Effects of tree invasion on understory vegetation in areas grazed by livestock, Madison Range, Montana

by Julia Wells Samuel

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Earth Sciences
Montana State University

Abstract:
Tree invasion is a widespread phenomena throughout the American West; The Madison Range .in southwestern Montana is the site of continued tree invasion. Young coniferous trees, primarily Douglas fir (Pseudostuga menziessii), limber pine. (Pinus flexilis), and Rocky Mountain juniper (Juniperous scopulorum) are encroaching on areas previously occupied by grass-shrub communities. This area is also extensively grazed by domestic livestock. The Madison Valley is arid, and livestock grazing is one of the only economically feasible agricultural pursuits possible.

Increase in tree canopy cover associated with tree invasion has been shown to affect under story vegetation, in terms of species and life form composition. Such alterations of the understory composition may be detrimental to the valley's livestock industry , and may alter the sustainability of the grazing resource as a whole. It is the purpose of this research to determine the effects of this tree invasion on the composition of the vegetative understory in areas that had been grazed by livestock.

Understory vegetation data was collected from invaded and noninvaded areas using transects originating in the mature forest and ending in the shrub-grassland community. Microplots with radii of 5 meters were separated by 15 meters along the transect. Within these microplots, percent ground cover of three vegetation life forms were visually estimated. Understory species were identified and their presence or absence within the microplots was noted.

Grazing histories for the Madison Valley were used from a recently completed study. I divided invaded areas into five dominant grazing categories in order to test for differences in understory in areas with different landuse histories.

Significance tests were used to determine relationships between tree canopy cover and understory life forms. Species frequency was also determined.

No significant relationships occurred between tree canopy cover and life form composition of the understory within grazing categories. Species frequency graphs indicated that certain plant species were affected by tree invasion. Grazing apparently has a limited effect on the understory as well. Tree invasion in the Madison Valley is not significantly altering the vegetation used by domestic livestock as forage. The sustainability of the grazing resource is not in jeopardy.

EFFECTS OF TREE INVASION ON UNDERSTORY VEGETATION

IN AREAS GRAZED BY LIVESTOCK,

MADISON RANGE, MONTANA

by

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

of

Master of Science

in

Earth Sciences

MONTANA STATE UNIVERSITY
Bozeman, Montana

May 1992

APPROVAL

of a thesis submitted by

Julia Wells Samuel

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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ACKNOWLEDGMENTS

I would like to thank Dr. Katherine Hansen, my advisor, for her patience and guidance throughout my academic career, and most especially during the writing of this thesis. Her ability to endlessly read and reread was most appreciated. In addition, I thank her for allowing me to participate in the project from which much of my data was drawn. Not only was she a great advisor, she is a great friend.

Thanks also go to my co-advisor Dr. William Wyckoff, and Dr. Bret Olson for their suggestions and help during all phases of this project. Special thanks to Dr. Olson for his knowledge of bio-statistics .

I would also like to thank Chris Brown for her help in the field and her support throughout all my trials.

Most of all, I'd like to thank my husband David, not only for emotional support given, but for his expertise in statistics and computer programming, all of which made the completion of this thesis so much easier.

Partial support of this study came from a National Science Foundation Grant, the Center for High Elevation Studies, and Montana State University.

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ABSTRACT

Tree invasion is a widespread phenomena throughout the American West. The Madison Range in southwestern Montana is the site of continued tree invasion. Young coniferous trees, primarily Douglas fir (*Pseudostuga menziessii*), limber pine (*Pinus flexilis*), and Rocky Mountain juniper (*Juniperous scopulorum*) are encroaching on areas previously occupied by grass-shrub communities. This area is also extensively grazed by domestic livestock. The Madison Valley is arid, and livestock grazing is one of the only economically feasible agricultural pursuits possible.

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CHAPTER 1

INTRODUCTION

Problem and Objectives

Tree invasion is occurring along the western slope of the Madison Range of southwestern Montana. Young coniferous trees have encroached into areas previously occupied by sagebrush-grassland vegetation communities (Hansen et. al. submitted publication). This area is also being grazed by domestic livestock. Livestock grazing and the increased canopy cover associated with tree invasion have the capacity to alter understory vegetation, both in composition and the species present (Pase 1958; Humphrey 1962; Pieper 1990). This study focused on the effects of tree invasion on understory vegetation in areas with different grazing histories.

Grazing and tree invasion working together may have altered the vegetational composition of the understory along the west slopes of the Madison Range. The specific objective of this study was to identify, measure, and analyze changes in understory vegetation in areas of tree invasion. The hypothesis of this study was that there would be measurable changes in composition and species frequency of the understory communities from areas with no tree canopy to areas with full tree canopy in invaded areas. The hypothesis was tested in a variety of settings with different livestock grazing histories.

Increases in tree canopy cover have been shown to change the composition of plants of the understory (Pase 1958; McConnell and Smith 1965; Jameson 1970; Schott and Pieper 1985; Pieper 1990). These changes have been attributed primarily to an increase in shading of the understory by the tree canopy (Arnold 1964; Jameson 1967 and 1970; Schott and Pieper 1985).

The influence of tree canopy on understory plant communities has been shown to change with distance from the tree trunk. Four consecutive zones of tree influence have been identified by Arnold (1964). The first zone, found directly adjacent to the tree trunk, was influenced most by tree canopy cover. The three other zones showed a progressively reduced tree canopy influence as the distance from the tree increased.

As trees mature, and their canopy coverage increases, their influence on the understory vegetation should also increase. Schott and Pieper (1985) found that as the tree canopy increases, and as a result, the ground covered by shading increases, the amount of understory vegetation decreases. Pase (1958) found that understory vegetation types react differently to increases in canopy. Grasses, in general, tend to decrease the most rapidly with increases in canopy cover. Forbs decrease at a slower rate, and shrubs appeared to be affected the least by increased canopy cover. In some instances, the more shade tolerant species which were not found in open environments actually became more common as tree canopy cover increased (Pase 1958).

Along the west slope of the Madison Range, young trees, primarily Douglas fir (*Pseudostuga menziessii*), limber pine (*Pinus flexilis*) and Rocky Mountain juniper (*Juniperous scopulorum*), have been encroaching into areas previously occupied by sagebrush-grassland communities. Hansen et al. (submitted publication) found invasion occurring on over 1500 hectares of the west slope of the Madison Range. These areas are adjacent to the lower border of forest stands and are becoming wide transition zones, known as invasion ecotones, between the previously established forest and the sagebrush-grassland community. The width and length of these ecotones vary throughout the region. In some areas, invasion ecotones extend into the grassland-sagebrush communities for several hundred meters, while in others, the invasion ecotone is quite narrow. Invasion often extends along the lower forest-grassland border over thousands of meters. While invasion is relatively widespread throughout the study area, it can be very site specific. Invasion may occur in one area and not occur in adjacent areas that appear to be similar. Overall change in canopy cover can also vary in newly-invaded zones. For the study area, canopy cover in invaded areas ranged from five to 100 percent and averaged approximately 24 percent.

Invasion by trees has been documented throughout the American West. Causal factors of invasion are usually thought to be lack of fire, grazing impacts by livestock, and climatic change (Sindelar 1971; Vale 1981; Madany and West 1983; Arno and Gruell 1986; Dando and Hansen 1990; Hansen et. al., submitted publication). Along the Madison Range, all three of these factors appear to be responsible for tree encroachment (Hansen et. al. submitted publication).

Much of the Madison Valley and many of the invasion ecotones are currently used for livestock grazing. Grazing practices by different types of livestock may also affect the understory plant species. Domestic animals prefer certain forage types over others. For example, sheep often prefer forbs over grasses, and cattle and horses prefer grasses over forbs (Stoddard and Smith 1955; Humphreys 1962). Grazing of areas within the invasion ecotones during certain seasons of the year and for certain lengths of time may influence the effects of overstory canopy cover increases on understory plant communities.

The Madison Range and Valley supports a relatively large amount of livestock grazing. Madison County supported 92,300 cattle and 18,600 sheep in 1990 (Montana Agricultural Statistics Service 1991). Due to the area's aridity and rocky soil, livestock production is one of the only economically feasible agricultural pursuits. As tree canopy increases, vegetative species adapted to full light decrease and species adapted to shade may increase (Pase 1958). Often species adapted to full sunlight are also those used by livestock for forage. Pase (1958) noted that cattle tend to avoid shade-grown vegetation when given a choice. Halls and Schuster (1965) and Ehrenreich and Crosby (1960) found that with a decrease in livestock-preferred grasses and forbs, unpalatable grasses and forbs increase as canopy overstory increases.

The increasing tree canopy may lead to 1) a decrease in total understory vegetation, 2) a decrease in species palatable to livestock, and 3) an increase in unpalatable species (Pase 1958; Halls and Schuster 1965). If this is the case in the Madison Valley, such an increase in unpalatable vegetation in the invasion ecotones may increase grazing pressure on areas that have not been invaded. Sustainability of the grazing resource in the whole valley may then be in jeopardy.

Tree invasion is occurring along the western slope of the Madison Range. The study area is bordered to the east by the Lee Metcalf Wilderness Area and by the Madison River on the west (Figure 1).

The wilderness area and adjacent land support large numbers of wild ungulates, (approximately 2700 elk, 300 antelope, and over 100 deer), which frequent the invasion areas during various times of the year (Alt personal communication). It is important to understand what effects such invasion will have on the understory to determine the possible effects on the wildlife as well as on the domestic livestock that use the area.

Hansen et. al. (submitted publication) found that of the 6,800 potentially invadable hectares along the forest-grassland ecotone, 1,500 hectares (22 percent) have shown increases in tree numbers. Increases of trees on such a large scale may make it impossible to maintain a sustainable forage source for livestock.

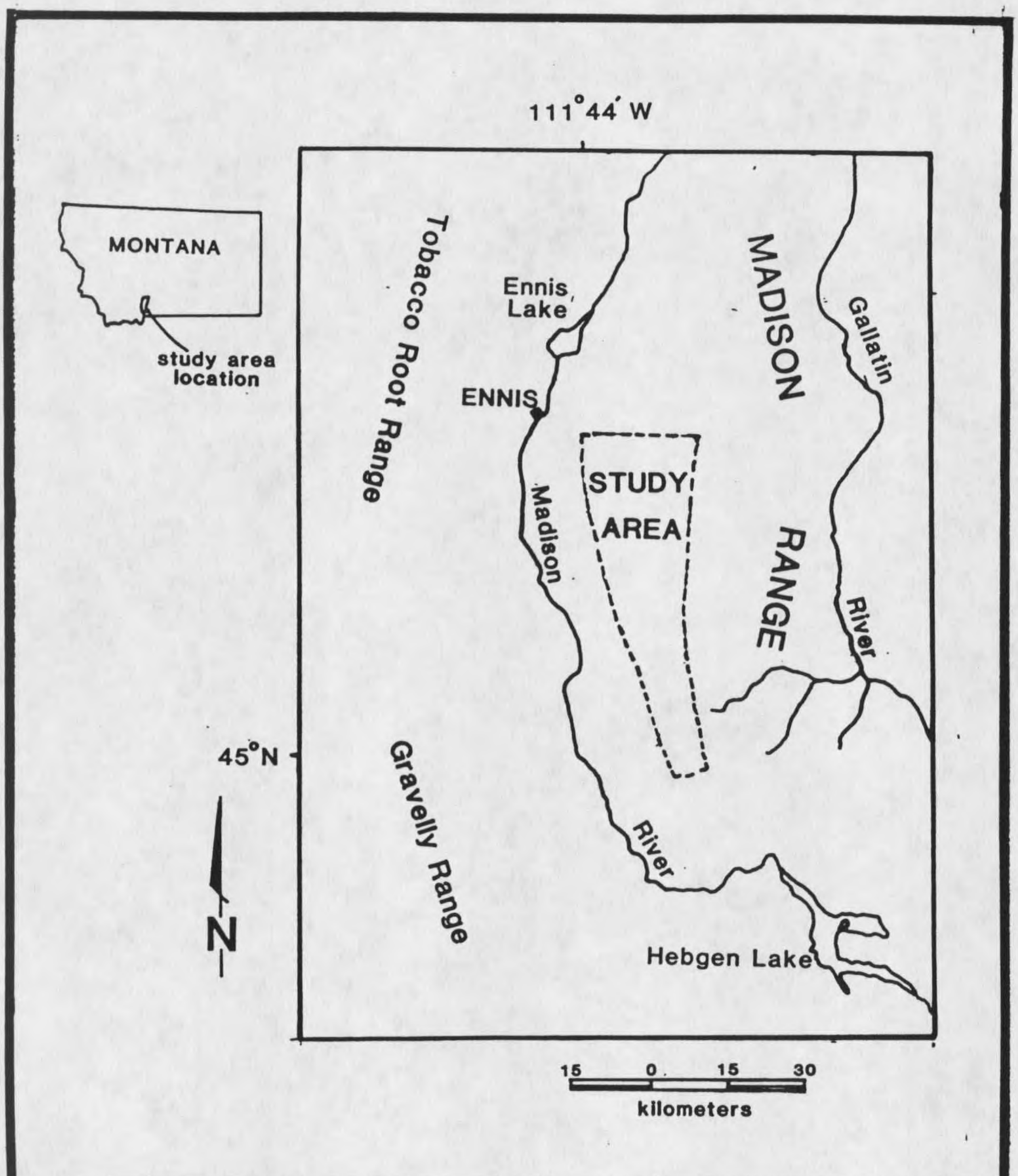

Figure 1. The study area is located along the west slope of the Madison Range in southwestern Montana.

