Response of understory vegetation to varied lodgepole pine (Pinus contorta) spacing intervals in western Montana
by Terry Michael Conway

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Range Science
Montana State University


Abstract:
During 1981, research was conducted on five forested sites in Montana and Idaho to determine the response of understory vegetation to five spacing intervals of lodgepole pine (pinus contorta). The sites were located on the Lewis and Clark, Gallatin, Bitterroot, and Kootenai National Forests in Montana and on the Targhee National Forest in Idaho. The five sites represented varied latitudes, elevations, and forest habitat types. Yield and canopy cover of understory vegetation were determined for each spacing interval on each site. Soil temperature and moisture, and vegetative crude protein content, with respect to the varied spacings, were also determined. Yield and canopy cover of understory vegetation on the five sites decreased from wide to narrow tree spacings. Tree canopy cover correlated with yield and canopy cover of understory vegetation showed significant negative linear relationships on all sites but the Kootenai. Although overstory/understory correlations were significant, tree canopy cover generally accounted for less than 60 percent of the variation in understory yield and canopy cover on the sites.

The responses of vegetative classes to the varied tree spacings differed, with grasses showing the greatest response followed by forks and shrubs. Crude protein content of grass, forb, and shrub species did not vary significantly among the spacing intervals. The greatest difference between maximum and minimum soil temperatures occurred under the widest tree spacing, while the least difference occurred under the narrowest spacing. Soil moisture did not vary significantly among the varied tree spacings. The results of the study indicate that thinning lodgepole pine stands to wide spacing intervals may result in a significant increase of understory vegetation compared to unthinned or lightly thinned stands. Tree canopy cover may serve as a fairly good predictor of understory vegetation.

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Date June 17 1982

RESPONSE OF UNDERSTORY VEGETATION TO VARIED LODGEPOLE PINE

(*PINUS CONTORTA*) SPACING INTERVALS IN WESTERN MONTANA

by

TERRY MICHAEL CONWAY

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

of

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in

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Approved:

Chairperson, Graduate Committee

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# ABSTRACT

During 1981, research was conducted on five forested sites in Montana and Idaho to determine the response of understory vegetation to five spacing intervals of lodgepole pine (*Pinus contorta*). The sites were located on the Lewis and Clark, Gallatin, Bitterroot, and Kootenai National Forests in Montana and on the Targhee National Forest in Idaho. The five sites represented varied latitudes, elevations, and forest habitat types. Yield and canopy cover of understory vegetation were determined for each spacing interval on each site. Soil temperature and moisture, and vegetative crude protein content, with respect to the varied spacings, were also determined. Yield and canopy cover of understory vegetation on the five sites decreased from wide to narrow tree spacings. Tree canopy cover correlated with yield and canopy cover of understory vegetation showed significant negative linear relationships on all sites but the Kootenai. Although overstory/understory correlations were significant, tree canopy cover generally accounted for less than 60 percent of the variation in understory yield and canopy cover on the sites.

The responses of vegetative classes to the varied tree spacings differed, with grasses showing the greatest response followed by forbs and shrubs. Crude protein content of grass, forb, and shrub species did not vary significantly among the spacing intervals. The greatest difference between maximum and minimum soil temperatures occurred under the widest tree spacing, while the least difference occurred under the narrowest spacing. Soil moisture did not vary significantly among the varied tree spacings. The results of the study indicate that thinning lodgepole pine stands to wide spacing intervals may result in a significant increase of understory vegetation compared to unthinned or lightly thinned stands. Tree canopy cover may serve as a fairly good predictor of understory vegetation.

# Chapter 1

## INTRODUCTION

Natural regeneration of lodgepole pine (*Pinus contorta*) commonly results in overstocking and stagnation (Tackle 1959). Overly dense stands contribute little timber or understory vegetation. Most forest managers agree that if these stands are to make reasonable progress toward producing merchantable products they must be thinned.

While increased wood production on merchantable sized trees is the primary objective of thinning, this silvicutural practice also results in modification of the understory environment. Soil moisture, temperature, nutrients, and understory vegetative production, may be altered by stand manipulation (Kittredge 1948). This warrants an effort to more fully comprehend overstory/understory relationships. A more complete understanding may prove beneficial to management of forest resources, particularly if managers are trying to optimize product mix.

