of the herbicide holding the plant in a somewhat constant phenological stage which would prevent the normal decline in alkaloid content.

Laycock (1975) noted the report of Aldous (1917) which stated that the generally high palatability of the tall larkspurs and the relative immunity of sheep to larkspur poisoning resulted in early attempts to control larkspur by grazing infested areas heavily with sheep before cattle reached the areas. This method reduced the amount of larkspur available to the cattle but was not effective as a permanent control measure.

Tall Larkspur Control

Cronin and Nielsen (1981) reported that controlling larkspur through livestock management, grubbing, or with applications of herbicides seems to be the only options open to the rancher for reducing or preventing losses. They stated that livestock management does not appear to be an effective or economical method of control because tall larkspur is a palatable climax species that increases in density with improving range conditions. Furthermore, it is a tenacious and long-lived species that has survived overgrazing in the past (Cronin and Nielsen 1981).

The most obvious means of controlling losses to larkspur poisoning is to remove larkspur from the grazing environment. This has been attempted many times in the past, most often with 1 of 2 methods: grubbing or herbicide application.

The impracticality of grubbing was emphasized by Torrell and Higgens (1963), noting that for many years hand-grubbing

of larkspur was the only control available. The method is effective if the vertical root stock is completely removed. Although grubbing still has some use for destroying a few isolated plants, it is slow and expensive for wide-spread control. As noted by Cronin in his review article of 1981, grubbing has been rejected as impractical for many years (Aldous 1917, Durrel et al 1952, Marsh and Clawson 1918).

Herbicide treatment of the larkspurs has been given extensive research attention (Cronin 1974, Cronin et al 1976, Hyder 1972, Nielsen and Cronin 1977). However, few if any of the treatments deemed to be effective are legal, practical or economically viable at the present time. It is doubtful any chemical treatment will meet all management and legal criteria in all situations; i.e. public land, inaccessible areas, low production rangeland.

Management of Toxicosis Risk

Cronin and Nielsen (1981) offered several options for control when grazing larkspur areas. The grazing can continue and the producer can (1) accept the losses, (2) use other areas to graze the animals, (3) build fence around patches of larkspur or (4) control the larkspur. The first alternative reduces income and the second is often unfeasible due to the unavailability of alternate grazing areas and/or the distribution of poisonous plants.

Ralphs et al (1988) noted that the first range improvement on many forest allotments was the "poison" fence to keep cattle away from the larkspur until it matured and became less toxic. As the Forest Service separated allotments for cattle from those for sheep, the greatest factor determining allotment boundaries was larkspur distribution (Ralphs et al 1988). However, fencing cattle out of larkspur patches generally is not seriously considered. The number, sizes, and shapes of the patches tend to make the cost prohibitive. Larkspur also tends to grow in areas receiving high amounts of snowfall, making extensive and expensive springtime fence repair work necessary (Cronin and Nielsen 1981).

Pfister et al (1988a) reported that cattle did not eat leaves of D. barbeyi during the vegetative growth stage. After flowering, leaves made up to 15 to 30% of diets. Because leaves of vegetative plants were high in total alkaloids and then declined as plants matured, Pfister suspected a negative correlation between alkaloid content and palatability. Negative correlations have been observed between alkaloid levels and palatability in other forage species (Nielsen and Ralphs 1987), presumably due to the bitter taste of alkaloids (Ralphs et al 1988). Flowers made up 2% of diets during the short time they were available and pods were selected for 5% of diets. Consumption was limited by availability (Ralphs et al 1988).

There appears to be a time window of intoxication, the "toxic window", between early vegetative growth, when the plant is unpalatable and toxic, and maturity, when larkspur is palatable and relatively nontoxic (Ralphs et al 1988). Thus, cattle can occasionally ingest large quantities of tall larkspur with no deaths (Pfister et al 1988a).