The results of this study may be used by land managers in the area to determine appropriate use of invaded areas. Grazing strategies may be developed to promote sustainable use of the area that account for invasion ecotone conditions. These strategies may include limiting animal numbers in sensitive areas, promoting rotational grazing schemes within invasion ecotones to limit animal impact on sensitive areas, implementing prescribed burning, and managing for wildlife and overall ecosystem health.

Previous Studies

In stable communities all plant species are in a state of equilibrium with each other and with their environment. Invading species, or species that are not usually found in a particular community, are often not able to compete successfully in a stable community. Often only after some disturbance of the community equilibrium do invaders come in (Zamora 1982; Etherington 1982; Walter 1985). Disturbances within natural ecosystems may disrupt succession and may eventually alter plant composition within a community (Humphrey 1962; Krueger and Winward 1974; Walter 1985). In the Madison Valley and in other parts of southwestern Montana young coniferous trees have invaded areas previously occupied by grassland-sagebrush communities (Sindelar 1971; Dando and Hansen 1990; Hansen et. al submitted publication). These studies found that trees advanced into the previously stable communities following a disturbance of the natural plant community. These disturbances apparently were caused both by nature, and by humans. Hansen et. al. (submitted publication) found that the Madison invasion was caused by the implementation of a fire suppression policy in the early years of this century, by grazing, and sometimes overgrazing, by livestock for more than a century, and by climatic change. Sindelar (1971) and Hansen et. al. (submitted publication) found no evidence of past invasive episodes in their study regions.

Patten (1969) found that lodgepole pine (*Pinus contorta*) was invading pure stands of sagebrush in northwestern Yellowstone National Park, an environment similar to that found in the Madison study area. In contrast to the results of studies completed in southwestern Montana, no historic or present disturbance was identified by Patten (1969). Patten concluded that lodgepole pine was invading areas that either supplied adequate seed beds or had supported pine forests during a previous ice age.

Increases in tree canopy overstory often change the existing understory vegetation communities (McConnell and Smith 1965; Jameson 1967; Patten 1969; Schott and Pieper 1985; Pieper 1990). Jameson (1970) and Pieper (1990) found that as tree canopy overstory increases the actual number of individual plants and plant species in the understory decreases. This decline was attributed to sunlight and precipitation interception by the tree canopy (Jameson 1966 and 1970; Scott and Pieper 1985). Plant species adapted to direct sunlight and open conditions decreased with increased canopy cover. In some cases, these declining species were replaced by species that preferred shade, drier conditions, or both (Pase 1958; Halls and Schuster 1965; Patten 1969). Often, plants that are adapted to more shade and drier conditions are less palatable to livestock. In addition, several other studies found that different understory life forms react differently to overstory increases (Ehrenreich and Crosby 1960; McConnell and Smith 1965). In those studies, dense timber stands were thinned and the effects to the understory were measured. They found that grasses tended to increase at a faster rate per degree of canopy decrease than did shrubs or forbs. Forbs and shrubs eventually increased as canopy decreased but at a slower, more constant rate than grasses.

Arnold (1964) and Schott and Pieper (1985) discovered that vegetation grew better around the canopy periphery than directly beneath the canopy. Both studies found that lack of sunlight beneath the densest canopy restricted growth, whereas the less dense fringes of the canopy allowed infiltration of sunlight sufficient for plant growth.

Grazing by domestic livestock also affects understory plant communities in forest-grassland ecosystems (Sampson 1952; Blackburn and Tueller 1970; Zimmerman and Nuenschwander 1984). Krueger and Winward (1974) and Stoddard and Smith (1955) found that overuse or overgrazing of an area may alter existing plant communities. In support of these studies Humphrey (1962) explained that the removal of preferred plants by selective grazing may serve to disrupt the equilibrium of the plant community. Sheep prefer forbs to grasses, and cattle and horses prefer grasses to forbs (Stoddard and Smith 1955). These forage preferences may lead to an increase in grasses and a decrease in forbs on sheep ranges and increases in forbs and decreases in grasses on land grazed by cattle or horses (Holechek and Stephenson 1983). As favored plants are removed by the animals, less favored and often less palatable plants may replace them. These plants are often shorter lived and grow less densely than preferred plants. Such decreases in plant yields forces an increase in the energy expended by the animal in its search for food (Sampson 1952; Stoddard and Smith 1955).

Sindelar (1971), Dando and Hansen (1990), Wyckoff and Hansen (1991) and Hansen et. al. (submitted publication) found that coniferous trees are encroaching into areas used as rangeland for domestic livestock in southwestern Montana. Wyckoff and Hansen (1991) found that different kinds of grazing practices involving sheep, cattle and horses have existed in the Madison Valley for over a century. These grazing practices may further impact the understory plant communities in invaded areas.

Study Area

The study area is located in the Madison Valley along the west slope of the Madison Range in southwestern Montana. The west slope of the Madison Range was chosen for a variety of reasons. Tree invasion has been occurring for about the last forty years (Hansen et. al. submitted publication). The majority of the specific locations of invasion are on accessible public land and offer a variety of slopes, aspects, and exposures in which to study this phenomena. This region is representative of other sites of invasion in southwestern Montana, and a study focused on the magnitude, timing and causes of tree invasion has supplied relevant data (Hansen et. al. submitted publication). Some of the data used in this study was taken from the results of that study. Moreover, the Madison Valley is an area with a diverse and well documented grazing history. It has been grazed by livestock for over a century, and records of grazing leases and census data are readily available.

Elevations of the forest-grassland and invasion ecotones along the mountain front vary from 1,930 to 2,246 meters (6,300 to 7,300 feet). Slopes on which invasion is taking place vary from gentle (less than 10 degrees) to moderately steep (20-30 degrees). Invasion appears to occur primarily on west-to southwest-facing slopes, but also occurs, to some extent, on almost all aspects throughout the ecotone.

Geology, Geomorphology and Soils

Bedrock in the study area is primarily unexposed Archean metamorphics overlain by layers of Paleozoic and Mesozoic strata. The Paleozoic strata include clay shales, carbonates and sandstones. The Mesozoic strata are predominantly clastic sedimentary rock. Deposits of Upper Cretaceous alluvium and colluvium can be found overlying the older strata throughout the valley (Hadley 1969). Several distinct and well-defined alluvial fans, including the Cedar Creek alluvial fan, are found along the range front.

The geomorphology of the area is quite complex. Madison River terraces extend from the western flanks of the Madison Range westward to the Madison River. Three sets of well defined terraces exist, as well as several less distinct and possibly incomplete terraces. Four stages of Quaternary glaciation have shaped the Madison Range and covered the valley floor with glacial outwash. Mass movement and debris slides, both active and historic, are common throughout the valley (Hall 1960; Brown unpublished).

Soils throughout the study area are relatively homogeneous and consist primarily of well-drained silty to stony loams of varying degrees of development. Underlying bedrock determines the texture and depth of the soils. Soils overlying the metamorphics tend to be deep, well-drained, coarse sandy loams. Soils over the Paleozoic sedimentary rocks tend to be shallow, well-drained, calcareous stony loams, whereas soils over the Paleozoic shales and sandstones tend to be well-drained, deep silty clay to sandy loams. Soils found over unconsolidated depositional materials are well-drained and of varying degrees of development (United States Department of Agriculture 1989).

Forest soils of the area are considered to be members of the Whitore-Hanson-Rock-outcrop complex. Soils are light brown to gray-brown with a thin to thick layer of overlying tree litter (United States Department of Agriculture 1989). These soils tend to be coarse and stony and lack well-defined horizon layers. Permeability is moderate with an available water capacity of 10 cm (five inches) (Patten 1963; United States Department of Agriculture 1989). Grassland soils are primarily members of the Crago-Shravo-Attewan complex in the northern parts of the study area and members of the

Maxville-Bearmouth complex to the south. Both complexes are characterized by deep, well-drained, sandy to gravely loams (Veseth and Montagne 1980; United States Department of Agriculture 1989).

Climate

The climate of the Madison Valley consists of relatively low temperatures and precipitation and is considered a continental climate. Summers have moderate temperatures, but rather low precipitation in the valley, and often have lower temperatures and higher precipitation in the mountains. Winters are characterized by quite low temperatures and snow covers the ground much of the season (United States Department of Agriculture 1989).

Annual precipitation ranges from less than 30 cm (12 inches) in the valley to approximately 65 cm (25 inches) in the mountains. Most of the area's precipitation occurs in late spring and early summer, and may occur in late summer in the form of late afternoon thundershowers (United States Department of Agriculture 1989).

Temperatures in the region reach their maximum in July and their minimum in January (Table 1). The average summer temperature in Ennis, Montana is 17° C (62° F); the average winter temperature in nearby Ennis is -3° C (26° F). Extreme fluctuations and high degrees of variability in precipitation and temperature are common on an annual and a daily basis (NOAA 1990).

Table 1: Climatic conditions at Ennis, Montana at 1505 m (4939 feet) (after NOAA 1990).

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Av.
0.9	0.9	1.7	2.6	4.9	5.9	2.9	3.0	3.3	2.3	1.3	1.0	30.5
-5.2	-2.1	0.0	5.2	10.3	14.6	18.4	17.4	12.4	7.6	0.7	-1.9	6.4

Row 1 = Average precipitation in centimeters (1951-1980)
Row 2 = Average temperature in degrees C (1951-1980)
Av. = Annual average

Vegetation

Vegetation habitat types are controlled by elevation, slope, aspect, and soils (Patten 1963; Despain 1973; Pfister et. al. 1977; Weaver and Perry 1978; Dargie 1987). Understory vegetation is primarily composed of rangeland grasses, forbs and shrubs. Dominant grasses found in the area include bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), Great Basin wild rye (*Elymus cinereus*), Kentucky bluegrass (*Poa pratensis*) and several species of brome (*Bromus* spp.). Forbs include yarrow (*Achillea millefolium*), fringed sagewort (*Artemisia frigida*), cudweed sagewort (*Artemisia ludoviciana*), salsify (*Tragopogon dubius)* and lupine (*Lupinus* spp.). Shrub species include big sagebrush (*Artemisia tridentata*), Wood's rose (*Rosa woodsii*) and snowberry (*Symphoricarpus* spp.).