In 1964 the U.S.D.A. Intermountain Forest and Range Experiment Station at Bozeman, Montana, initiated a study to evaluate effects of spacing on growth of lodgepole pine. While the basic intent was to investigate effects of spacing on tree growth the study provided an opportunity to answer questions aout modification in understory vegetation and environment which occur as a result of overstory manipulation.

During 1981 the previously established Forest Service study plots were examined to determine the response of understory vegetation to varied spacing intervals of lodgepole pine. The primary objective was to measure and compare understory vegetative canopy cover and yield on five sites with five pine spacing intervals and ultimately determine overstory/understory relationships. An additional objective was to evaluate the effects of environmental factors, as modified by the overstory, on understory vegetation.

Data concerning litter, moss, lichen, and bare ground coverage, tree canopy cover and basal area, soil temperature and moisture, and understory vegetative crude protein content, with respect to spacing intervals, were also collected. With this combination of data, a better understanding of the effects of lodgepole pine overstory on understory vegetation may be provided. Such information may furnish insight into causes of understory responses and provide possible management implications.

Chapter 2

# REVIEW OF LITERATURE

The manipulation of pine overstory results in the modification of understory environmental factors as well as vegetation. A number of studies have been conducted to determine these overstory/understory relationships.

## Relationship of Pine Overstory to Understory Vegetation

Trappe and Harris (1958), in northeastern Oregon, reported approximately 280 kg/ha dry weight of understory vegetation produced under open stands of lodgepole pine (*Pinus contorta*). Dense stagnated stands had less than 56 kg/ha.

Basile and Jensen (1971) observed clearcutting of lodgepole pine in western Montana stimulated productivity of understory vegetation. Maximum production of 890-1120 kg/ha occurred 11 years after clearcutting.

In central Oregon, Dealy (1975) conducted a study to determine the response of understory vegetation to five spacing intervals of mature lodgepole pine. Spacing intervals of 8, 6, 4, 3 and 2 m were established by thinning. After nine years, the stands produced between 300 and 1000 percent more understory vegetative cover than before thinning, with 4 and 6 m pine spacings being more productive.

Dodd, McLean, and Brink (1972), in British Columbia, reported a significant negative relationship between lodgepole pine overstory and understory vegetative production. Pine canopy cover accounted for 66 percent of the variation in understory yield. They determined that estimates of understory production may be made from estimates of tree canopy cover derived from aerial photographs.

Studies indicate understory vegetative production tends to decrease under other species of pine. Arnold (1950), in a study conducted on ponderosa pine (*Pinus ponderosa*) bunchgrass range in northern Arizona, reported herbaceous density declined under increasing amounts of pine canopy. Grass yield under 10 percent canopy was about five and one-half times as great as the yield under 100 percent canopy.

Gaines, Campbell, and Brasington (1954) observed forage production under longleaf pine (*Pinus palustris*) in southern Alabama. They reported a curvilinear overstory/understory relationship with 1120 kg/ha of forage produced under 0 basal area compared to 532 kg/ha under a basal area of 25 $m^2$/ha.

In the forest of Georgia, Halls (1955) reported a curvilinear relationship between longleaf and slash pine (*Pinus elliottii*) crown cover and understory grass production. In open forests grass production of 1120 kg/ha declined consistently as pine canopy cover increased from 50 to 35 percent. After 35 percent canopy cover, less decline was noted.

Smith, Campbell, and Blount (1955) observed a curvilinear relationship between longleaf pine and understory herbage production in Georgia. Average grass yields for three years for open, moderate, and dense stands were 952, 504, and 448 kg/ha, respectively.

Pase (1958) noted a curvilinear relationship between mature stands of ponderosa pine and understory vegetation in the Black Hills of South Dakota. Total understory vegetation produced ranged from 45 kg/ha under 70 percent pine canopy cover to 2,419 kg/ha on clear-cut areas. Grasses, forbs, and shrubs produced 1,937, 342, and 140 kg/ha on clear-cut areas compared to 28, 6, and 10 kg/ha under unthinned stands, respectively.