Using sheep to control tall larkspur not only may reduce the risk of cattle loss but allows utilization of a potentially valuable forage resource. Pfister et al (1988b), working with D. barbeyi, measured crude protein levels of 12 to 20%, and fiber levels <20% during most of the growing season.

MATERIALS AND METHODS

Experimental Area

In the summers of 1984 and 1985 a tall larkspur toxicosis control program was studied on 3 sites in the Upper Ruby River Valley. The Ruby Valley is in southwest Montana's Beaverhead National Forest east of Dillon, Montana (Figure 1). This is a high mountain valley ($\pm$2000 - 2400 m) located between the Gravelly and Snowcrest Mountain ranges. Ross and Hunter (1976) classify this region in the foothills and mountains geographical area, on a silty range site in the 51-61 cm precipitation zone. Precipitation comes primarily in the form of snow and intense summer rainstorms. The area has a mountain climate with cool summers and cold winters. Soils are typically more than 50 cm deep, with very fine sandy loam, loam, or silt loam textures.

The distinguishing feature of this sub-type is the sagebrush covered foothills and rich variety of graminoids. The principal forage species are bluebunch wheatgrass (Agropyron spicatum (Pursh) Scribn. and Smith) and Idaho fescue (Festuca Idahoensis Elmer.). Relict areas indicate that the original sub-type had a dense stand of Idaho fescue and other mountain grasses with little big sagebrush (Artemisia tridentata Nutt.) (Interagency Range Committee 1973). The sites were located in the Idaho fescue/big sagebrush vegetation type. Associated species included
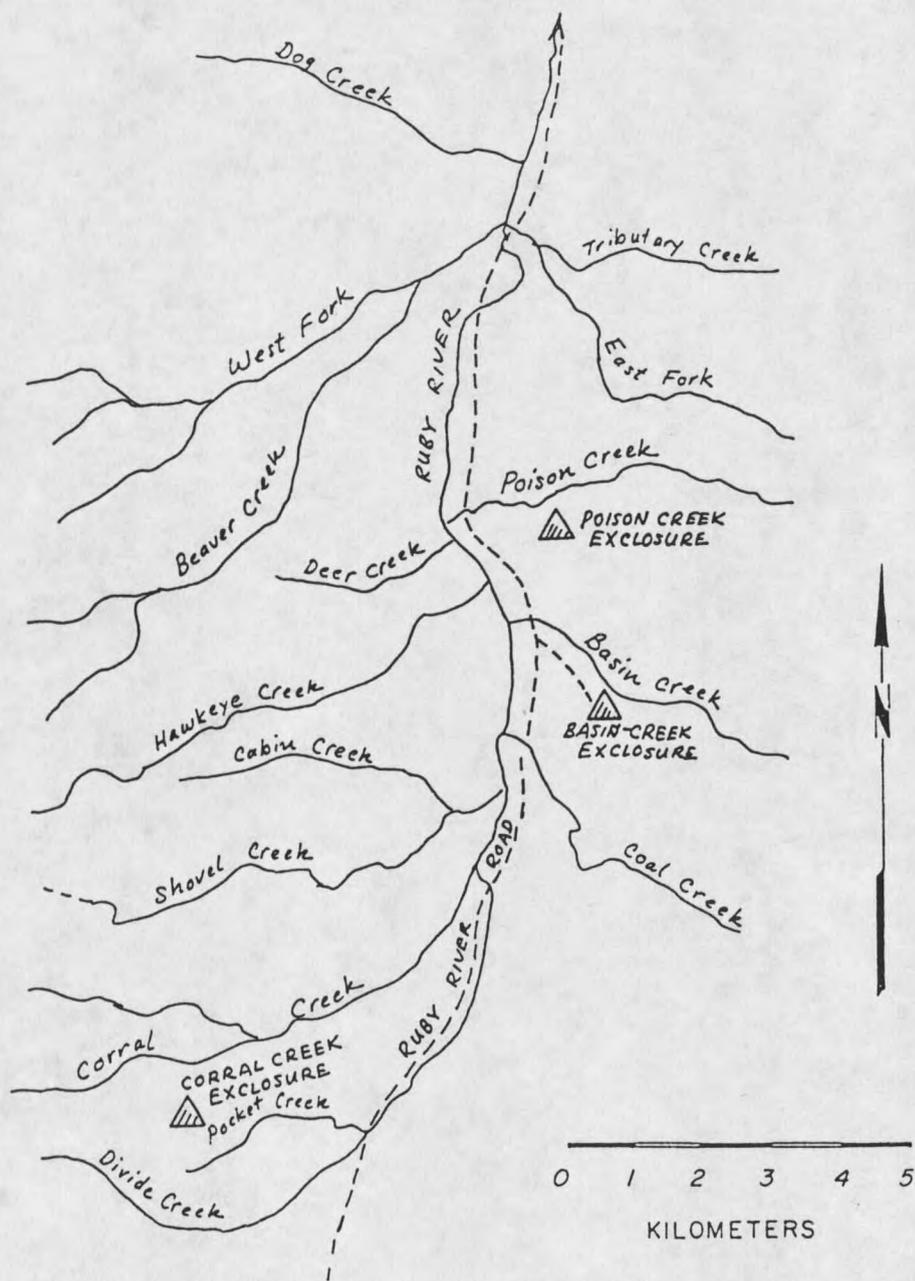
Figure 1. Map of Ruby River Valley with study sites.