Douglas fir (*Pseudotsuga menziesii*) , the apparent climax species of the region, usually occupies south- and west-facing mountain slopes and valleys composed of well-drained coarse stony loam soils. Its elevational distribution ranges from the lower forest ecotone, approximately 1515 m (5000 feet) up to about 2424 meters (8,000 feet) depending on slope, aspect and moisture availability (Patten 1963; Sindelar 1971; Pfister et.al. 1977). Rarely does this species extend for any distance into the grassland community. In the Madison region this species is associated with four distinct forest habitat types (Pfister et. al. 1977). Forage production for wildlife and livestock varies considerably between habitat types .

Limber pine (*Pinus flexilis*) forest stands in southwestern Montana are commonly found at low to mid-elevations, usually between 1212 and 2424 meters (4,000 to 8,000 feet). Limber pine in the study area are usually found on rocky, dry slopes covered by well-drained shallow gravely soils. This species usually dominates sites which are too dry for Douglas fir (Patten 1963; Pfister et.al. 1977). Because they are able to withstand semi-arid conditions, limber pine are able to grow farther into the grassland community than are Douglas fir. In the Madison Valley, limber pine are usually associated with three habitat types (Pfister et. al. 1977). In addition to occurring in pure stands, limber pine often occurs as a co-dominant with Douglas fir. With increasing soil moisture, Douglas fir begins to dominate. Forage value for wildlife and livestock varies among the habitat types depending on soil moisture .

Rocky Mountain juniper (*Juniperous scopulorum*) is usually found locally in association with limber pine and Douglas fir at drier and lower elevation sites, but may occur in pure stands throughout the lower forest border (Patten 1963). Understory vegetation associated with the juniper stands are those species often associated with drier Douglas fir and limber pine sites. Juniper is adapted to a variety of soil types and can occupy a variety of habitat types (Johnson 1962).

Scattered stands of quaking aspen (*Populus tremuloides*) occur in moister areas. Stands of aspen are relatively small and are typically composed of a variety of size and age classes (Patten 1963).

Land Use History

The Madison Valley has been used for the grazing of domestic livestock since the 1860s. Cattle and horses were brought to the valley to provide meat and transportation for the miners at the Grasshopper Creek and Alder Gulch gold strikes (Burlingame and Toole 1957; Lange and Myers 1979; Wyckoff and Hansen 1991). Animals were brought into the area in spring and allowed to range free until fall, when they were rounded up and moved to winter range or market. Winters in the area are harsh, and year long use by livestock was often costly in terms of numbers of animals lost to cold and exposure. Permanent settlement of the valley did not accelerate until the early 1870s, when cattle and horse numbers increased and sheep were first introduced to the region (Madison County Historical Society 1976; Wyckoff and Hansen 1991). The expansion of the railroads into Montana in the 1880s provided easier access to national markets. In response, ranchers continued to increase herd sizes in an attempt to fill local and national demands. By 1890, there were 25,000 sheep, 38,000 cattle and 16,000 horses in the area (Lange and Myers 1979; Wyckoff and Hansen 1991; Hansen et. al., submitted publication).

Much of the acreage grazed by livestock was undeeded and unregulated public land. Ranchers took advantage of the unfenced lands and allowed their stock to range freely. Herds tended to congregate and graze areas of lush foliage and plentiful water. Riparian areas and the more easily reached bench lands were usually grazed first and most frequently and, therefore, were most subject to early overgrazing (Wyckoff and Hansen 1991).

The numbers of permanent settlements and livestock continued to increase in the early twentieth century. Herd sizes rose, and ranchers began to purchase and fence the open rangelands their animals had been freely grazing for years in an effort to protect the range resources and to maximize profits. After the creation of the United States Forest Service in the 1890s, much of the mountainous public lands previously used by livestock was taken out of unregulated public use. This switch from open range to private ownership and regulated use of public lands established the system of land use in the valley today (Madison County Historical Society 1976; Wyckoff and Hansen 1991). .

Regulation of grazing on public lands increased throughout the remainder of the twentieth century. Fee schedules, grazing allotments and regulated periods of use on public lands were established by the U.S. Forest Service in 1906. Market shifts and changes in demand for animal products throughout the 1900s resulted in shifts in animal numbers and type of animals raised. Demand for wool and meat during World War I increased the numbers of sheep and cattle in the valley. Requests for permits to graze increased as did the total number of animals allowed to graze in the National Forest. In 1918, the market for beef declined as demand for wool and mutton continued to increase. As a result, the number of cattle in the valley and on leased forest lands was reduced and the number of sheep was increased (Lange and Myers 1979; Wyckoff and Hansen 1991; Hansen et. al. submitted publication).

Low market prices for livestock in the late 1920s and early 1930s encouraged ranchers to keep their animals rather than sell them at a loss. As a result, income earned from livestock sales declined and grazing pressure in the valley increased. Downward trends in the livestock industry and range conditions continued until the 1940s (Lange and Myers 1979).

Moist years in 1938 and 1939 helped to alleviate drought conditions. Increased national demands for animal products improved the livestock economy. During World

War II an increase in demand for cattle and a decrease in available labor led to an increase in numbers of cattle and a decrease in numbers of sheep in the valley. Many of the sheep raisers in the valley still relied on herders to manage their flocks, but as the war progressed, many of the people previously employed as shepherds left the valley for the armed services or for employment in wartime industries. As a result, many sheep ranchers switched to less labor intensive cattle ranching. Sheep numbers in Madison County declined from 200,000 animals in 1930 to less than 80,000 in 1960 (Lange and Myers 1979; Wyckoff and Hansen 1991).

Management philosophies underwent changes in the post-War era. The effects of poor management on public and private land had been felt during the drought and Depression years of the 1930s. New grazing policies, implemented by the U.S. Forest Service, the State of Montana, and private landowners, encouraged more sustainable grazing methods. Shorter grazing seasons, less intensive use of the land by livestock, and fewer numbers of animals allowed to graze public allotments were among the alternative landuse practices tried. Livestock ranchers began to place more emphasis on the quality of animals than on the quantity of animals raised. Herd sizes were reduced, and breeding programs which were designed to produce larger animals were established. Range conditions began to improve, and more realistic and long-term goals were set (Wyckoff and Hansen 1991; Hansen et. al., submitted publication).

The trend toward more responsible range management continues today. The majority of the ranchers actively raising livestock in the valley managed to optimize profits without degrading the quality of the range. In addition, many ranchers have placed an emphasis on managing for wildlife. On many ranches in the area, hunting is allowed on private land for a small fee. The desire to increase land-derived income can thus become an incentive for protecting wildlife habitat.

Leasing of grazing land to non-resident livestock growers is becoming increasingly common in the valley. Local livestock raisers permit the use of their land for grazing by imported cattle. Animals are grazed throughout the summer and then are sold to eastern markets. In this way, local ranchers are able to augment their incomes by leasing unused lands to non-local ranchers (Holden personal communication).

CHAPTER 2

METHODS

Specific Site Selection

Sites specifically chosen for study were those identified by Hansen et. al. (submitted publication) as having been measurably invaded. All data recorded on invaded sites were taken from that study.

Grazing by different types of livestock, and/or during different times of the year, may result in different vegetative understory composition. For this study, dominant grazing histories in the valley, both in terms of type of animal and length of use were identified using U. S. Forest Service grazing allotment records and personal information from livestock raisers in the region. These data were collected by Dr. William Wyckoff and were taken from the Wyckoff and Hansen study (1991). For each invaded transect, I identified its grazing history. I then divided all invaded transects into grazing categories based on their grazing records. Grazing categories with the greatest number of invaded transects were selected for study. Five categories of grazing practices were chosen. These five categories included : a) areas that had been grazed by cattle for roughly 50 years, but had not been grazed by livestock for the last 15 to 35 years, b) areas that had been grazed exclusively by cattle since around 1920 (70 years), c) areas that had been grazed by horses and cattle for 20 years and then grazed only by cattle for the last 47 years, d) areas that had been grazed by cattle and horses for 20 years, then grazed by sheep for 50 years and then grazed again by cattle for the last 12 years, and e) areas that had been grazed by sheep for at least 27 years and then grazed by only cattle for the last 45 years. These five categories appeared to best represent the grazing practices throughout the Madison Valley. Additionally, the locations of these categorized areas within the study area could be easily identified (Figure 2).

Field Data Collection

Data were collected over a four year period (1986-1989) separately and in conjunction with a National Science Foundation funded project conducted by Hansen and Wyckoff of the Earth Sciences Department, Montana State University, entitled "The Dynamics and Magnitude of Forest Invasion, Madison Range, Montana" (Hansen et. al. submitted publication).

The selected sites were all located along the lower forest-grassland ecotone. Transects were sampled from within the established, mature forest, through the invaded ecotone and into the sagebrush-grassland community downslope. Data from these invaded transects were taken from the Hansen et. al.(submitted publication) study. I then sampled sites adjacent to selected invaded sites. Twenty invaded transects and thirteen noninvaded transects were sampled within the five grazing categories (Table 2).

For invaded areas, circular microplots, with a 5 m (18 ft) radii, were sampled along the transects. The outside perimeter of each plot was separated from the next by 15 m (50 feet). The entire length of each transect varied depending on the extent of tree

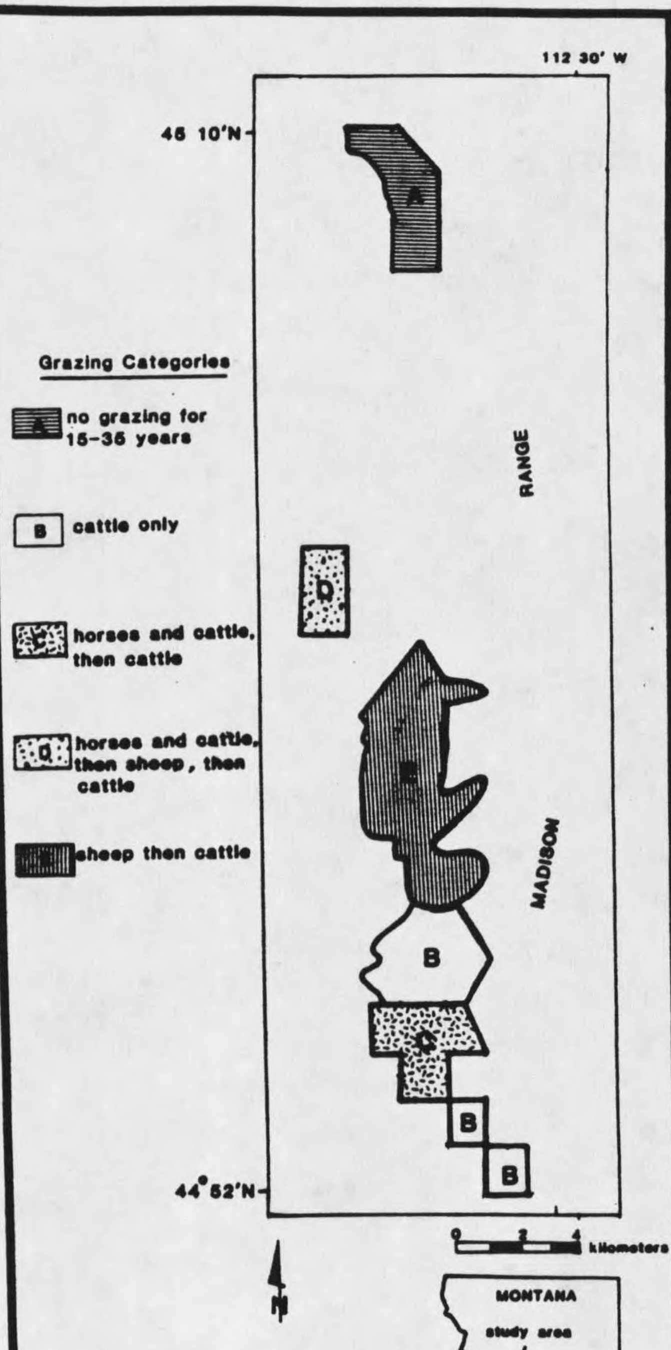

Figure 2. Five grazing types were identified and located along the western edge of the MadisonRange.

Table 2. Grazing categories and numbers of invaded and noninvaded transects within each.