In a study conducted in central Washington, McConnell and Smith (1965) observed a linear relationship between recently thinned ponderosa pine and understory vegetative production. Total yield ranged from 78 kg/ha under 80 percent pine canopy cover to 257 kg/ha under 10 percent canopy cover. Forbs produced more than grasses under a pine canopy cover greater than 45 percent, while below 45 percent grasses produced more than forbs.

In central Oregon, Barrett (1970) noted that eight years after thinning, understory vegetative cover was significantly greater under widely spaced ponderosa pine than under narrow spaced trees. Vegetative cover ranged from 42 percent under an 8 m pine spacing to 29 percent under a 2 m spacing.

Young, Hedrick, and Keniston (1967) in a mature, mixed forest in northeast Oregon discovered a significant negative association between pine crown cover and understory vegetative yield ($r^2 = .25$). Pine crown cover accounted for more of the variation in vegetative yield than either tree basal area ($r^2 = .10$) or stems per acre ($r^2 = .09$).

Modification of Understory Environment by Pine Overstory

It has been widely recognized that understory environmental factors such as light quantity and quality, soil moisture, precipitation, and temperature may be altered by the overstory. These factors may be significant in determining relationships between pine overstory and understory vegetation.

Light. Studies generally indicate that light intensity in the understory is inversely related to pine canopy, spacing, basal area, and density. Shirley (1945), in jack pine (*Pinus banksiana*) forest of northern Minnesota observed a negative curvilinear relationship between stand density and light intensity. In an uncut stand, light intensity was 23 percent of full sunlight compared to 36 percent in a lightly thinned stand (20 percent of basal area removed). In a heavily thinned stand (70 percent of the basal area removed) light intensity was recorded at 80 percent. Surface soil temperatures were 6 to 9° C higher and air temperatures 3° C higher on the heavily thinned areas compared to the uncut stand.

In thinning plots of 25 year old red pine (*Pinus resinosa*) plantation in Minnesota, Cheo (1946) found light intensity to increase with an increase of spacing intervals. A 1 by 1 m pine spacing (6,724 trees/ha) revealed a light intensity of approximately 15 percent of full sunlight. Under a 3 by 3 m spacing (1,329 trees/ha), light intensity had increased to approximately 60 percent.

Wellner (1948) related light intensity to stand basal area of small-crown trees, including lodgepole pine, and large-crown trees. He noted a greater reduction of light intensity by large-crown compared to small-crown trees for the same basal area. The basal areas of mature lodgepole pine and other small-crown species correlated with light intensity revealed negative curvilinear relationships. Under a heavily thinned stand (basal area of 5 $m^2$/ha) light intensity was 94 percent of full sunlight. Under a moderately thinned stand (23 $m^2$/ha) light intensity was 63 percent, compared to an uncut stand (92 $m^2$/ha) where light intensity was reduced to 12 percent of full sunlight.

Tisdale and McLean (1957) investigated the possibility of solar radiation limiting understory vegetation developed under mature stands of lodgepole pine. They reported that under a fairly dense stand (basal area of 28 $m^2$/ha) light intensity averaged 38 percent of full sunlight and may not have been influential in limiting plant growth. Soil moisture may have been the more important controlling factor.

Similar relationships were reported by Miller (1959) who observed negative curvilinear correlations of light intensity with mature lodgepole pine canopy closure and stem density. He noted canopy closure, in conjunction with canopy depth, was probably the more important factor influencing light intensity. Light intensity ranged from 5 percent of full sunlight under a 70 percent canopy to 30 percent under a 40 percent canopy to 80 percent under a 10 percent canopy.

In northwestern Washington, Moir (1966) reported that a decline in understory vegetation was partially due to increased light interception by ponderosa pine canopy. He noted under the densest canopy, light levels dropped as low as 20 percent of full daylight conditions. The linear relationship of light intensity with total understory vegetative cover (r = -.45) was less than with glass inflorescence number (r = -.66).

In northern Wisconsin, Anderson, Loucks, and Swain (1969) investigated the influence of red pine canopy cover on light intensity, precipitation, and understory vegetative responses. They observed positive curvilinear relationships of percent pine canopy opening with light intensity (r = .76) and throughfall precipitation (r = .81). Correlation of understory vegetative cover with light intensity (r = .70) was less than with throughfall precipitation (r = .84). They noted that light levels in the understory were above minimum threshold for understory species. This suggests correlation of vegetative cover with light intensity may have been due to the close association of precipitation and light, as both depend on canopy opening.