sticky geranium (<u>Geranium viscosissimum</u> Rydb.), snowberry (<u>Symphoricarpos albus</u> (L.) Blake), big sagebrush, mountain brome (<u>Bromus marginatus</u> Nees), lupine (<u>Lupinus</u> spp.), and mountain dandelion (<u>Agoseris glauca</u> (Pursh) Raf.).

The study site contained as much as 20% canopy cover of DEGL growing in non-uniform clumped patterns in the drainages of Poison Creek, Basin Creek and Corral Creek. These areas have large, dense stands of tall larkspur which are of the type reported to be the most dangerous to cattle (Cronin and Nielsen 1979) as well as being the type hypothesized to be the most efficiently grazed with bands of sheep (Johnston and Peake 1960).

Study Sites

This study was carried out using three study sites, each had an exclosure to provide a comparison of grazed and ungrazed areas. The Poison Creek site, at 2100 m elevation is the northernmost site. It has a northwest aspect, and is located on the east side of the Ruby River in the Basin pasture. The Basin Creek site, 2200 m elevation, is 3.5 km SSW of the Poison Creek site. The Basin Creek site has a west aspect, and is on the east side of the river in the Basin pasture. The Corral Creek site, 2300 m elevation, is the southernmost site, 10 km SSW of the Poison Creek site. It has an east aspect and is on the west side of the river in the Divide pasture.

Plant impact data were collected on another area grazed by sheep in 1984, which was not a part of the original study plan. This site, Dog Creek, was located approximately 6 km NW of the Poison Creek site. It has east aspect and is on the west side of the Ruby River in the West Fork pasture. This area was grazed after Basin Creek but before Corral Creek in 1984. Grazing was completed 8 Aug 1984. It was not grazed by sheep in 1985. This site was grazed at the request of the USFS.

Exclosures

Exclosures were placed in such a manner as to have a truly representative control treatment with which to compare grazing treatments. Exclosures were built on each of these sites; however the Corral Creek exclosure was not installed until after the end of the 1985 season, because agency approval was not received until that time.

The exclosures were of the following sizes: Basin Creek - 25 x 25 m; Poison Creek - 25 x 50 m; and Corral Creek - 50 x 50 m. Exclosures were 5 strand barbed wire fences with the exception of Corral Creek which was enclosed by an electric fence.

