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Aspen stand recruitment and ungulate impacts : Gardiner Ranger District Gardiner Montana

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Abstract

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Aspen Stand Recruitment and Ungulate Impacts: Gardiner Ranger District, Gardiner, Montana (84 pp.)

Director: Donald J. Bedunah

Cattle and wild ungulates, mainly elk (*Cervus elaphus*), are impacting aspen stands (*Populus tremuloides*), aspen stand recruitment, and understory vegetation composition on the Gardiner Ranger District, Gardiner, MT.

Ungulate impacts I examined included bole scars caused by bark stripping and browse hedging of aspen and shrubs. I found significantly less ungulate impacts in aspen scree communities than non-scree communities. Ungulate impacts to the aspen stands were significantly less within 500 m of main roads and human habitations than in stands greater than 500 m. Ungulate impacts were greater on non-allotment lands than on allotment lands.

I examined canopy coverage of grazing/trampling resistant species (*Poa pratensis, Phleum pratense, Calamagrostis rubescens,* and *Fragaria* spp.) and grazing/trampling sensitive species (*Heracleum lanatum, Epilobium angustifolium,* and *Thalictrum* spp.) in stands on allotment versus non-allotment lands. Allotment stands had significantly more resistant species and less sensitive species than non-allotment stands.

Canopy coverage of graminoids, forbs, and shrubs was compared between allotment and non-allotment lands. There was significantly greater graminoid canopy coverage in allotment versus non-allotment stands. There was significantly less forb canopy coverage in allotment compared to non-allotment stands. There was not a significant difference in shrub canopy coverage between allotment and non-allotment stands.

Aspen stand recruitment was calculated by dividing the number of stems over 2 m high with a dbh of less than 5 cm (e.g. large saplings) by the number of stems greater than 2 m high and greater than 5 cm dbh (e.g. pole and mature size). There was significantly greater recruitment within scree communities compared to non-scree communities. Aspen stands with higher ungulate impacts produced less recruitment than stands with lower ungulate impacts. There were more aspen stands with recruitment on non-allotment lands than on allotments. Cattle grazing appears to further reduce recruitment stem production on allotment lands. Finally, aspen stands within 500 m of main roads and human habitations had significantly greater recruitment than stands farther than 500 m.

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INTRODUCTION

Aspen (*Populus tremuloides*) stands supply livestock and wildlife forage, wildlife habitat, and are also important for aesthetic, recreation, and watershed values (DeByle 1978, 1985, DeByle and Winokur 1985, Reed 1971). The mosaic of colors, whether it is the subtle summer greens or the red and gold fall colors, are aesthetically pleasing. Recreationist are often attracted to the beauty and utility of aspen stands. Aspen stands are commonly associated with riparian areas, hence, can be important for hydrologic considerations.

When compared to conifer canopies, aspen canopies are relatively open. This open canopy increases the amount of sunlight reaching the forest floor resulting in greater forage and browse production. Livestock prize aspen stands for their forage resources and as shade during the hot season.

Aspen are also important to wildlife species. The multi-layered synusia associated with aspen stands, especially aspen-conifer mixes (Johns 1993), provide a diversity of niches. Aspen can provide important habitat for threatened and endangered species such as the grizzly bear (*Ursus arctos*). The diversity of forage classes produced in aspen stands make aspen a desirable vegetative cover. When compared to adjacent vegetation types, the graminoids, forbs, and browse are produced in abundance (DeByle and Winokur 1985, Mueggler 1988). Wildlife also utilize aspen for security cover and for thermal protection.

Aspen is the North American tree species with the widest distribution (Little 1971). However, in the northern Rocky Mountains of the United States aspen distribution is sporadic, with aspen typically occurring at the grass-shrubland and forest ecotone (Reed 1971). This sporadic distribution serves to underscore the value of