McLaughlin (1978) studied the predictability of light and precipitation reaching the forest floor based on measurements of ponderosa pine canopy and basal area in northern Arizona. Overhead canopy cover accounted for most of the variation in light ($r^2$ = .55) and throughfall precipitation ($r^2$ = .66) compared with basal area ($r^2$ = .44, $r^2$ = .34, respectively).

The pine overstory appears to have minimal effect on light quality. Freyman (1968) observed the spectral composition of light under mature stands of lodgepole pine in British Columbia. He reported minimal influence of light quality by overhead canopy and suggested the total amount of light rather than quality exerted the greater influence on understory vegetation.

Soil moisture. Studies generally indicate that following thinning soil moisture withdrawal is reduced until remaining trees and understory vegetation reoccupy the site. In southwestern Oregon, Hallin (1967) compared soil moisture depletion rates for clearcut and adjacent uncut stands of Douglas-fir (*Pseudotsuga menziesii*). The invading vegetation on the clearcut was shown to be as effective as the stand of Douglas-fir in depleting soil moisture at the 15 cm and 46 cm depths and nearly so at the 91 cm depth.

Barrett (1970) reported ponderosa pine spacing and understory vegetation had an effect on seasonal water use in pumice soils of central Oregon. Total water use was 1.6 times greater on plots containing 2,471 trees/ha than on plots containing 153 trees/ha. Soil moisture use on plots which had allowed understory vegetation to develop naturally was 45 percent greater than on plots which had the vegetation removed. He also noted under thinned stands that as crowns and roots of remaining trees and invading vegetation reoccupied the site, an increasing amount of soil moisture was withdrawn.

In central Oregon, Dahms (1971) reported that immediately following thinning of mature lodgepole pine, soil moisture withdrawal was significantly greater from high density stands than from low density stands. Soil moisture withdrawn from the top 152 cm of soil was 20 cm for a low density stand with a basal area of 10 $m^2$/ha. Moisture withdrawn from a high density stand with a basal area of 22 $m^2$/ha was 28 cm. As roots and crowns of remaining trees on lower density stands expanded, soil moisture withdrawal increased relative to high density stands.

Dahms (1973), in central Oregon, observed soil moisture withdrawal was definitely less after thinning mature lodgepole pine. For a low density stand, with basal area of 7 $m^2$/ha, additional moisture left in the top 120 cm of soil after thinning averaged 13 cm compared to pre-thinning. For a high density stand, with basal area of 27 $m^2$/ha, additional moisture left after thinning averaged 2 cm compared to pre-thinning.

Johnston (1975), in northeastern Utah, compared soil water depletion by cut and uncut stands of lodgepole pine on glacial till. He noted soils on clearcut plots contained from 18 to 71 cm more water than uncut plots at the end of each summer after cutting. These changes in soil water content were restricted to the top 180 cm of soil. He also observed snow accumulation was greater in clearcut than in adjacent timbered sites. Average snow water equivalents on the clearcut plots was 264 cm compared to 147 cm under the uncut stand. Snow disappeared approximately at the same time from both cut and uncut plots.

Precipitation. Studies generally indicated throughfall precipitation varies inversely with pine canopy. Niederhof and Wilm (1941), in north central Colorado, reported net rainfall reaching the forest floor in mature stands of lodgepole pine was increased through thinning. They noted net rainfall should increase approximately .8 cm for each meter increase in radius of the canopy opening up to about 5 m.

Wilm and Dunford (1948), in north central Colorado, observed that net precipitation reaching the forest floor was strongly influenced by cutting of mature lodgepole pine. On the average 9 cm of rainfall reached the litter surface under an uncut stand compared to 11 cm under a heavily cut-over stand. Snow water equivalent under the uncut stand was 18 cm compared to 25 cm under the heavily cut stand. It was noted that timber cutting exerted no significant influence on the duration of snowmelt. Snow disappeared at approximately the same time from under cut and uncut stands. While the melting of snow was considerably accelerated on cut-over areas, the accelerated rate was balanced by excess accumulation of snow.