It is important that exclosures be of sufficient size so that 200-400 plants may be removed for toxicity sampling without impacting an area of approximately 3 X 25 m which was reserved for the plant phenology transect. The exclosure at

Basin Creek is too small to achieve this objective. The
Poison Creek exclosure is marginally acceptable in size; it
appears to be sufficient in near average or above average
larkspur production years. In a year with low numbers of
larkspur plants there may be too few individuals for the
collection of toxicity samples during the later phenologic
stages.

The Grazing Treatment

Traditionally, cattle were held on the lower pastures of
the grazing allotment until the tall larkspur on higher
pastures had been allowed to mature and its toxicity had
declined. This reduced the opportunity to fully utilize the
forage resource in the pastures containing tall larkspur.

During this study sheep were herded onto a pasture
immediately before cattle were allowed onto that pasture.
This was to allow effective reduction in the risk of larkspur
toxicosis as well as allowing differentiation between cattle
use and sheep use for study purposes. Having the cattle
immediately follow the sheep also minimized the opportunity
for regrowth of the larkspur and of associated species.

A band of approximately 1,500 yearling ewes were grazed
through large, dense patches of DEGL under the direction of
a herder. The sheep were moved onto the larkspur after flower
stems had begun to elongate and were herded on the patches for
2-5 days until thorough grazing of the DEGL was complete.

Cattle immediately followed the sheep allowing little time for regrowth.

Domestic sheep were used to attempt to control poisoning losses from a plant which is dangerous to domestic cattle. The necessary features of such a program are outlined by Stoddart et al. (1975) who noted that the effectiveness of domestic livestock as agents for manipulating vegetation rests upon four conditions: (1) effective control over livestock, (2) acceptance of the target plant as forage by livestock, (3) presence of other forage species which can replace the target species or a site favorable to artificial revegetation, and (4) differential susceptibility of "target" plants to grazing at some time of the year. These conditions are met with this program as follows:

1) The sheep were controlled by a resident herder.

2) The purpose of the utilization transects performed as a part of this study was to determine the acceptance of DEGL by sheep. The extent to which this acceptance took place is reported later in this thesis.

3) The replacement for the target species was additional DEGL patches in other parts of the cattle allotments. A grazing allotment was available for the sheep outside of this cattle allotment should it have been necessary. There was abundant native vegetation within and adjacent to the treated areas which also provided forage for the sheep in the control band.

4) This study was not designed to determine if there was differential susceptibility of tall larkspur to grazing. However, the susceptibility of cattle to larkspur toxicosis does vary with the plants state of growth. The sheep were used to manipulate the vegetation in an effort to reduce this risk.

Yearling sheep were used in this project at the request of the sheep owner who felt risk of larkspur toxicosis in the band would be minimized. There were fears that if a ewe/lamb band were used there would be a chance of the lambs consuming a harmful or lethal dose of alkaloids either directly in forage or through the mother's milk. It is not known whether this concern is justified. It was not within the scope of this study to determine the possible dangers to ewes with lambs grazing tall larkspur. It is rumored that other ranchers in the area use ewe/lamb bands in tall larkspur control. Because there are fewer livestock husbandry chores with a yearling band than with a ewe/lamb band the sheep owner thought that the herder would be able to better control the band's grazing and therefore concentrate more intently on increasing larkspur consumption.

The sheep were grazed not only on the study patches of larkspur but on any other nearby patches deemed to be of potential danger to the cattle.

A herder was used to influence grazing behavior of the poison control band because as noted by Heady (1975), the

evenness of use on a range by sheep depends almost wholly upon the herder and the herding methods used. It should also be noted that herding of sheep offers closer control of forage use than does herding of cattle (Heady 1975). Since the control band is tended by a sheep herder, grazing can be concentrated on the dense patches of larkspur, which are generally the greatest threat to cattle (Cronin and Nielsen 1979). Familiarity of sheep owners with herding simplifies the installation of this type of a program.