aspen. On suitable sites aspen can occur as a climax species (Fetherolf 1916, Baker 1925, Daubenmire 1943, Lynch 1955, Langeheim 1962, Morgan 1969, Reed 1971, Mueggler 1988), but primarily aspen occurs as a pioneer seral species (Stahelin 1943, Morgan 1969, Mueggler 1976) following fire (Stahelin 1943, Morgan 1969, Patton 1970, Bartos 1979, Bartos et al. 1981, 1982, DeByle 1985, DeByle et al. 1987), timber harvest (Sheilds 1981, Bartos 1982), or other disturbances. Even as a seral species aspen is often able to persist for lengthy periods of time until replaced by conifers or grass-shrublands (Morgan 1969) and can be classified as a long-term stable species (Morgan 1969, Mueggler 1988, Reed 1971). Three criteria can be used to differentiate between climax (or long-term stable) stands and seral stands (Kay 1990): 1) multiple age or size classes, 2) the understory species composition, and 3) if conifers are either absent or not prevalent enough to be considered reproducing successfully. The reproducing successfully criterion must be emphasized because conifers may also occur as incidentals.

Aspen can reproduce either through seed or vegetatively through root suckers. In the Intermountain West reproduction through seeding appears to be infrequent (Ellison 1943, Larsen 1944, Schier 1981), whereas sucker shoots are the primary means of reproduction (Baker 1918, Day 1944, Cottam 1954). Following the Yellowstone fires of 1988 numerous aspen seedlings were established, especially in burned riparian areas (Kay 1993). The unusual prolific seedling establishment in YNP followed an extended drought with extreme fire conditions. Kay (1993) states it is unlikely for these aspen seedlings to develop into clones because of spring flooding in the riparian areas, high levels of ungulate browsing, competition with lodgepole pine (*Pinus contorta*) seedlings, and because few existing clones are found in similar topographic locations.

An aspen stand can be a clone entirely composed of genetically identical ramets

originating from a single ortlet (Barnes 1966, Schier 1981). Theoretically, many of today's aspen clones originated at the close of the last ice age (Smith 1941, Schier 1981). Therefore, the aspen clones could be 8, 000 to 15, 000 years old (DeByle and Winokur 1985). Since individual aspen trees, whether ramet or ortlet, are relatively short lived, 80 to 200 years (Jones et al. 1986), clone longevity hinges on the ability of an aspen clone to replace itself.

A number of researchers have noted the progressive deterioration of aspen stands in the Intermountain West (Krebil 1972, Loope and Gruell 1973, Gruell and Loope 1974, Houston 1973). In Yellowstone National Park (YNP) alone, aspen canopy coverage has decreased from 5-6% to 2-3%, a reduction of 50% since the early 1900's (Houston 1982). The reasons for this reduction has been the topic of much controversy (Tyers 1981).

Some researchers attribute the cause of deteriorated aspen clones to excessive ungulate browsing (Kay 1984, 1985, 1987, 1990, 1993, Chase 1986, Skinner 1928, Smith et al. 1972). Kay (1990, 1994a, 1994b in press, 1995) and Kay and White (1994 in press) postulate the aspen decline is due to erupting elk populations as a consequence of the extirpation of the highly efficient GYE predator - aboriginal americans. According to Kay (1995c) the loss of aspens and willows by overgrazing ungulates has led to the extirpation of beaver in YNP from most of their former range. Consequentially, this loss of beaver in YNP and has resulted in extensive reduction of suitable sites for aspen and willow establishment.

Others attribute the cause of aspen decline to fire suppression, climatic changes, natural succession, and natural processes (Cole 1971, Houston 1973, 1982, Gruell 1980, Despain 1986). Despain (1990) suggests the YNP aspen clones survive in a hedged shrub form or perenial herb form until optimal conditions allow the suckers to grow above browsing height. Despain (1990) also suggests initial browsing is

necessary for the suckers to produce toxins which inhibit further browsing, and that the scars formed from bark scrapping protect the ramet from additional browsing. The 1988 Yellowstone fires provided an oportunity to test the fire suppression hypothesis. As of 1995 new clones have not successfully established nor old clones regenerated (Kay 1993). Aspen regeneration has also been unsuccessful following fires in western Wyoming where ungulate use is high (Bartos et al. 1991).

Other researchers favor genetic variability and susceptibility to aging, reduced reproductive capabilities, pathogens, or viral infections as a possible explanation for deteriorating clones (Schier 1975, Mueggler 1976, Schier and Campbell 1980). Cryer and Murray (1992) and Kay (1995a) suggest a decrease in soil pH as clones deteriorate produces less than favorable conditions for regeneration. Other studies fall some where in the middle of this continuum, assigning different weights and combinations to these causative factors (Loope and Gruell 1973, Gruell and Loope 1974, Mueggler and Bartos 1977, Schier 1975).