In central Colorado, Goodell (1952) reported that thinning dense, young lodgepole pine stands increased net precipitation reaching the forest floor. Net summer rainfall under an unthinned stand with basal area of 21 $m^2$/ha was 8 cm compared to 11 cm under a thinned stand with basal area of 8 $m^2$/ha. Snow water equivalent under the unthinned stand was 25 cm compared to 30 cm under the thinned stand. Higher snow melt rates occurred under the thinned stand.

Berndt (1965), in southeastern Wyoming, investigated accumulation of snow in lodgepole pine clearcuts of varying sizes. Snow accumulation and rate of snow disappearance were similar for 2, 4, and 8 ha clearcut blocks. Snow persisted in the adjacent uncut stand approximately 10 days longer than in the cut-over area.

<u>Temperature</u>. In southeastern Wyoming, Bergen (1971) observed during summer months that lodgepole pine canopy affected windspeed and air temperature. Minimum windspeed and maximum air temperature occurred in the midcanopy region (6 m above the ground) where needle and branch weight were concentrated. Subcanopy windspeed near 3 m was greater than midcanopy due to lack of understory reproduction and vegetation.

Maximum windspeed for all levels occurred in early afternoon. Maximum air temperatures were always found near minimum level of windspeed.

Similar results were reported by Gary (1974). He noted in lodgepole pine forest of southeast Wyoming that subcanopy maximum windspeed was near 3 m in height and midcanopy minimum windspeed was near 6 m.

## Chapter 3

## STUDY AREAS

The original pine spacing experiment was replicated at several sites selected to represent varying productive capabilities, based upon site index, and geographic location (Figure 1). Physical characteristics of the study sites are summarized in Table 1.

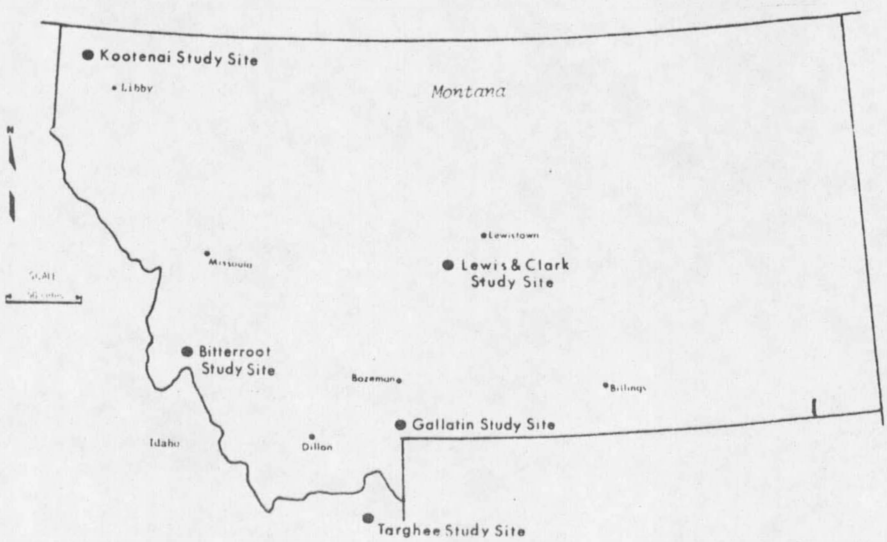


Figure 1. Location of Study Sites.

### Targhee Study Site

Location. The site was located on the Island Park Ranger District of the Targhee National Forest, approximately 5 km north of Island Park, Idaho (SW one fourth of Section 10, T13N, R43E).