Cattle movement and inspection were carried out by riders for the Ruby Valley Grazing Association. They checked cattle daily and were consulted regularly for information on cattle movement and on possible larkspur poisoning losses. Personnel from this project also checked the study sites daily and were alert for livestock problems.

Data Collection

Animal Impact Transects

In order to estimate DEGL density and the impact of the sheep on DEGL, animal impact transects were run outside the exclosure at each site immediately following sheep grazing. In 1984 a 50 m tape was placed through the larkspur stand and measurements were taken within 0.5 m of each side of this line, creating a 50 m^2 area. Measurements were recorded in 5 contiguous 10 m^2 blocks. In 1985 the transects again were done in five 10 m^2 blocks, but each 10 m^2 block was

independently located. This change was made because the patchy distribution of DEGL made it difficult to locate a transect in such a manner that it ran within a DEGL stand for the entirety of its 50 m length. Since the objective of this study was to determine the effectiveness of grazing as a control method on the dense stands of DEGL deemed to be dangerous, a change was made to a method more suited to measurement of density and animal impact in the dense portions of the stand.

All plants encountered within the sheep impact transect were counted and noted whether they were grazed or ungrazed. Ungrazed plants were classified as trampled, unattractive, non-toxic, potentially toxic, or toxic. Plants in the "trampled" category were those that were removed from offer due to physical damage inflicted by the grazing sheep. Plants placed in the "unattractive" category were those plants that were dead, aborted, damaged by insects, or were in the vegetative stage. "Non-toxic" plants were those that were still determined to be attractive to cattle but were in a late maturation stage- i.e. fruiting or pod stages which were determined by Pfister et al (1988b) to be non-lethal. "Toxic" plants were those plants of the flowering stage which fit into the "toxic window" postulated by Pfister et al (1988b). Plants classified as "potentially toxic" were those with healthy buds which could mature into dangerous plants which then would be attractive to cattle.

Because each plant within the transect was recorded, it was possible to calculate DEGL densities from these data.

It should be noted that year to year comparisons cannot be made for impact or for density because sampling methods were different in the 2 years.

Plant Phenology Transects

In order to study the phenological characteristics of DEGL located on the various sites throughout the growing season, measurements of several physical characteristics were regularly made. At each site 2 transects were read every 10 days ($\pm$ 1 day), one inside and one outside the exclosure. These transects consisted of a 25 plant transect taken along a permanent line. This was a belt approximately 2 m x 25 m within which the nearest plant was selected at each pace. At each plant 5 measurements were taken and notes made as to any unusual occurrence or appearance (i.e. insect damage, aborted flower stalks, curled raceme). Measurements were made of floral height and of the height of the basal group of leaves (Figure 2). The number of flower stalks was counted and subjective scores were given for floral stage as well as phenological condition. The floral stage was determined by the percentage of flowers in bud, bloom or fruit. The phenological condition was determined by leaf color. The

dates on which these transects were run varied between years according to initial plant growth (Table 1). The description of these classifications is found in the Appendix.
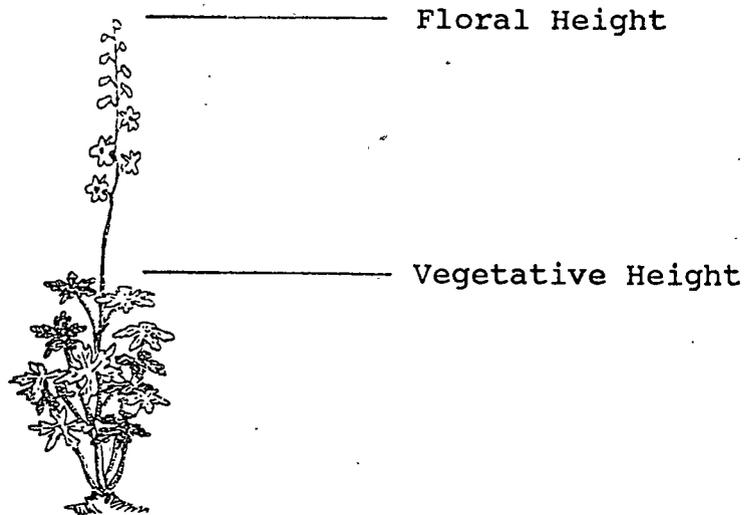

Figure 2. Diagram of vegetative and floral height measurements.