Whether responsible for the deterioration of aspen clones or not, ungulate use can also impact aspen understory species composition. Shrub canopy coverage can decrease under grazing pressure (Mueggler and Bartos 1977). Kay (1990) found a significant increase in the proportion of grass dominated aspen communities in YNP when compared to areas adjacent to YNP. The decrease in shrub and forb community types can potentially have undesirable effects on some wildlife species associated with aspen. Some forbs are less resistant to grazing and trampling damage than others e.g. *Heracleum lanatum, Epilobium angustifolium,* and *Thalictrum* spp. (Kay 1990). This can be evidenced by the paucity of these forbs in areas of relatively high ungulate use. Conversely, some plant species are more resistant to ungulate grazing and trampling than others e.g. *Poa pratensis, Phleum pratense, Calamagrostis rubescens,* and *Fragaria* spp. Species which are grazing and/or trampling resistant would be expected to

increase under relatively higher ungulate use.

If ungulate numbers are responsible for the decline in aspen coverage, the potential may exist for similar aspen coverage reductions and community changes on the Gardiner Ranger District (RD) as observed in YNP. In addition, cattle grazing could potentially have an additive effect thereby reducing aspen canopy coverage to an even greater extent. The Gallatin National Forest Plan mandates protection of wildlife habitat (for both game and non-game species with special emphasis on habitat for threatened and endangered species), hydrologic values, visual quality, and vegetation diversity in regards to species, age classes, and size classes. In addition, the Forest Service is a multiple use agency providing resources for a broad spectrum of forest users. Long term overutilization of vegetation resources can result in resource productivity declines in vegetation, livestock, and wildlife (Irwin et al. 1994). At present there aren't any quantitative data on historic aspen coverage on the GNF. Therefore this study was undertaken in conjunction with an aspen inventory providing baseline information for managing aspen on the Gardiner RD. Also, additional information is needed to help land managers understand the cause of aspen decline.

OBJECTIVES

The objectives of this study were to assess cattle and wild ungulate, mainly elk, impacts on aspen recruitment and aspen community composition on the western half of the Gardiner Ranger District, Gardiner, Montana.

The study objectives were addressed through the following hypothetical statements:

1) Ho: there was no significant difference in the proportion of aspen stands with low, moderate, or high ungulate impacts between major community types.

2) Ho: there was no significant difference in the proportion of aspen stands with low, moderate, or high ungulate impacts located within 500 m of main roads or human

habitations when compared to stands located greater than 500 m.

3) Ho: there was no significant difference in the proportion of aspen stands with low, moderate, or high ungulate impacts on allotment lands when compared to non-allotment lands.

4) Ho: there was no significant difference in the proportion of aspen grass community types located on allotments when compared to non-allotment lands.

5) Ho: there was no significant difference in the mean canopy coverage of grazing/trampling sensitive species (*Heracleum lanata, Epilobium angustifolium*, and *Thalictrum* spp.) in aspen stands located on allotments when compared to non-allotment lands.

6) Ho: there was no significant difference in the mean canopy coverage of grazing/trampling resistant species (*Poa pratensis, Phleum pratense, Calamagrostis rubescens*, and *Fragaria* spp.) in aspen stands located on allotments when compared to non-allotment lands.

7) Ho: there was no significant difference in the mean canopy coverage of graminoids, forb, and shrubs in aspen stands located on allotments when compared to non-allotment lands.

8) Ho: there was no significant difference in the proportion of aspen stands with recruitment between major community types.

9) Ho: there was no significant difference in the proportion of aspen stands with recruitment in the low, moderate, and high ungulate impact categories.

10) Ho: there was no significant difference in the proportion of allotment aspen stands with recruitment compared to non-allotment aspen stands.

11) Ho: there was no significant difference in proportion of aspen stands with recruitment located within 500 m of main roads or human habitation when compared to stands located greater than 500 m.

STUDY LOCATION

The study area was located on the western half of the Gardiner Ranger District, Gallatin National Forest. Included were portions of Bear Cr., Eagle Cr., Trail Cr., Basset Cr., Cedar Cr., Slip and Slide Cr., Joe Brown Cr., Six Mile Cr., Sphinx Cr., Cinnabar Basin and Tom Miner Basin which are under Forest Service jurisdiction (Fig. 1 & 2, in Appendix B).