GRAZING CATEGORY	NUMBER OF TRANSECTS
A) 15-35 years since cattle grazing	invaded.......... 4 noninvaded.... 4
B) Cattle only	invaded.......... 5 noninvaded.... 2
C) Horses and cattle, then cattle	invaded.......... 4 noninvaded.... 2
D) Horses and cattle, then sheep, then cattle	invaded.......... 4 noninvaded.... 2
E) Sheep, then cattle	invaded.......... 3 noninvaded.... 3

invasion into the sagebrush-grassland community. For each transect, aspect was recorded using a Brunton compass and elevation was estimated using U.S.G.S. 1:24,000 topographic maps (Hansen et. al. submitted publication).

Noninvaded transects were sampled using methods from the Hansen et. al. study (submitted publication) to determine vegetative cover. Transects began at the mature forest border and extended into the sagebrush-grassland community. The noninvaded transects were sampled adjacent to (within 300 m (1000 ft) on average) the sampled, invaded transects, and aspect and slope of the noninvaded transects were similar to those of their invaded counterparts. Selection of sites for noninvaded transects was based on accessibility and proximity to invaded transects. Figures 3, 4 and 5 show the locations of the invaded and non-invaded transects within individual grazing categories.

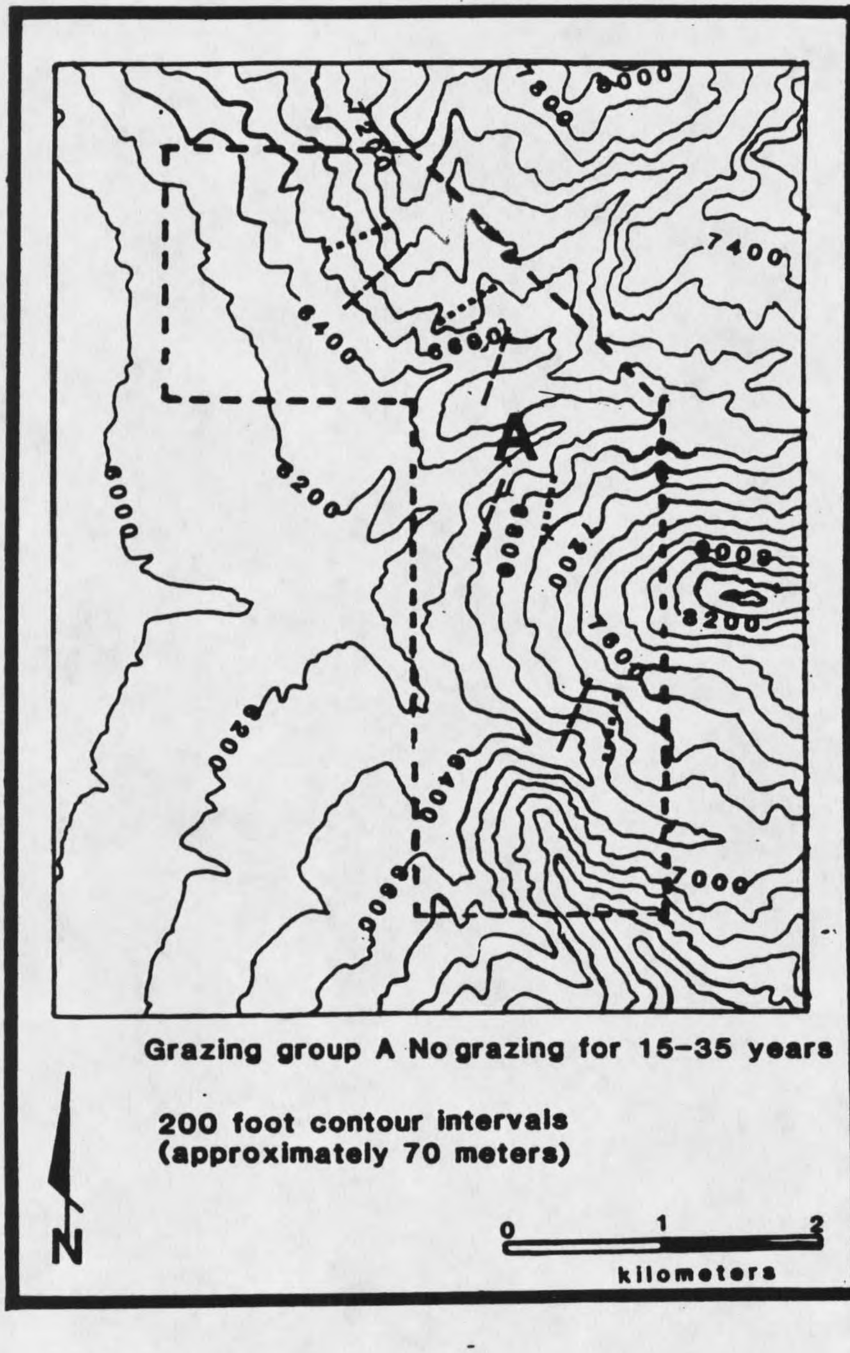

Figure 3. Locations of individual transects sampled within grazing category A (no grazing for 15-35 years). Dotted lines indicate location of invaded transects, dashed lines indicate location of noninvaded transects.

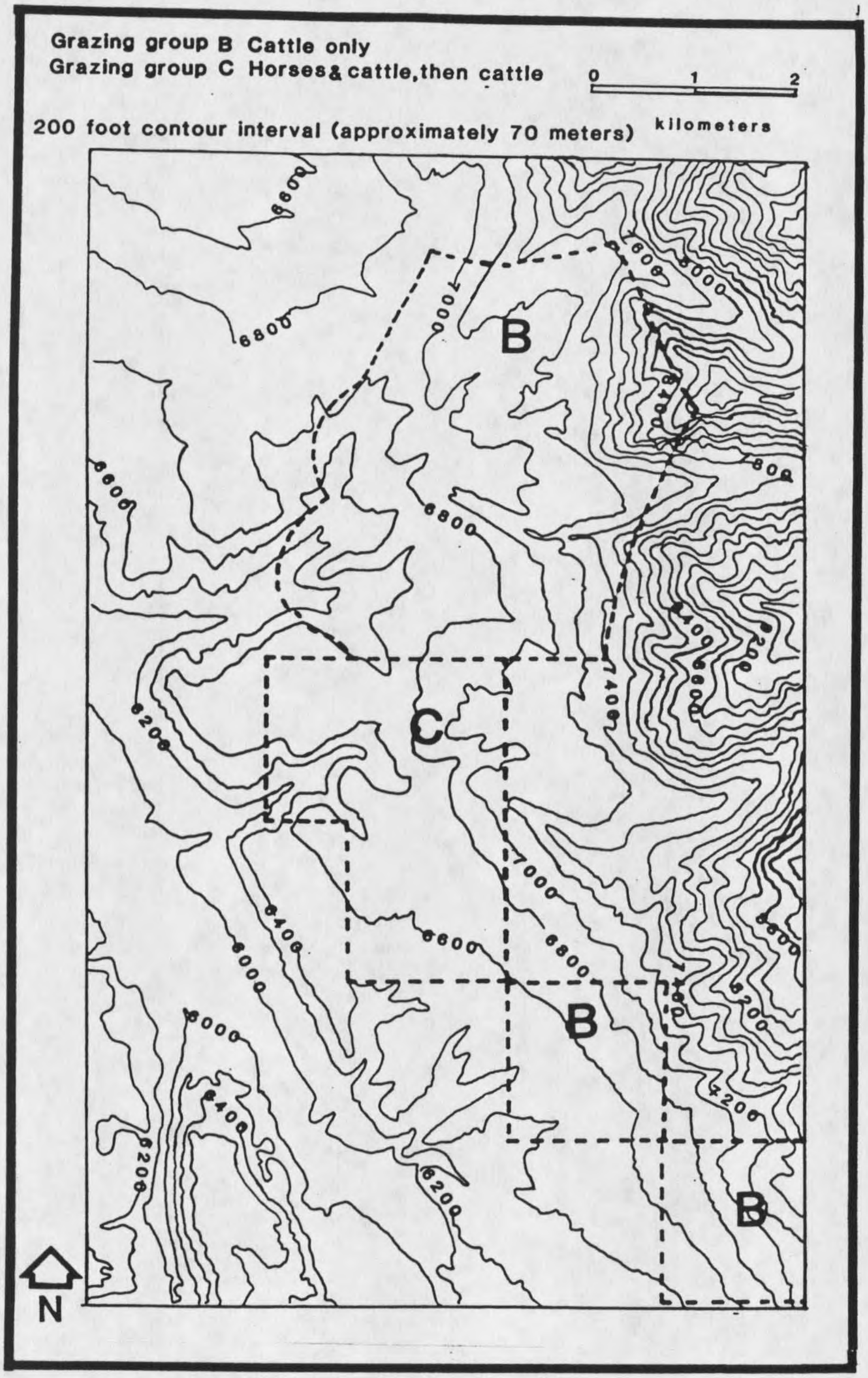

Figure 4. Location of transects sampled within grazing categories B (cattle only) and C (horses and cattle, then cattle). Dotted lines indicate location of invaded transects, dashed lines indicate location of noninvaded transects.

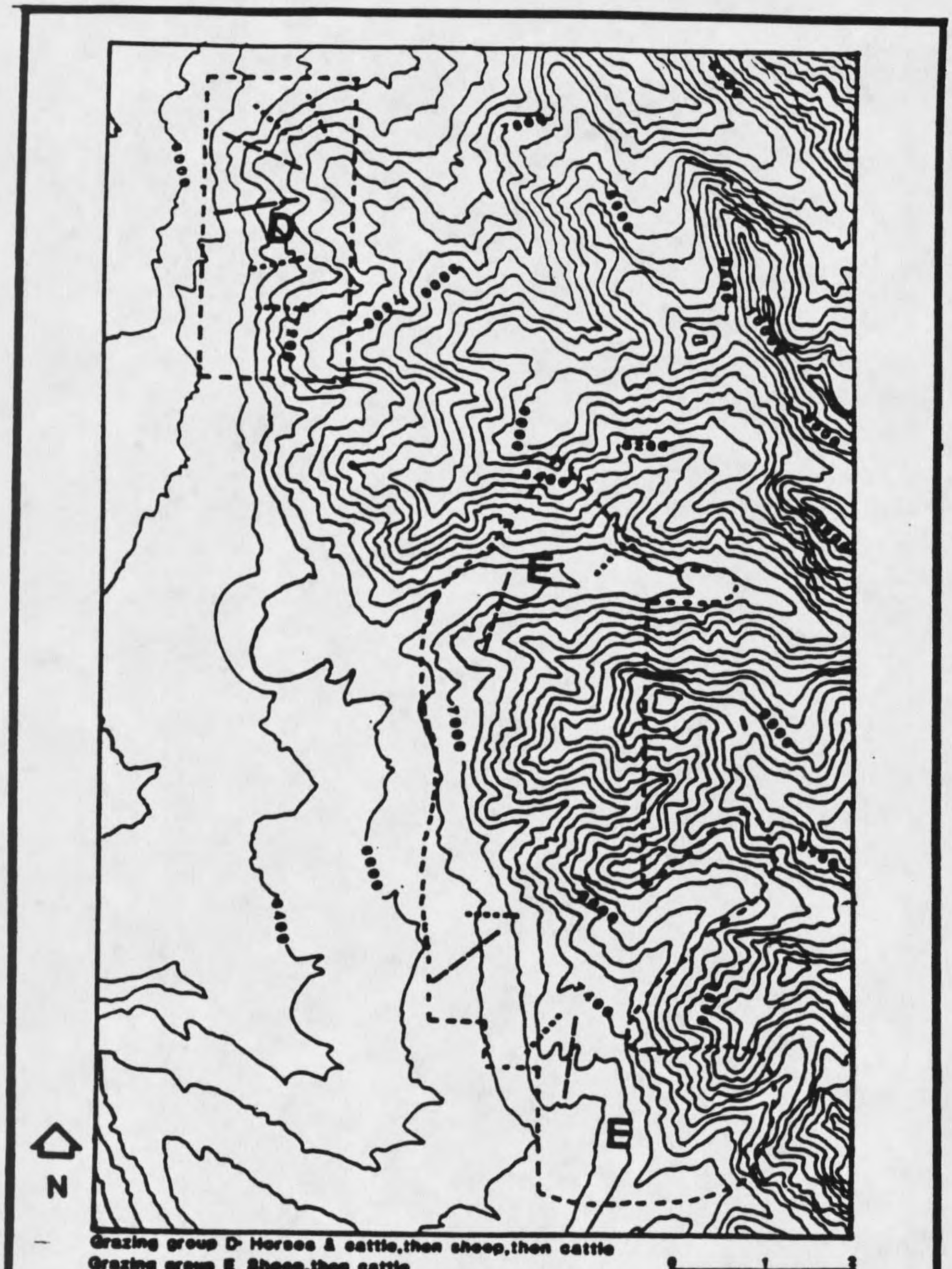

Figure 5. Locations of sampled transects within grazing categories D (horses and cattle, then sheep, then cattle) and E (sheep, then cattle). Dotted lines indicate location of invaded transects, dashed lines indicate location of noninvaded transects.