Table 1. Physical Characteristics of the Study Sites.

| SITES | Township Range Section | Elevation (m) | Slope | Aspect | Soils | Habitat Type[1] | Site Index | Mean Annual Temp (°C) | Mean Annual Ppt (cm) |
|---|---|---|---|---|---|---|---|---|---|
| Targhee | 13N43ES10 | 1951 | 2 | East | cryopsamment | PSME/CARU | 75 | 7 | 78 |
| Kootenai | 37N30WS19 | 973 | level | - | cryochrept | THPL/CLUN | 110 | 6 | 90 |
| Lewis and Clark | 11N10ES16 | 1946 | 3 | Southeast | cryoboralf | ABLA/VASC | 55 | 5 | 42 |
| Gallatin | 8S9ES35 | 2408 | 2 | West | cryochrept, cryoboralf | ABLA/VASC | 65 | 5 | 68 |
| Bitterroot | 3N18WS21 | 2088 | 6 | Southwest | cryochrept, cryorthent | ABLA/XETE | 85 | 5 | 40 |

[1]PSME/CARU = *Pseudotsuga menziesii/Calamagrostis rubescens* h.t.; THPL/CLUN = *Thuga plicata/Clintonia uniflora* h.t.; ALBA/VASC = *Abies lasiocarpa/Vaccinium scoparium* h.t.; ABLA/XETE = *Abies lasiocarpa/Xerophyllum tenax* h.t. (Pfister et al. 1977).

The study area, elevation 1951 m, sloped gently toward the east at approximately 2 percent.

Vegetation. Forest vegetation was classifed as *Pseudotsuga menziesii/Calamagrostis rubescens* habitat type (Pfister et al. 1977). The overstory was composed solely of lodgepole pine (*Pinus contorta*). Understory vegetation was dominated by pinegrass (*Calamagrostis rubescens*), elk sedge (*Carex geyeri*) silky lupine (*Lupinus sericeus*), and grouse whortleberry (*Vaccinium scoparium*).

A species list for the study sites is presented in Appendix A.

Soils. Soils were classified as cryopsamment (Stermitz et al. 1974). Cryopsamment soils are well drained sandy loams of moderate to deep depth commonly associated with cold, mountainous areas.

Climate. Climate data were derived from the closest recording weather station at Island Park, Idaho. Mean annual temperature and precipitation, based on an 11 year average from 1970-1980, was 7° C and 78 cm. Precipitation and mean temperature from April through August 1981 was 29 cm and 11° C compared to 24 cm and 9° C for the 11 year average over the same period.

Past History. The even-aged original stand was approximately 67 years old at the time of harvest in 1956. The following year slash was broadcast burned. Regeneration was thinned in 1966 when the pine spacing study was established. Stocking density prior to thinning averaged 16,556 trees per hectare.

## Kootenai Study Site

Location. The site was located on the Yaak Ranger District of the Kootenai National Forest, approximately 12 km northeast of Yaak, Montana (S one-half of Section 19, T37N, R30W).

The study area, elevation 973 m, was relatively level.

Vegetation. Forest vegetation was classified as a *Thuga plicata/ Clintonia uniflora* habitat type (Pfister et al. 1977). The dominant overstory species was western redcedar (*Thuga plicata*), accompanied by grand fir (*Abies grandis*), Douglas-fir (*Pseudotsuga menziesii*), and subalpine fir (*Abies lasiocarpa*). Understory vegetation was dominated by pinegrass, elk sedge, bearberry (*Arctostaphylos uva-ursi*), and whortleberry (*Vaccinium globulare*).

Soils. Soils were classified as cryochrept (USDA Soil Conservation Service 1978). Cryochrept soils are well drained gravelly loams to silts of deep depth. Parent material, deposited by glacial action, consists of clayey alluvium and colluvium.

Climate. Climate data were derived from the closest recording weather station at Troy, Montana. Mean annual temperature and precipitation, based on an 11 year average from 1970-1980, was 6° C and 90 cm. Precipitation and mean temperature from April through August 1981 was 40 cm and 13° C compared to 25 cm and 13° C for the 11 year average over the same period.

Past History. The original stand was harvested in 1962. The site was prepared for planting by dozer piling and slash burning in 1965. In 1968 the area was stocked with 80 percent lodgepole pine, 18 percent western larch (*Larix occidentalis*), and 2 percent subalpine fir. The spacing study was established in 1971 by planting of lodgepole pine seedlings.

Lewis and Clark Study Site

Location. The site was located on the Judith Ranger District of the Lewis and Clark National Forest, approximately 35 km west of Utica, Montana (SE one-fourth of Section 16, T11N, R10E).

The study area, elevation 1946 m, sloped gently toward the southeast at approximately 3 percent.