Historically, the study area included fourteen cattle allotments and one sheep allotment. The sheep allotment did not include any of the aspen communities sampled in this study. Therefore, all livestock influences were associated with cattle. The fourteen cattle allotments provided 3,621 AUMs. These allotments are utilized June 16th through October 15th (Table 1, in Appendix A). During the last ten years the AUMs have gradually been reduced, either through non-use, discontinued use, or stocking rate reductions, to the present level of 2,867 AUMs.

Potential wild ungulate impacts to the aspen stands were primarily caused by substantial populations of elk (*Cervus elaphus*). Elk populations have been increasing since the 1970s. Current aerial census counts for elk on the study area indicate an approximate average of 4,000 head during the winter months of December through March (Fig. 3, in Appendix A). Mule deer (*Odocoileus hemionus*) will occasionly utilize aspen. Aerial census counts indicate an increase in mule deer numbers with an estimated population of 2,250 head (Fig. 4, in Appendix A). Moose (*Alces alces*) will readily browse aspen during certain times of the year (Peek 1963, Miquelle 1989). Moose numbers are not sufficient in the study area to impact the aspen stands as much as the elk.

Small populations of whitetail deer (*Odocoileus virginianus),* pronghorn antelope (*Antilocapra americana),* bison (*Bison bison*), and bighorn sheep (*Ovis canadensis*) also inhabit localized areas on the study area. However, the impact of

these species on the aspen clones is considered minimal.

METHODS

The study objectives were met by comparing ungulate impacts, aspen community type (Mueggler 1988) composition, and aspen recruitment within the aspen communities located on Forest Service allotment and non-allotment lands. I separately classified aspen community types unique to the Gardiner area, which did not meet Mueggler's classification, or which merited a separate classification for management consideration. Aspen community types were considered to be a major community type if they were represented by ten or more stands sampled. I determined possible wild ungulate impacts by examining aspen recruitment and ungulate damage to the stands as a function of community type and distance from main roads or human habitations. Infrequently traveled roads such as logging roads, jeep trails, or "two tracks" were not considered to be main roads. Ungulate impacts were calculated as the sum of: 1) the severity of bole scars (caused by ungulate bark stripping (Figs. 5,6 & 7, in Appendix C), 2) the extent of the bole scaring activity (less than one third of the trees scarred = 1, between one third and two thirds of the trees scarred = 2, and more than two thirds of the trees scarred = 3), and 3) the severity of browse hedging (Peek 1981)(Fig 8, in Appendix C).

Heavy ungulate use can result in a decrease in species sensitive to grazing and trampling pressure, especially perennial forbs and shrubs, and a concurrent increase in grazing resistant species, especially graminoids (Kay 1990, Smith et al. 1972). I assessed the potentially additive effect of cattle grazing causing vegetation composition changes by examining 1) mean canopy coverage of graminoids, forbs, and shrubs, 2) mean canopy coverage of grazing/trampling sensitive, and 3) mean canopy coverage of grazing/trampling resistant species. I compared occurrence and canopy coverage of

Heracleum lanatum, Epilobium angustifolium, and *Thalictrum* spp. in aspen stands located on allotment lands compared to non-allotment lands. These species are palatable and/or sensitive to trampling by ungulates. I compared occurrence and mean canopy coverage of several grazing and/or trampling resistant species (*Poa pratensis, Phleum pratense, Calamagrostis rubescens,* and *Fragaria* spp.) in aspen communities located on allotment lands compared to non-allotment lands. In addition, these species were selected as a comparison or supplement to Kay's (1990) study comparing these species in YNP and surrounding areas. I did not differentiate between changes caused by grazing or by trampling.