Table 1. Plant phenology transect dates for each year.

DATE	1984	1985
1	16 July	19 June
2	25 July	29 June
3	2 August	9 July
4	11 August	18 July
5	21 August	30 July
6	31 August	7 August

Toxicity Samples

Plant samples were collected periodically from both within and outside exclosures at each site. These samples were collected at times specified by Dr. John Olsen, USDA Poisonous Plant Lab, Logan, Utah, and were to be analyzed for toxicity. Plants were uprooted.

Sufficient plants were collected to provide 25 gm (dry matter basis) of floral and vegetative parts. Floral parts were stripped from the stalk and air dried. Leaves were stripped and air dried separately from the floral parts. Stalks were discarded. The dried plant parts from each site were packaged separately and sent to Dr. Olsen for analysis. To date, toxicity analyses have not been completed.

Plants were uprooted rather than clipped because clipping may simulate grazing -- this was not desirable in the exclosure since one objective of the exclosure was to determine long-term effects of grazing on plant ecology. This "artificial" loss of entire plants was not determined to have an effect on the results of this study because plants for toxicity samples were removed from areas of the stand which would not affect any study transects.

Data Analysis

The analysis of the mean vegetative and floral heights consisted of a paired t-test comparing means between inside and outside the exclosures on each date. The results were reported as significant if $P \leq 0.05$.

Because this study was carried out using producer's livestock, it was not possible to have a control to compare with treated areas. A chi-square test was used to determine if a significant number of plants were impacted by sheep grazing. The categories of "toxic" plants, "non-toxic" plants, and "impacted" plants were compared. Theoretical values were determined by assuming that no plants would fall into the impacted category if the treatment had not been run. The effect of the treatment was reported as significant if $P < 0.05$.

RESULTS AND DISCUSSION

Grazing Impact and Plant Density

Sheep impact on the number of tall larkspur plants on offer in a toxic form was significant ($P \leq 0.001$) on all sites in each year. The percentage of plants removed from the toxic category by animal impact ranged from 72.5% to 100%. The number of plants which either were grazed or otherwise rendered unattractive was high in relation to the number of toxic plants left on offer (Table 2).

The number of DEGL plants impacted by the control band, i.e. grazed or trampled, ranged from 171 per 100 m^2 (total density 349/100 m^2, Dog Creek 1984) to 611/100 m^2 (981.4/100 m^2 Corral Creek 1985). This reduced to low levels the number of potentially dangerous plants present after grazing. The number of toxic plants left ranged from 0 on the Basin Creek site (18 July 1984) to a high of 49 DEGL plants per 100 m^2 on Dog Creek (8 Aug 1984).

It is yet to be determined at what level the density of plants within the "toxic window" becomes dangerous. The size of the stand as well as the likelihood of a single animal being able to obtain a sufficient quantity of DEGL would affect the risk of toxicosis.

Table 2. Larkspur density and number of plants per 100 m^2 in each toxicity category after sheep grazing.

SITE YEAR	BASIN CREEK		CORRAL CREEK		DOG CREEK
	1984	1985	1984	1985	1984
DENSITY					
Number of plants/100 m^2	394	502	388	981	349
TOXICITY CATEGORY					
Impacted					
Grazed	84	280	272	601	137
Trampled	108	9	26	10	34
Flowering	0	29	82	7	49
Not Hazardous					
Vegetative	8	160	6	154	14
Aborted Flower Stalk	4	24	2	209	84
Dead	0	0	0	0	17
Insect Damaged	2	0	0	0	8
Fruiting Stage	0	0	0	0	6
Bud Stage	188	0	0	0	0
PERCENT IMPACTED[*]	100	90	73	99	71

[*]Percentage of toxic plants (impacted + flowering) removed from offer by sheep impact.