Vegetation. Forest vegetation was classified as an *Abies lasiocarpa/Vaccinium scoparium* habitat type (Pfister et al. 1977). The dominant overstory species was lodgepole pine, accompanied by Engleman spruce (*Picea engelmannii*), sulalpine fir, and whitebark pine (*Pinus albicaulis*). Undergrowth was dominated by elk sedge, silky lupine, showy aster (*Aster conspicuus*), and whortleberry.

Soils. Soils were classified as cryoboralf (USDA Soil Conservation Service 1978). Cryoboralf soils are well drained stony loam to sandy loam of moderate to deep depth formed over granitic parent material.

Climate. Climate data were derived from the closest recording weather station at Utica, Montana. Mean annual temperature and precipitation, based on an 11 year average from 1970-1980, was 5° C and 42 cm. Precipitation and mean temperature from April through August 1981 was 38 cm and 11° C compared to 28 cm and 11° C for the 11 year average over the same period.

Past History. The original stand was approximately 150 years old at the time of harvest in 1954. Slash was dozer piled and burned the same year. Regeneration was thinned in 1965 when the pine spacing study was established. Stocking density prior to thinning averaged 36,793 trees per hectare.

Gallatin Study Site

Location. The site was located in the Gardiner Ranger District of the Gallatin National Forest, approximately 10 km north of Jardine, Montana (SW one-fourth of Section 35, T8S, R9E).

The study area, elevation 2408 m, was located on a flat ridge top that sloped gently to the west at approximately 2 percent.

Vegetation. Forest vegetation was classified as an *Abies lasiocarpa/Vaccinium scoparium* habitat type (Pfister et al. 1977). The dominant overstory species was lodgepole pine, accompanied by subalpine fir, Douglas-fir, and limber pine (*Pinus flexilis*).

Understory vegetation was dominated by elk sedge, showy aster, and whortleberry.

Soils. Soils were classified as cryochrepts and cryoboralfs (USDA Soil Conservation Service 1978). These soils are well drained gravelly sandy loam to silts of moderate to deep depth, associated with high mountainous areas. Parent material consisted of loess, colluvium, alluvium, and sedimentary rock.

Climate. Climate data were derived from the closest recording weather station at Mystic Lake, Montana. Mean annual temperature and precipitation, based on an 11 year average from 1970-1980, was 5° C and 68 cm. Precipitation and mean temperature from April through August 1981 was 39 cm and 12° C, compared to 35 cm and 12° C for the 11 year average over the same period.

Past History. The even-aged original stand was approximately 108 years old at time of harvest in 1953. Slash was dozer piled and burned the same year. Regeneration was thinned in 1967 when the spacing study was established. Stocking density prior to thinning average 11,663 trees per hectare.

## Bitterroot Study Site

Location. The site was located on the Sula Ranger District of the Bitterroot National Forest, approximately 16 km northeast of Sula, Montana (S one-half of Section 21, T3N, R18W).

The study area, elevation 2088 m, sloped rather steeply to the southwest at approximately 6 percent.

Vegetation. The forest vegetation was classified as an *Abies lasiocarpa/Xerophyllum tenax* habitat type (Pfister et al. 1977). The dominant overstory species was lodgepole pine. Understory vegetation was dominated by pinegrass, elk sedge, lupine (*Lupinus sulphureus*), beargrass (*Xerophyllum tenax*), and whortleberry.

Soils. Soils were classified as cryochrepts and cryothents (USDA Soil Conservation Service 1978). These soils are well drained gravelly sandy loam to silts of shallow to deep depth.

Climate. Climate data were derived from the closest recording weather station at Sula, Montana. Mean annual temperature and precipitation, based on an 11 year average from 1970-1980, was 5° C and 40 cm. Precipitation and mean temperature from April through August 1981 was 30 cm and 14° C, compared to 23 cm and 12° C for the 11 year average over the same period.

Past History. The study area was included in the Sleeping Child Fire of 1961. The lightning caused blaze consumed 28,000 acres on the Bitterrot National Forest. In 1962, 180 tons of a mixture of smooth brome (*Bromus inermis*), annual rye (*Secale cereale*), timothy (*Phleum pratense*), and dutch white clover (*Trifolium repens*) were applied to the burned area for watershed protection (Lyon 1976). Chemical thinning of regeneration was conducted from 1966 through 1969. The spacing study was established in 1967 by mechanical thinning of regeneration.