Aspen recruitment was assessed by counting aspen recruitment stems and non-recruitment stems within the sample plots. Recruitment stems are defined as aspen stems which are less than 5 cm diameter at breast height (dbh) and greater than 2 m in height (e.g. 2 m high saplings). Non-recruitment stems are defined as aspen stems which are greater than 5 cm dbh and taller than 2 m (e.g. pole and mature aspen). It has been suggested that aspen suckers which reach a height of 2 m are tall enough to survive most browsing of the terminal leader (Kay 1984, 1985, 1990). Kay suggests if the number of recruitment stems is less than the number of non-recruitment stems the aspen stand is not replacing itself. The lack of sufficient recruitment stems will, if conditions are unchanged, eventually result in the demise of that stand. For the purpose of this study this measure will be referred to as "Kay's criterion".

In order to get a more complete picture of aspen recruitment, I further refined Kay's criterion by classifying the fraction of recruitment stems/non-recruitment stems into four groups: recruitment = 0; 0 < recruitment <= .5; .5 < recruitment <= 1; and recruitment > 1. These categories were abbreviated as follows: (rec = 0), (0 < rec <.5), (.5 <= rec <1), and (rec => 1). This refined classification was referred to as "recruitment stem production criterion". In addition to being a recruitment indicator, the data

collected will also serve as a relative comparison/supplement to Kay's (1984, 1985, 1990) studies. I stress relative comparison because the methods employed by Kay were different than this study, i.e. a systematic belt transect versus a representative circular plot. Unfortunately, Kay's 1990 study was not completed when this study was initiated.

Stand selection

The aspen communities within the inventory area were delineated on 1:15,840 aerial photos. Stands observed in the field, yet undetected on the aerial photos, were delineated on aerial photos while in the field. Stands too small to be delineated on the aerial photographs were marked with an X at the approximate location. An "aspen stand" was defined using Kay's (1984) definition: any aspen tree, or group of aspen, more than 30 m from any other aspen; large continuous groups of aspen (potentially consisting of more than one aspen clone) were recorded as only one stand.

I used a systematic sampling method to sample approximately 25% of the aspen stands. The study area was partitioned into main stream drainages. As I proceeded through the drainages I sampled every fourth aspen community. However, when I encountered aspen community types which occurred infrequently, e.g. scree community types or aspen/serviceberry (*Populus tremuloides/Amelanchier alnifolia*) community types, or aspen community types which occurred in unique conditions, I sampled these community types in order that these community types would be represented in the study and to achieve an effective sample size for that community type. Aspen community types were considered to be a major community type if they were represented by ten or more stands sampled.

Plot selection and measurement

Aspen stands vary tremendously in size and shape. Initial sampling showed a 0.05 acre plot to be the most feasible size. Larger plots often included ecotones,

exceeded the stand boundaries, and/or included so many aspen stems that counting would have been unfeasible and prone to error. After selecting a stand I established a 0.05 acre circular plot that was representative of the stand conditions. The perimeter of the plot was marked with flagging and two tapes divided the plot into quadrants. Dividing the plot into quadrants aided in estimating canopy coverage.

After locating the plot, the following environmental parameters were recorded: elevation (from a topographic map); aspect (using a compass); slope (using a clinometer); and physiographic position (from USDA FS Ecodata handbook). The plot was photographed before sampling altered the plot appearance. The plant species and ocular canopy coverage estimates were recorded. Canopy coverage was determined by ocular estimation and recorded using USDA FS Ecodata methods (Ecosystem Classification Handbook FSH 12/87 R-1 SUPP 1, p. 4.53--3)(Table 2, in Appendix A).

After completing the species list and canopy coverage, the structural stage, cover type (Matteson and Despain 1985), community type, stand physiognomy, and habitat type (Pfister et al. 1977) were determined. Under certain conditions aspen can be long-term stable seral communities. In such communities determining the habitat type was tentative. In such cases, adjacent areas with similar environmental attributes were used to extrapolate the habitat type.

The presence of conifers successfully reproducing was recorded. Stands with conifers occurring as incidentals were recorded as not reproducing successfully. Aspen stands with conifers occurring as incidentals or having a multi-aged stand structure were considered to be long-term stable seral communities or climax communities. The canopy coverages of mature, pole, sapling, and seedling aspen were recorded.

The number of recruitment stems (stems greater than 2 m and less than 5 cm dbh) and non-recruitment stems (greater than 2 m and greater than 5 cm dbh) were counted. This data was used as an indicator of stand recruitment success as

previously described.