For all sampled microplots, the percentage of ground covered by bare soil, gravel, rock, tree litter, and dead wood was visually estimated and recorded. These values were combined and represent the total percentage of the quadrat not presently covered by vegetation. The percentage of vegetative cover, in terms of grasses, forbs and shrubs was estimated in the same manner. Understory vegetation species were identified and recorded for each quadrat. Species identification were checked using vegetation field guides (Strickler 1986; Dorn 1984), the Montana State University herbarium, and Kevin Suzuki of the Madison District of the United States Forest Service, Beaverhead National Forest. Tree canopy cover was visually estimated and recorded for all invaded microplots.

Data Analysis

Data collected in the field were analyzed using a variety of statistical methods. Renormalization equations were used to insure consistency of data. A two sample t-test was used to test for differences in percent vegetated ground cover between invaded and noninvaded areas. To determine the degree and strength of the relationship between tree canopy and understory life form, i.e. grass, forb or shrub, a rank correlation test was used. Finally, species frequency distribution graphs were used to indicate alterations in species-understory vegetation in areas that had been invaded by trees. Combined, the results of these procedures contributed to a better understanding of the effects of tree invasion, and particularly of increases in tree-canopy cover, on the understory.

Renormalization

In several instances, the combined percentages of vegetated and nonvegetated ground cover did not total 100 percent of the quadrat. This was primarily attributed to sampling errors by the data collectors. Often these errors resulted from estimating multiple layers of vegetation rather than the top layer visible from eye level. In these instances, a renormalizing procedure was employed to insure that a total of all percentages within each quadrat equaled 100. The equation used (Moore and McCabe 1989) was :

$$G + F + S + O = 100 \text{ percent,}$$

where G = percent grasses, F = percent forbs, S = percent shrubs, and O = percent nonvegetated ground. To determine the renormalized values, the percentage of a particular vegetation type was divided by the total percentage of ground cover accounted for originally in the quadrat, and then multiplied by 100. In most cases, the renormalization procedure did not substantially alter the existing percentage values of the variables. Usually the resultant changes in percent cover amounted to less than two percent. The percentage of tree canopy cover was not considered to be an element of the understory or ground cover, and therefore did not require renormalization.

t-test

A t-test was used to determine if there were significant differences between understory vegetation ground cover between invaded and noninvaded transects within a specific grazing category. A two-sample t-test was applied using the equation:

$$t = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{N_1S_1^2 + N_2S_2^2}{N_1 + N_2 - 2}}\sqrt{\frac{N_1 + N_2}{N_1N_2}}},$$

where $\overline{X_1}$ and $\overline{X_2}$ = sample mean of percent ground cover from all invaded and noninvaded transects (respectively) within a grazing category, N_1 and N_2 = total number of invaded and noninvaded transects (respectively) within a grazing category, and S_1 and S_2 the sample standard deviations of percent cover of invaded and noninvaded transects (respectively) within a grazing category. Degrees of freedom, $N_1 + N_2 - 2$, were used to determine t values, which were then used to access the P values from the t-table.

Percent life form ground cover for each microplot within an individual transect were combined to determine means and standard deviations of life form cover for individual invaded transects. This method was also used for noninvaded transects. Means and standard deviations for invaded and noninvaded transects were then combined to produce average invaded, or noninvaded, percent life form cover for each grazing category. Data sets used for the test consisted of the combined means and standard deviations of understory life form percentages for invaded and noninvaded transects within a grazing category.

A $P<.05$ level was set to reject the null hypothesis that no difference existed between invaded and noninvaded transects within specific grazing categories. Results of the t-tests from different grazing categories were compared .

Rank Correlation

Relationships between tree canopy cover and understory vegetation, and between vegetation types within an individual transect were determined using rank correlation (Ractliffe 1978; Moore and McCabe 1989). Rank correlation is a good test for relationships about which there are no previously developed specific hypotheses (Boik personal communication). It was believed that different amounts of tree invasion-induced canopy cover would affect the understory vegetation composition, but the precise effects could not be predicted.

For each microplot within a transect, the percentages of tree canopy cover, grasses, forbs and shrubs were compared two at a time until all combinations of comparison between variables had been established. For a total data set analysis, all possible combinations were compared to one another. For noninvaded transects, grasses, forbs, and shrubs were compared using the same method used for invaded transects. A probability value (P), and a tau value, were determined for each variable combination analysis using a rank correlation computer program written in C (Press et al. 1990). Tau values indicate the strength and "direction" (positive or negative) of a relationship. A tau value of +1 indicates a perfect, positive relationship between two variables, and a -1 indicates a perfect negative relationship between variables. Values between +1 and -1 are less than perfect positive or negative relationships.

A probability significance value of $P < .05$ was used. The smaller the probability value (P), the greater the significance and the stronger the relationship between the variable combinations (Ractliffe 1978; Moore and McCabe 1989). Probability values for all invaded transects within a grazing category were then averaged to yield a mean probability value for each life form combination for each grazing category. Standard deviations of the combined transect probability values were calculated to determine the spread of the data. Tau values for variable combinations from each transect were combined for grazing category in the same way as mean and standard deviations of probability values. In this way, it was possible to determine overall mean relationship strength and direction of each variable combination within grazing categories. Due to differences in transect lengths, slope, and aspect among grazing categories, rank correlation was used only to determine the relationships existing within a particular grazing category. Rank correlation results for grazing categories were compared and discussed.

Species Frequency

Changes in species composition of the understory between invaded and noninvaded transects were also noted by use of frequency distributions. Frequencies of certain species of grasses, forbs and shrubs indicative of environmental conditions found in the study area (Table 3) were graphed by specific grazing categories for four levels of canopy cover. The four canopy cover selections were chosen to determine if differences occurred between the frequency of a species and the amount of shading or full sunlight within the site. High canopy cover was set at greater than 50 percent, moderate canopy cover fell between 49 and 20 percent, low canopy was between 19 and five percent , and areas with canopy less than five percent were considered to be noninvaded, and for this study, were considered to have no canopy cover influence. These selections were based on the studies of the effects of thinning of coniferous tree canopy on understory composition by Pase (1958), Ehrenreich and Crosby (1960), and McConnell and Smith (1965).

Specific species used in the frequency distribution graphs were chosen based on their habitat preferences. Species that are adapted to a limited range of environmental conditions are only found where those conditions exist. These species can be readily

Table 3. Indicator species (and their abbreviated notation) and the environment they are indicative of used in the frequency distribution graphs (from USDA 1989).

INDICATOR SPECIES	INDICATIVE ENVIRONMENT
Agropyron spicatum (Agsp)	partial shade to full sun
Poa pratensis (Popr)	moist soil conditions (associated with shade)
Achillea millefolium (Acmi)	full sun
Berberis repens (Bere)	partial to dense shade
Mertensia ciliata (Meci)	dense shade
Eriogonum umbellatum (Erum)	full sun
Artemisia tridentata (Artr)	full sun

identified with a certain habitat and are often called indicator species (Humphrey 1962). The presence or absence of a plant species depends on the environmental conditions found in a particular area. If an indicator species is absent, it may mean that the conditions promoting the survival of that species are not present or that the species has not yet become established in the area. Indicator species were used in this study to compare relative environments in invaded and noninvaded sites. Noninvaded sites were more open, and therefore it would be expected that species adapted to full sunlight would be the dominant species in these areas. Consequently, as trees invade an area, their increasing canopy leads to increasing shade. It follows then that species occurring most frequently in areas of heavy canopy would be adapted to shade. In areas where canopy is intermediate in intensity a mixture of sunlight-preferring and shade-preferring species would be expected.

Frequency graphs of the selected species under these various canopy densities were compared to determine if any patterns of species frequency exist within a certain grazing category. Quattro graphing programs were used to develop frequency graphs for the grazing groups. These graphs were used to compare the species frequency results of one grazing category to another.

CHAPTER 3

RESULTS AND DISCUSSION

The effects of increased canopy cover associated with tree invasion on the understory composition were determined using two analytical techniques. Significant differences in percent ground cover between invaded and non-invaded areas were determined using a t-test. Rank correlation was used to determine significant relationships between the amount of tree canopy and the type of understory vegetation within an individual transect.

Percent Ground Cover

Percent ground cover of grasses, forbs, and shrubs in invaded and in noninvaded areas was similar ($P>0.05$) within the grazing categories, based on the t-test results (Table 4). In addition, average percent cover of life forms (grasses, forbs, and shrubs), per grazing category, as used in the t-test calculations, showed large standard deviations. from one microplot to the next, indicating that percent cover of a life form followed no predictable pattern within a transect.

Tree Canopy and Understory

Percent cover of tree canopy and understory life form were not significantly

Table 4. Differences in percent cover of grasses, forbs, and shrubs between invaded and noninvaded sites under different grazing categories (based on t-test).

		Mean ± Standard Deviation				
Grazing Category	**Life form**	**Invaded**	**Noninvaded**	**t-test Value**	**P Value**	**Reject/Do Not Reject H_0**
A) No grazing for 15-35 years		N=4	N=4			
	grasses	25.7 ± 14.9	49.5 ± 20.0	t=1.653	P=.075	do not reject
	forbs	22.0 ± 12.7	17.9 ± 9.8	t=0.140	P=>.25	do not reject
	shrubs	16.6 ± 14.7	18.9 ± 11.8	t=0.708	P>.25	do not reject
B) Cattle		N=5	N=4			
	grasses	36.6 ± 20.1	42.4 ± 21.2	t=0.287	P>.25	do not reject
	forbs	20.5 ± 13.0	11.7 ± 5.0	t=0.780	P=.22	do not reject
	shrubs	20.9 ± 13.0	29.7 ± 17.7	t=0.613	P>.25	do not reject
C) Horses/cattle, cattle		N=4	N=2			
	grasses	33.3 ± 20.8	52.7 ± 11.0	t=1.165	P=.16	do not reject
	forbs	34.0 ± 20.0	30.2 ± 12.0	t=0.724	P>.25	do not reject
	shrubs	17.7 ± 14.8	18.3 ± 3.4	t=0.685	P>.25	do not reject
D) Horses/cattle, sheep, cattle		N=4	N=2			
	grasses	44.5 ± 29.1	29.3 ± 13.4	t=0.574	P>.25	do not reject
	forbs	13.3 ± 9.7	13.2 ± 5.7	t=1.099	P=.17	do not reject
	shrubs	17.0 ± 19.9	14.9 ± 11.9	t=0.112	P>.25	do not reject
E) Sheep, cattle		N=3	N=3			
	grasses	56.9 ± 21.1	38.0 ± 19.9	t=0.919	P=.17	do not reject
	forbs	9.3 ± 3.4	14.9 ± 5.5	t=1.175	P=.17	do not reject
	shrubs	13.2 ± 12.9	23.6 ± 12.4	t=0.822	P=.22	do not reject

related, regardless of grazing categories (Tables 5 through 9). The means of the percent probability values were quite high, greater than 10 percent in most cases, for all grazing categories, signifying a high probability of randomness. Many of the average standard deviation values were also relatively large (in some cases, even larger than the average mean values), indicating a large variation in the data. Increases in tree canopy have had a limited effect on understory life form composition in this study area.