## Chapter 4

## METHODS AND PROCEDURES

The complete spacing experiment was replicated at five locations; four sites were in Montana and one was in Idaho. Sites were selected to represent varying productive capabilities and geographic locations.

### Sampling

Each experimental site included a randomized complete-block of two replications of five treatments. Treatments consisted of thinning lodgepole pine to five spacing intervals: 1.8 by 1.8 m (260 trees/treatment plot), 2.7 by 2.7 m (176 trees/treatment plot), 3.6 by 3.6 m (114 trees/treatment plot), 4.5 by 4.5 m (98 trees/treatment plot), and 5.4 by 5.4 m (98 trees/treatment plot). Treatment plot dimensions from the narrowest to the widest spacing level were: 18 by 47 m, 22 by 60 m, 22 by 68 m, 32 by 64 m, and 37 by 77 m, respectively. Each experimental area covered 1.7 hectares.

Each site was sampled at approximately the time of peak standing crop. The sample schedule was based upon latitude, elevation, and accessibility. Sample dates were: Targhee site June 29-July 5, Kootenai site July 9-July 14, Lewis and Clark July 18-July 24, Gallatin site July 27-August 2, and Bitterroot site August 6-August 12.

Vegetative Sampling. To determine herbaceous and shrub species yield, 25 concentric circular quadrats of 0.45 and 0.90 $m^2$ were used. Yield quadrats were located systematically from a randomly selected starting point. Individual species yields from four harvested and 21 estimated quadrats were combined in double sampling. Regression analysis was performed to adjust estimates from non-harvested quadrats. Vegetative samples were oven-dried at 60° C for 24 hours and weighed to the nearest 0.1 g.

Understory herbage and shrub canopy cover, litter, moss, lichen, rock, and bare ground were estimated from 40 systematically located 2 by 5 dm quadrats along a line transect (Daubenmire 1959). To prevent overestimation of low coverage species, an additional cover class (0-1%) was used. Canopy cover estimates were: class 1 = 0-1 percent; class 2 = 2-5 percent; class 3 = 6-25 percent; class 4 = 26-50 percent; class 5 = 51-75 percent; class 6 = 76-95 percent; class 7 = 96-100 percent.

Tree basal area was derived from circumference measurements taken 1.5 m above the ground. Tree canopy was measured by the crown-diameter method as described by Mueller-Dombois and Ellenberg (1974). From each treatment plot, 12 estimates of tree canopy cover and basal area were made.

Crude protein analyses were performed on herbage and shrub samples collected August 2 from the Gallatin site and August 11 from the Bitterroot site. Three samples of a selected grass, forb, and shrub species along with a composite sample were collected from four treatment plots (1.8 by 1.8 m, 3.6 by 3.6m, 5.4 by 5.4 m, and control). Composite samples were provided by harvesting three 0.45 $m^2$ quadrats. Crude protein analyses were performed by the Montana State University Livestock Nutrition Center.

Measurement of physical characteristics. Limited soil temperature and soil moisture data were collected on the Gallatin site. Soil temperatures, using stem mercury thermometers, were recorded at a depth of 20 cm from 10 randomly selected sample points. Maximum temperatures were measured between 12 and 2 p.m.; minimum temperatures were recorded between 6 and 8 a.m.

Soil moisture determinations were made for samples collected at a depth of 25 cm from 10 randomly located sample points. Samples were weighed, oven-dried at 105° C for 24 hours, and percent moisture of each sample was determined. Water content at 15 atmospheres tension was determined by the pressure membrane method. Soil temperature and moisture data were collected July 27, August 16, and September 18.

## Statistical Analyses

Analysis of variance and Duncan's New Multiple Range Test

(Duncan 1955) were used to compare understory vegetative canopy cover and yield, tree canopy cover and basal area, and vegetative crude protein content values among the five spacing treatments. Linear regression and correlation analyses were used to determine the relationship between understory vegetative canopy cover and yield (dependent variables) and tree canopy cover and basal area (independent variables). The term "significant" in the study means $P \leq .05$. Statistical procedures follows Steel and Torrie (1960).