35

Density of DEGL plants on the Basin Creek site ranged from 394 plants per 100 m^2 on 18 July 1984 to 502.2 on 2 July 1985. Density at the Corral Creek site ranged from 388 plants per 100 m^2 on 29 Aug 1984 to 981.4 plants per 100 m^2 on 31 July 1985. Density at Dog Creek was 349 plants per 100 m^2 on 8 August 1984.

There may have been an effect on reported plant densities due to the difference in sampling. Although these data would appear to indicate that density increased from 1984 to 1985, observation of the stands indicated that this was not the case and that this difference can be attributed to sampling technique. The high degree of spatial variability apparently caused method to be confounded with year. It is proposed that the noncontiguous block method used in 1985 more accurately reflected stand density.

Animal impact data on the Poison Creek site were inconclusive because it was impossible to isolate use by the control band from other use. This site was along the route of a great number of both cattle and sheep being trailed through the Ruby Valley and was a favored bed ground for many of the herds.

On 8 Aug 1984 a animal impact transect was run on the Dog Creek Flats after this area was grazed by the control band at the request of the USFS. The density at this site was 349 DEGL plants per 100 m^2. Sheep were not grazed on this site in 1985 nor was a utilization transect taken.

Plant Phenology

In 1984 the sheep band arrived at the Basin Creek study site before the first data collection could be made (Figure 3). There was evidence of extensive grazing by the control band on date 1 (16 July 1984). Mean floral height was different between inside and outside at date 1 and plants inside the exclosure were taller than those outside throughout the 1984 season.

Mean vegetative heights were different between inside and outside samples from dates 1 (16 July) through 3 (2 August). Plants that were exposed to grazing had a lower mean height than did those inside the exclosure. From date 4 (11 Aug) through date 6 (31 Aug) no difference between inside and outside was determined. This can be explained by the maturity of bud stage plants which would have been disproportionately represented in the plant condition transect in the time period immediately following grazing. Also, it is possible that due to high moisture conditions many plants were able to recover from grazing.