Table 5. Relationships between tree canopy, grasses, forbs, and shrubs in invaded and noninvaded areas, grazing category A (no grazing by livestock for 15-35 years) with average means and standard deviations of percent probability and tau for the entire grazing category.

A) No grazing for 15-35 years

TRANSECT TYPE	RELATIONSHIP	MEAN (P)	STANDARD DEVIATION (P)	MEAN (TAU)	STANDARD DEVIATION (TAU)
Invaded					
	Tree canopy vs grasses	15.39	13.75	-0.2	0.3
	Tree canopy vs. forbs	28.46	23.85	0.1	0.3
	Tree canopy vs shrubs	14.90	13.04	-0.2	0.3
	Grasses vs forbs	16.43	15.40	0.2	0.5
	Grasses vs shrubs	3.57	4.03	0.0	0.5
	Forbs vs shrubs	19.18	19.33	0.0	0.4
Noninvaded					
	Grasses vs forbs	15.33	18.44	-0.4	0.4
	Grasses vs shrubs	15.33	29.10	-0.1	0.3
	Forbs vs shrubs	28.60	13.62	-0.3	0.1

Table 6. Relationships between tree canopy and grasses, forbs, and shrubs in invaded and noninvaded areas, grazing category B (cattle only), with average means and standard deviations of percent probability and tau for the entire grazing category.

B) Cattle only

TRANSECT TYPE	RELATIONSHIP	MEAN (P)	STANDARD DEVIATION (P)	MEAN (TAU)	STANDARD DEVIATION (TAU)
Invaded					
	Tree canopy vs grasses	46.30	40.80	0.2	0.4
	Tree canopy vs forbs	33.92	13.16	0.0	0.3
	Tree canopy vs shrubs	17.22	25.46	-0.1	0.5
	Grasses vs forbs	37.73	33.55	0.0	0.4
	Grasses vs shrubs	23.55	33.70	-0.3	0.3
	Forbs vs shrubs	48.04	41.85	0.0	0.4
Noninvaded					
	Grasses vs forbs	16.19	9.61	-0.2	0.5
	Grasses vs shrubs	0.04	0.05	-0.9	0.1
	Forbs vs shrubs	12.87	1.52	0.1	0.6

Table 7. Relationships between tree canopy, grasses, forbs, and shrubs in invaded and noninvaded areas, grazing category C (horses and cattle, then cattle) with average means and standard deviations of percent probability and tau for the entire grazing category.

C) Horses and cattle, then cattle

TRANSECT TYPE	RELATIONSHIP	MEAN (P)	STANDARD DEVIATION (P)	MEAN (TAU)	STANDARD DEVIATION (TAU)
Invaded					
	Tree canopy vs grasses	38.79	23.68	-0.2	0.2
	Tree canopy vs forbs	62.55	36.49	-0.1	0.2
	Tree canopy vs shrubs	57.27	22.07	0.0	0.2
	Grasses vs forbs	25.93	25.17	-0.2	0.2
	Grasses vs shrubs	11.72	14.63	-0.4	0.2
	Forbs vs shrubs	29.31	26.78	-0.2	0.3
Noninvaded					
	Grasses vs forbs	28.94	40.11	-0.4	0.2
	Grasses vs shrubs	30.66	37.88	-0.4	0.4
	Forbs vs shrubs	74.47	15.03	0.0	0.1

Table 8. Relationships between tree canopy, grasses, forbs, and shrubs in invaded and noninvaded areas, grazing category D (horses and cattle, then sheep, then cattle) with average means and standard deviations of percent probability and tau for the entire grazing category.

D) Horses and cattle, then sheep, then cattle

TRANSECT TYPE	RELATIONSHIP	MEAN (P)	STANDARD DEVIATION (P)	MEAN (TAU)	STANDARD DEVIATION (TAU)
Invaded					
	Tree canopy vs grasses	33.53	41.38	-0.1	0.3
	Tree canopy vs forbs	26.53	46.69	0.4	0.2
	Tree canopy vs shrubs	18.16	16.64	-0.3	0.2
	Grasses vs forbs	34.39	39.70	0.3	0.4
	Grasses vs shrubs	3.57	4.15	-0.5	0.2
	Forbs vs shrubs	31.49	30.38	-0.3	0.3
Noninvaded					
	Grasses vs forbs	39.59	35.57	0.2	0.4
	Grasses vs shrubs	56.93	47.36	-0.2	0.2
	Forbs vs shrubs	91.57	1.62	0.0	0.0

Table 9. Relationships between tree canopy, grasses, forbs, and shrubs in invaded and noninvaded areas, grazing category E (sheep, then cattle) with average means and standard deviations of percent probability and tau for the entire grazing category.

E) Sheep, then cattle

TRANSECT TYPE	RELATIONSHIP	MEAN (P)	STANDARD DEVIATION (P)	MEAN (TAU)	STANDARD DEVIATION (TAU)
Invaded					
	Tree canopy vs grasses	17.30	29.93	-0.5	0.4
	Tree canopy vs forbs	19.28	22.80	-0.1	0.4
	Tree canopy vs shrubs	22.79	28.63	-0.3	0.2
	Grasses vs forbs	23.94	11.95	-0.3	0.3
	Grasses vs shrubs	3.14	4.57	-0.2	0.5
	Forbs vs shrubs	28.07	46.30	-0.3	0.2
Noninvaded					
	Grasses vs forbs	59.92	20.30	0.1	0.2
	Grasses vs shrubs	7.06	7.35	-0.6	0.3
	Forbs vs shrubs	22.59	19.19	-0.2	0.4

A significant, negative relationship was found between grasses and shrubs in both invaded and noninvaded sites in certain transects. This relationship appeared in invaded transects in grazing category D (grazing by horses and cattle, then cattle), and grazing category E (sheep, then cattle), and in noninvaded transects within grazing category B, (grazing by cattle), and E (grazing by sheep, then cattle). However, in grazing category A, (table 5) the P value and the tau value inexplicably contradict each other.

In a few comparisons, negative tau values exist. Negative tau values indicate that as the percent coverage of one life form increased, the percent of the other decreased. If plant competition is severe, the most competitive plant will often survive and reproduce at the expense of other less competitive plants (Etherington 1982). Walter (1985) found that woody plants often out compete herbaceous plants if they can physically grow taller than the herbs. I believe this to be the case in this study area. In the grazing categories where negative relationships exist, the sagebrush appear to be influencing the grasses more than tree canopy is.

Frequency of Indicator Species

Some species were more frequently found in certain sites, perhaps influenced by increases in tree canopy. (Figures 6 through 10) Numerous changes in the species frequency were not apparent. I believe this is because many of the invading trees are still quite small and the ground area that their canopy covers influence is still relatively small. As these trees increase in canopy cover, effects on the frequency of species may become more pronounced.

NO GRAZING BY LIVESTOCK FOR 15-35 YEARS

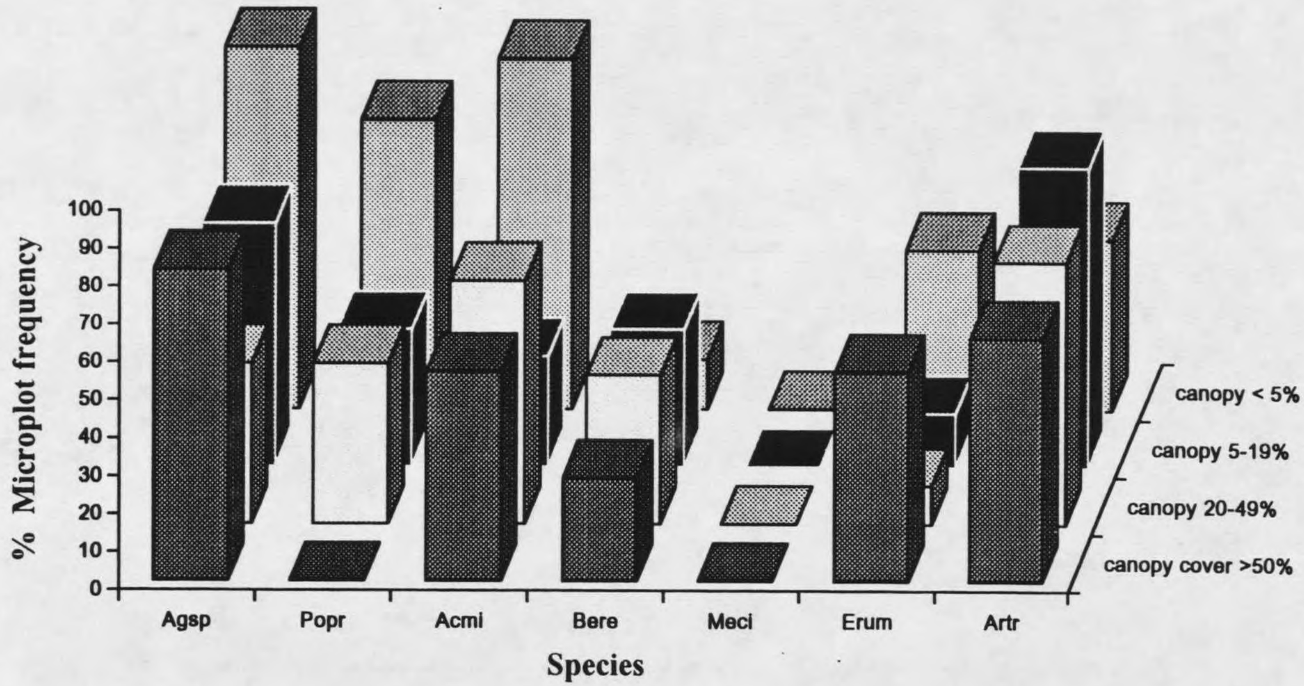

Figure 6. Frequency distribution of indicator species *Agropyron spicatum (*Agsp), *Poa pratensis* (Popr), *Achillea millifolium* (Acmi), *Berberis repens* (Bere), *Mertensia ciliati* (Meci), *Eriogonum umbellatum* (Erum), and *Artemisia tridentata* (Artr), for grazing category A (no livestock grazing for 15 to 35 years), under four categories of tree canopy cover.

CATTLE ONLY

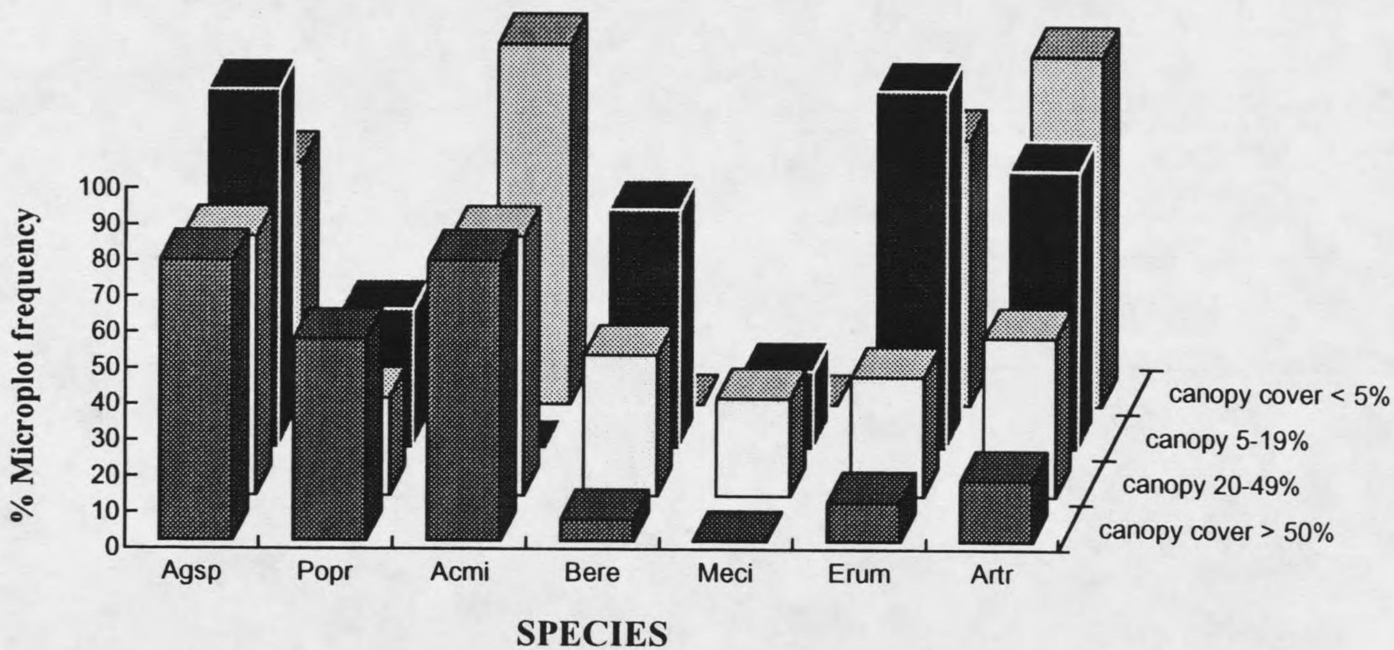

Figure 7. Frequency distribution graph of indicator species, *Agropyron spicatum*(Agsp), *Poa pratensis* (Popr), *Achillea millifolium* (Acmi), *Berberis repens* (Bere), *Mertensia ciliata* (Meci), *Eriogonum umbellatum* (Erum), *Artemisia tridentata*(Artr), for grazing category B (cattle only), under four categories of tree canopy cover.

HORSES AND CATTLE, THEN CATTLE

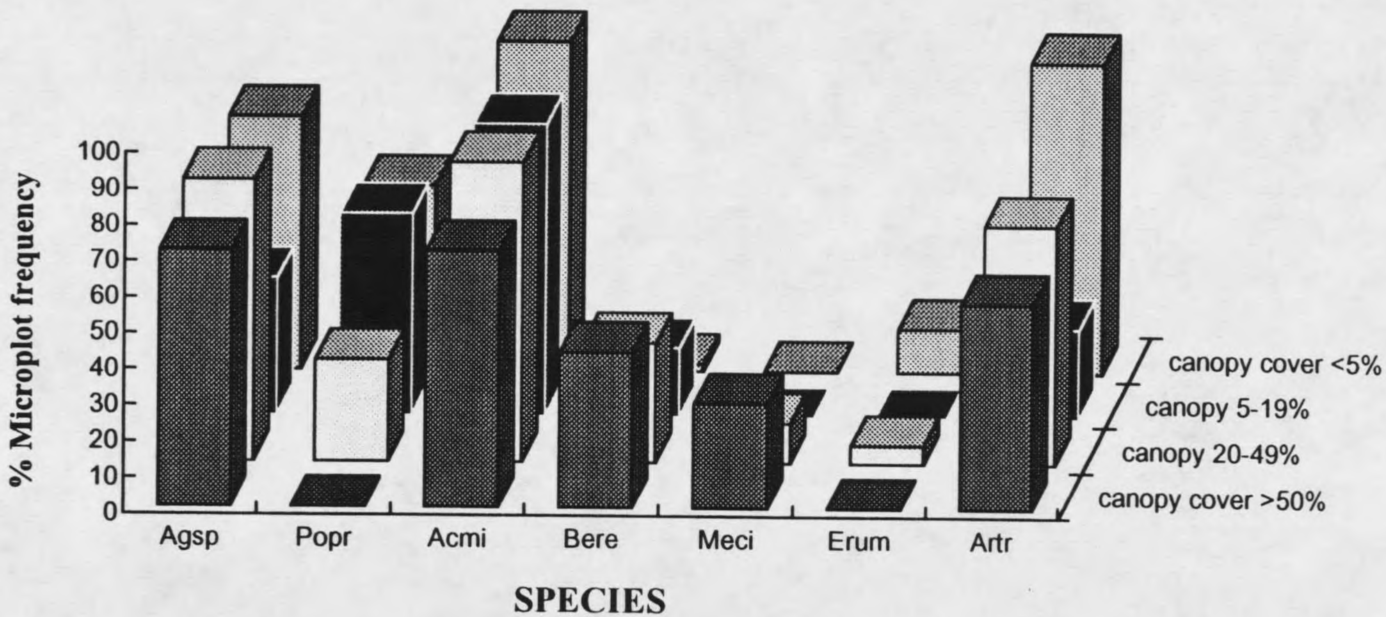

Figure 8. Frequency distribution graph for indicator species ,*Agropyron spicatum* (Agsp), *Poa pratensis* (Popr), *Achillea millefolium* (Acmi) , *Berberis repens* (Bere), *Mertensia ciliata* (Meci), *Eriogonum umbellatum* (Erum), and *Artemisia tridentata* (Artr) , for grazing category C (horses and cattle, then cattle), under four categories of tree canopy cover.

HORSES AND CATTLE, THEN SHEEP, THEN CATTLE

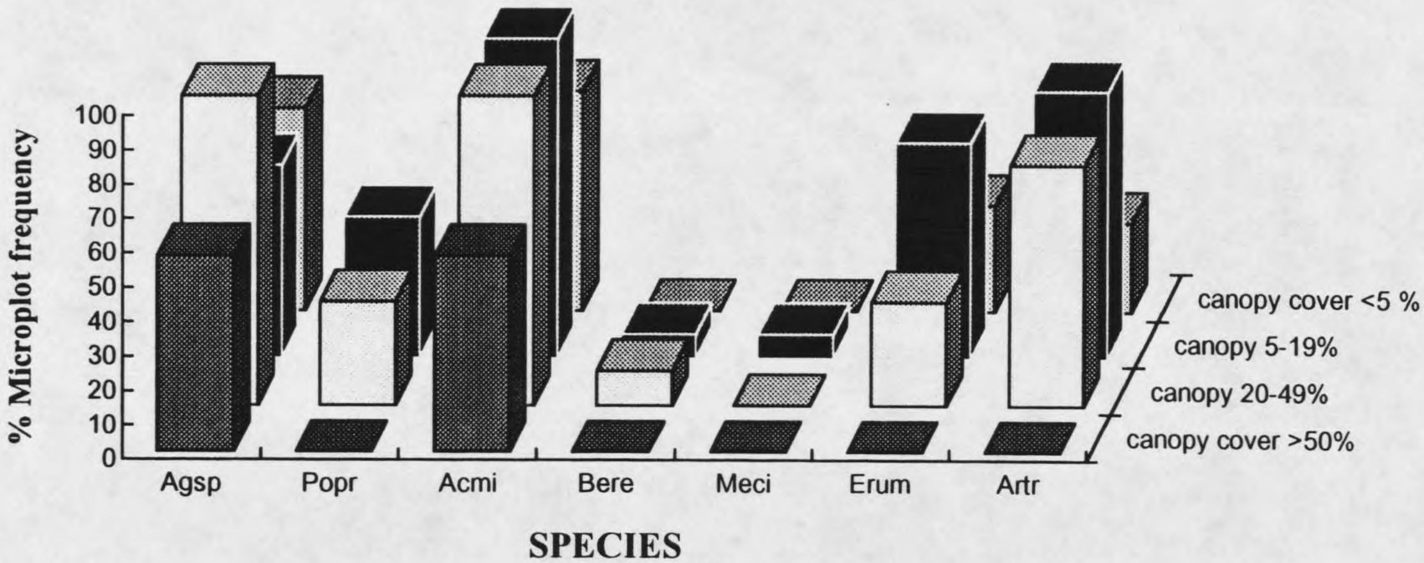

Figure 9. Frequency distribution graph for indicator species ,*Agropyron spicatum* (Agsp), *Poa pratensis* (Popr), *Achillea millifolium* (Acmi), *Berberis repens* (Bere), *Mertensia ciliata* (Meci), *Eriogonum umbellatum* (Erum), and *Artemisia tridentata*(Artr) , for grazing category D (horses and cattle, then sheep, then cattle), under four categories of tree canopy cover.

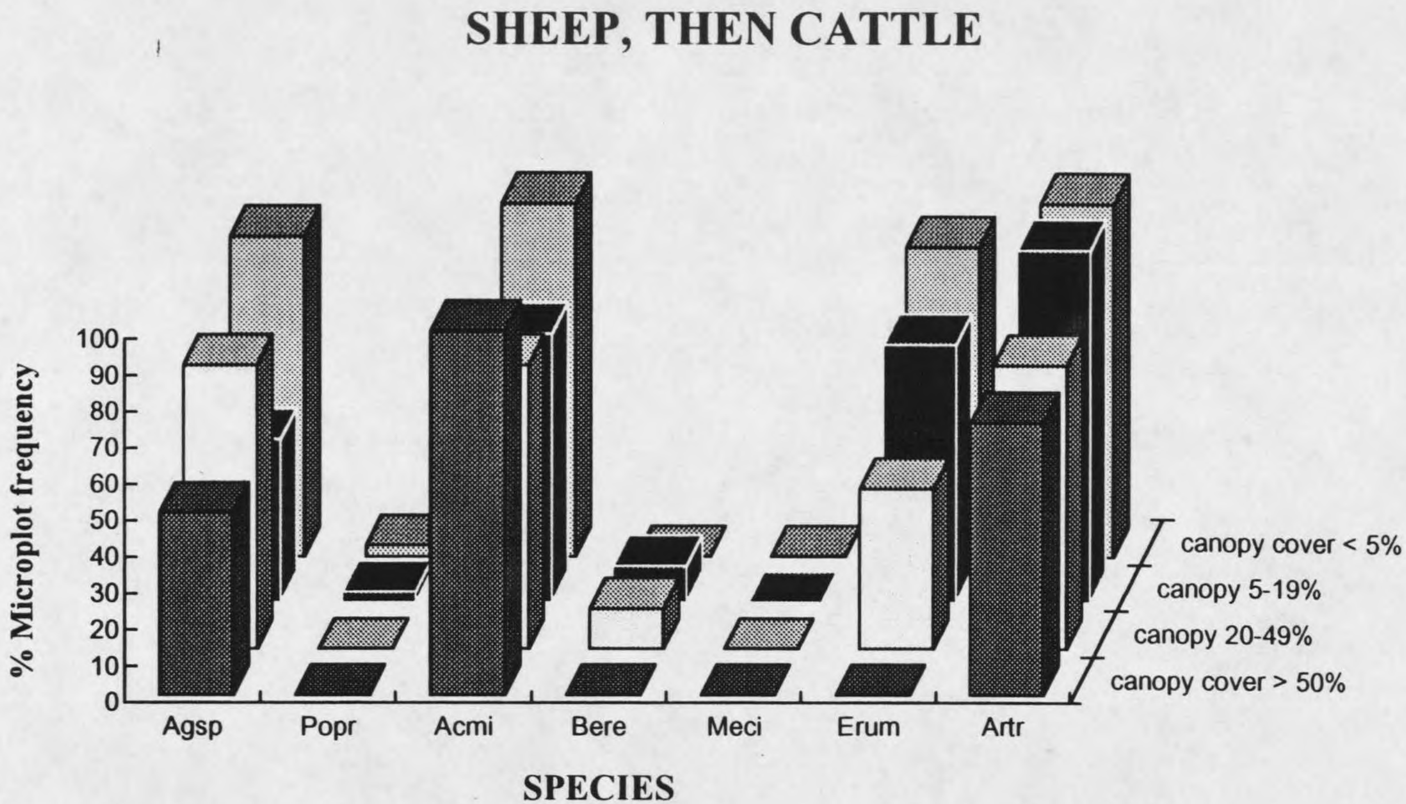

Figure 10. Frequency distribution graph for indicator species , *Agropyron spicatum* (Agsp), *Poa pratensis* (Popr), *Achillea millifolium* (Acmi), *Berberis repens* (Bere), *Mertensia ciliata* (Meci), *Eriogonum umbellatum* (Erum), and *Artemisia tridentata*(Artr), for grazing category E (sheep, then cattle), under four categories of tree canopy cover.