In 1985 the control band began grazing the Basin Creek site at about the same time as the first data collection (19 June). Mean floral heights inside and outside the exclosure were not different on this date. By the second sampling date (29 June) plants outside the exclosure were shorter than those inside, and the mean heights remained different for the rest of the growing season with the exception of date 5 (30 July).
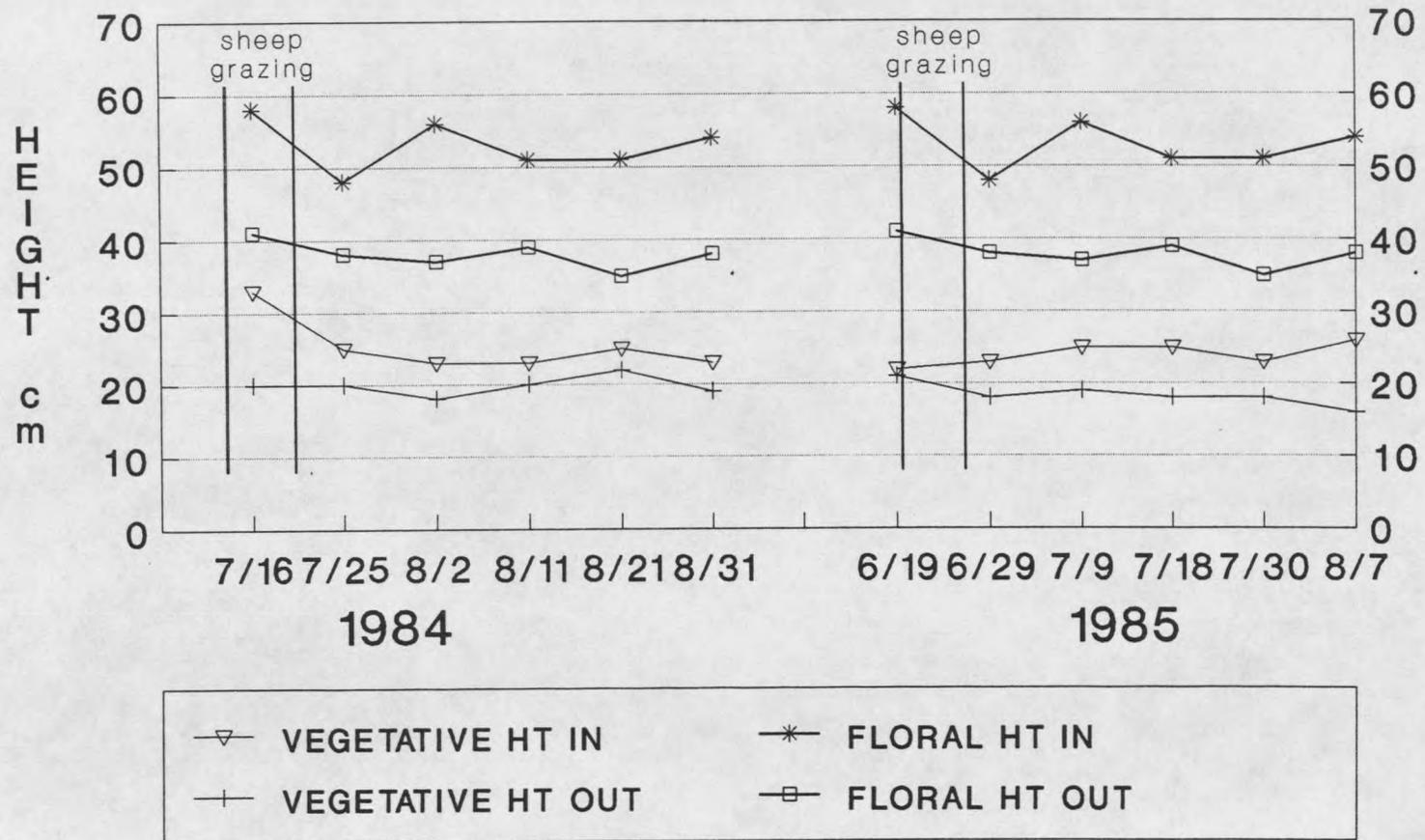
Figure 3. Vegetative and floral height comparison inside and outside Basin Creek exclosure, 1984 and 1985.

There was no difference between inside and outside mean vegetative heights on date 1 (19 June), which occurred during the grazing period. After grazing was completed the plants inside had a greater mean vegetative height than did those subject to grazing.

The Corral Creek exclosure was not constructed until October, 1985. Thus, transect data do not represent true inside and outside exclosure comparisons and require interpretation (Figure 4). They indicate that mean floral height and mean vegetative height were usually similar inside and outside the exclosures. Mean floral height on one transect on date 5 (30 July) in 1985 was significantly taller than on the other transect. Sheep were grazing on the site at the time and the area had not been completely nor uniformly grazed. By the next data collection, sheep use was uniform on this site, and the transects indicated vegetative height and floral height were similar.

No difference in mean floral height or in mean vegetative height between inside and outside samples was demonstrated on Poison Creek in 1984 (Figure 5). This may have been due to inefficient grazing of this site by the control band. Grazing by the sheep occurred primarily during moves from 1 site to another. In 1984, efficient grazing of this site was hampered by efforts to graze the Dog Creek Flats rather than concentrating on the study sites. The majority of grazing