Percent canopy categories used in the frequency graphs consisted of 1) canopy cover greater than 50 percent (heavy canopy), 2) canopy cover between 49 and 20 percent (intermediate canopy cover), 3) canopy cover between 19 and five percent (low canopy cover), and 4) canopy cover less than five percent (no canopy cover).

Indicator species are usually found in habitats that have certain environmental characteristics. If these characteristics are present, a particular species would be expected to be found there. If an indicator species is absent, then the habitat it is adapted to is probably not yet a dominant habitat in that area. By using indicator species, general environmental characteristics and the effect of tree canopy on these species may be determined. Noninvaded areas act as pseudo-control sites for invaded areas, given different grazing histories (pseudo-control because there was no way to determine frequency of species prior to the introduction of livestock grazing of any kind). These categories may indicate what the composition of the understory species should be if trees had never invaded.

Agropyron spicatum, or bluebunch wheatgrass, was often found in relatively high frequency regardless of tree canopy coverage. This indicates that this species was not affected by tree canopy changes that accompanied tree invasion. It has been shown previously that this species can grow in a variety of environments, from open areas to areas with partial shade (United States Department of Agriculture 1989). Its frequency may have been affected by grazing practices. This plant was found at its highest frequency in noninvaded areas that had not been grazed for 15 to 35 years (grazing category A) and had been grazed by sheep, then by cattle (grazing category E). Bluebunch wheatgrass is very good to excellent forage for cattle, horses, and sheep. It is, in fact, a key species on many western ranges (United States Department of Agriculture 1989).

In three of the five grazing categories (A, areas not grazed by livestock for 15-35 years, C), areas grazed by horses and cattle, then by cattle, and E), areas grazed by sheep and then cattle), *Poa pratensis,* Kentucky bluegrass, was found most frequently in areas with canopy cover less than five percent. Of 139 microplots in these grazing categories with canopy cover over five percent, bluegrass was only found in 53 (38 percent). These results are contrary to the United States Department of Agriculture (1989) description of Kentucky bluegrass as an indicator of an environment with adequate soil moisture. The relatively low frequency of this species in sites with higher canopy cover may indicate that moist soil conditions were not especially prevalent. In other words, for the three grazing categories, tree invasion, and the resultant increase in canopy cover, may not have been enough to influence a shift in the distribution of bluegrass at this time. In contrast, in grazing category, B (areas grazed by cattle), Kentucky bluegrass was found most frequently in areas with high canopy cover (greater than 50 percent). In grazing category D (areas grazed by horses and cattle, then sheep, then cattle), this species was found most frequently in areas with low canopy cover (canopy between 19 and five percent). Soil moisture may be more adequate in these two areas to support Kentucky bluegrass. Palatability of this grass is good for all livestock types and is often a preferred forage plant (United States Department of Agriculture 1989).

Achillea millefolium, or Western yarrow, is drought resistant and is a good indicator of environments exposed to full sunlight (Yager et. al. 1987; United States Department of Agriculture 1989). This species was found in 145 of 153 microplots (95 percent) with no canopy cover in grazing categories A, B, C, and E. In grazing category D, yarrow was most frequently found in areas with canopy cover between five and 49 percent (35 microplots out of 37). It appears that increases in tree canopy cover influences this species, but not until the tree canopy reaches 50 percent or higher.

High frequencies of yarrow are often a sign of either current or historic disturbance (United States Department of Agriculture 1989). Yarrow's presence in high frequencies throughout the microplots with less than 50 percent canopy cover may indicate disturbance. Wyckoff and Hansen (1991) found that widespread overgrazing had occurred historically throughout the valley. This overgrazing may have been the disturbance factor that induced the presence of yarrow. The palatability of yarrow is low, (Yager et. al. 1987; United States Department of Agriculture 1989) so a high frequency of this species throughout the study area may potentially decrease forage value for livestock.

Berberis repens, Oregon grape, was found most frequently in areas with canopy cover between 49 and five percent in grazing categories A (no grazing by livestock for 15-35 years), B (areas grazed by cattle), D (areas grazed by horses and cattle, then sheep, then cattle), and E (areas grazed by sheep) . Even though frequency for this species was highest in areas with intermediate tree canopy cover, Oregon-grape was not frequent in any grazing group. Because Oregon-grape prefers shaded areas to areas of full sunlight (United States Department of Agriculture 1989) this low frequency may mean that canopy in the invasion ecotone may not be dense enough to support a habitat conducive to frequent Oregon-grape. Although infrequent, this species appears in all grazing groups. While tree canopy may not currently provide enough shade to support abundant frequencies of Oregon-grape, it is adequate to support scattered individuals. This species is unpalatable to livestock, (United States Department of Agriculture 1989) but since it occurs in such low frequencies, the forage quality of the study area probably has not been substantially decreased.

The frequency of *Mertensia ciliata*, mountain bluebells, was very low, but it did occur in its highest frequency in areas with high canopy cover. It was found in only 16 of the 244 combined microplots (seven percent) with canopy between five and 100 percent. The low frequency of this species may be due to lack of adequate shade and soil moisture in the invasion ecotone, as mountain bluebells, *Mertensia ciliata,* are indicative of moist, shaded conditions (United States Department of Agriculture 1989). Again, it appears that the level of canopy cover has not increased to the point where a habitat adequate for this shade-preferring species has resulted.

In three of the five grazing groups (B), areas grazed by cattle, C), areas grazed by horses and cattle, then cattle, and E), areas grazed by sheep, then cattle) sulphur eriogonum , *Eriogonum umbellatum*, was found most frequently in areas with no canopy cover. In the other two grazing categories (A), areas with no grazing by livestock for 15-35 years, and D), areas grazed by horses and cattle, then sheep, then cattle) it was found in relatively high frequency in all canopy cover classes. Sulphur eriogonum prefers open sites over shaded sites, tending to be scattered and seldom grow in large stands (Yager et. al. 1987; United States Department of Agriculture 1989). The high frequency of this species, even in areas with high canopy cover, may be due to light penetration between the trees. This species, like the others that are adapted to open conditions, appears to not yet be affected by the increase in canopy cover. As the canopy cover of the invading trees increases, this sunlight adapted species may find it harder to grow. Palatability of this plant is low but because it does not grow in large stands its threat to forage quality is currently quite low.

Artemisia tridentata, or big sagebrush, often occurs in dense stands in open areas (United States Department of Agriculture 1989). In three of the five grazing categories (B), areas grazed by cattle, C), areas grazed by horses and cattle, then cattle, and E), areas grazed by sheep, then cattle) sagebrush occurred most frequently in open conditions with no canopy cover. In these grazing categories big sagebrush occurred in

107 of 115 microplots (93 percent) that had no canopy cover.

In grazing categories A (no grazing by livestock for 15-35 years) and D (areas grazed by horses and cattle, then sheep, then cattle) , sagebrush occurred in areas with canopy of greater than five percent. In grazing category A, sagebrush was most frequent in areas with canopy greater than 49 percent. In grazing category D, sagebrush was found most frequently in areas with intermediate canopy (five to 49 percent). This species was found in 22 of the 37 microplots with intermediate canopy cover. In these grazing categories, the environmental conditions may support the growth of big sagebrush, but not as abundantly as in areas with more open conditions.

Abundance of this species may indicate current or historical overgrazing (United States Department of Agriculture 1989). The relatively high frequency of this shrub may indicate that these areas were overgrazed in the past. If this is the case, overgrazing may have influenced frequency of sagebrush more than does tree invasion.

CHAPTER 4

CONCLUSIONS

Tree Invasion

The hypothesis of this study was that tree invasion would have a measurable effect on life form and species composition of understory vegetation in areas grazed by domestic livestock. Analysis of the data indicated that tree invasion, and increases in canopy cover associated with that invasion, have not had a measurable effect on life form composition of the understory. There were no significant differences between understory vegetative cover in invaded and noninvaded areas. Average percent cover of grasses, forbs, and shrubs, were not significantly altered by tree invasion. In many invaded areas where trees are encroaching on grass-shrub communities, the trees are scattered with areas of undisturbed understory between them. It may be that the trees affect only the vegetated areas immediately surrounding them. Arnold (1964) found that trees have the greatest influence on the understory directly beneath their canopy. The effects of the invading trees on the vegetation in between may be too small to detect. If tree invasion continues, and tree canopy increases, the changes between invaded and noninvaded areas may become large enough to measure a significant difference.

No significant relationships were found between the percentage of tree canopy cover and understory life form cover, within the grazing category. This lack of relationship may be due to the small, immediate area influenced by an invading tree.

Percentage canopy cover in these areas may not be enough yet to significantly affect vegetation cover. The tree invasion occurring along the west slope of the Madison Valley appears to affect vegetative species frequency in the understory. The results show that some species were more frequently found in open areas, and as canopy increased, other species became more frequent. Tree invasion, and the resultant increase in tree canopy cover, is apparently measurably changing plant species frequency in the understory. Different plants, rather than life forms as a whole, reacted differently to increases in canopy.

Livestock Grazing

Tree invasion within different grazing categories in the valley appears to have had a limited effect on understory composition. Generally, results of the data analysis indicate that the areas that had not been grazed in over 15 years, (grazing category A), were not significantly different from the areas currently being grazed. It may be that grazing by wild ungulates, primarily elk and deer, have "blurred" the effects of domestic livestock grazing. Large numbers of wildlife grazing large areas may erase much of the evidence of differences between domestic livestock grazing categories.

Uneven grazing pressure by domestic livestock may also have resulted in limited grazing effects on understory composition in areas invaded by trees. Grazing is a selective process (Sampson 1952; Stoddard and Smith 1955). Different livestock species prefer certain vegetation life forms over others (Stoddard and Smith 1955). If a plant species grows in one area, and not in another, animals that prefer that species may concentrate their grazing efforts in areas where the preferred species grows. Tree invasion and grazing by domestic livestock may not be taking place in the same area. During the two field seasons of the study, few domestic animals were observed in the study area.

Tree invasion along the western slopes of the Madison Range, at present, appears to pose a limited threat to the sustainability of the area's grazing resources. If invasion continues, however, or if trees begin to encroach on sites presently providing the best forage to the area's livestock, the grazing resource may begin to decline. If invasion begins to detrimentally affect the grazing resource, management steps, such as prescribed burning of the invading trees or grazing practices designed to limit invasion, may have to be implemented.

Implications

The study in the Madison Valley showed that, contrary to other studies (Pieper 1990; Schott and Pieper 1985; Patten 1969; McConnell and Smith 1965), tree invasion in this area does not appear to have a significant effect on the life form composition of the understory. In addition, changes in species frequency, brought about by tree invasion, are evident but appear to be quite localized. These frequency changes also appear to vary by grazing category.

This study serves to show that tree invasion does not always alter understory composition in a dramatic way. Understory species may have changed, and may continue to do so as invasion continues and the invading trees mature.

Suggestions for Future Studies

As the trees involved in the invasion of the Madison Range continue to mature, future research projects may provide insight into the effects of older trees on the understory. Mature trees with larger canopies will probably have a different affect on understory species composition than the smaller trees studied during this research.

Production of the understory in areas invaded by trees has not been studied in this area. By clipping and dry-weighing individual species in invaded areas directly under tree canopy and in areas without tree invasion, the change in production could be accurately measured and compared. By studying the effects of increases in tree canopy on the production of various important forage plants, long term range quality trends and sustainability of the grazing resource may be determined.

Studies on biodiversity changes in invaded areas should also be continued. As environmental conditions continue to change in tree invaded areas, species in the understory should also continue to change. Sampling techniques designed to count plant species under varying tree canopy covers would be helpful in determining how tree canopy affects plant species biodiversity. Statistical analysis that would be less conservative and would adequately recognize the high variability in this changing landscape could improve the strength of such a field study. Increases, or decreases, in numbers of understory plant species may aid in understanding the long-term effects of tree invasion on understory species composition, and the effects of those changes on the domestic livestock grazing resources in the Madison Range.

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