Data analysis

Data were managed using dBase IV data base management system (DBMS). Using this DBMS allowed me to integrate the data into the Forest Service Ecodata program, do the appropriate statistical analysis with SYSTAT, and use GRASS and ARCINFO Geographic Information System (GIS) for spatial analysis and presentation of my data.

The statistical test methods I used to test the null hypothesis were as follows:

i. Chi square: Pearson Chi square

1) Ho: there was no significant difference in the proportion of allotment aspen stands with recruitment compared to non-allotment aspen stands.

2) Ho: there was no significant difference in the proportion of aspen grass community types located on allotments when compared to non-allotment lands.

3) Ho: there was no significant difference in the proportion of aspen stands with recruitment between major community types.

4) Ho: there was no significant difference in the proportion of aspen stands with low, moderate, or high ungulate impacts between major community types.

5) Ho: there was no significant difference in the proportion of aspen stands with low, moderate, or high ungulate impacts on allotment lands when compared to non-allotment lands.

6) Ho: there was no significant difference in the proportion of aspen stands with recruitment located within 500 m of main roads or human habitation when compared to stands located greater than 500 m.

7) Ho: there was no significant difference in the proportion of aspen stands with low, moderate, or high ungulate impacts located within 500 m of main roads or human

habitations when compared to stands located greater than 500 m.

ii. t-tests on arcsine transformed data: pooled variance

1) Ho: there was no significant difference in the mean canopy coverage of grazing/trampling sensitive species (*Heracleum lanatum, Epilobium angustifolium*, and *Thalictrum* spp.) in aspen stands located on allotments when compared to non-allotment lands.

2) Ho: there was no significant difference in the mean canopy coverage of grazing/trampling resistant species (*Poa pratensis, Phleum pratense, Calamagrostis rubescens*, and *Fragaria* spp.) in aspen stands located on allotments when compared to non-allotment lands.

3) Ho: there was no significant difference in the mean canopy coverage of graminoids, forbs, and shrubs in aspen stands located on allotments when compared to non-allotment lands.

For the hypotheses addressing cattle impacts the plots analyzed were restricted to those stands which were accessible to cattle. Cattle accessible stands were considered to be those stands which occur on slopes less than 25 degrees (47%) (Mackie 1970) and without evident impediment to ungulate access, (e.g. scree community type). Although wild ungulates will browse aspen during various seasons the primary utilization seems to occur during the winter (Gruell and Loope 1974, Hobbs et al. 1981, Stevens 1970, Gaffney 1941, Krebil 1972). Therefore, when analyzing wild ungulate impacts the aspen stands located in snow accumulation area were not included in the analysis if inclusion would confound the analysis. Canopy coverages were transformed using an arcsine transformation of the midpoint of the canopy coverage class. For the rare cases in which the sum of the canopy coverages for the species being analyzed exceeded 100% (e.g. the sum of grazing/trampling resistant species) the sum of the canopy coverage was limited to 99% in order to permit

arcsine transformation. For determining a significant difference I utilized a probability level of 0.05.

Sources of variation

Any attempt to assign artificial categories to natural systems, which usually exist on a continuum and are highly variable, is difficult at best. Vegetation can vary with small changes in aspect, soils, available water, and season. I employed several techniques to limit some of this potential variation. To minimize observer variation, I was the sole observer determining canopy coverage, slope, elevation, aspect, and community type thus eliminating bias between observers. Personnel assisting on the inventory were used for counting stems and aid in equipment transport.

Vegetation canopy coverage can change dramatically through the growing season. By selecting indicator species which were prominent and less ephemeral than others, and by relying on my previous four field seasons on the same area, I limited this source of variation. The use of relatively broad canopy coverage classes also increased the precision of ocular estimates.

RESULTS

CHAPTER I: Ungulate Impacts

I. Ungulate impacts on major aspen community types

Ungulate impacts and community type were not independent (chi sq. = 70.1, df = 24, p < .000) (Table 3, in Appendix A) (Fig. 9 & 10). POTR/SCREE c.t.s and POTR-PSME/SCREE c.t.s were impacted significantly less than other community types. All POTR/SCREE c.t.s and 85% of the POTR-PSME/SCREE c.t.s were classified as having low ungulate impact.

POTR/TALL FORB and POTR/ARTR c.t.s had higher proportions of stands with high ungulate impacts than the other community types. For these

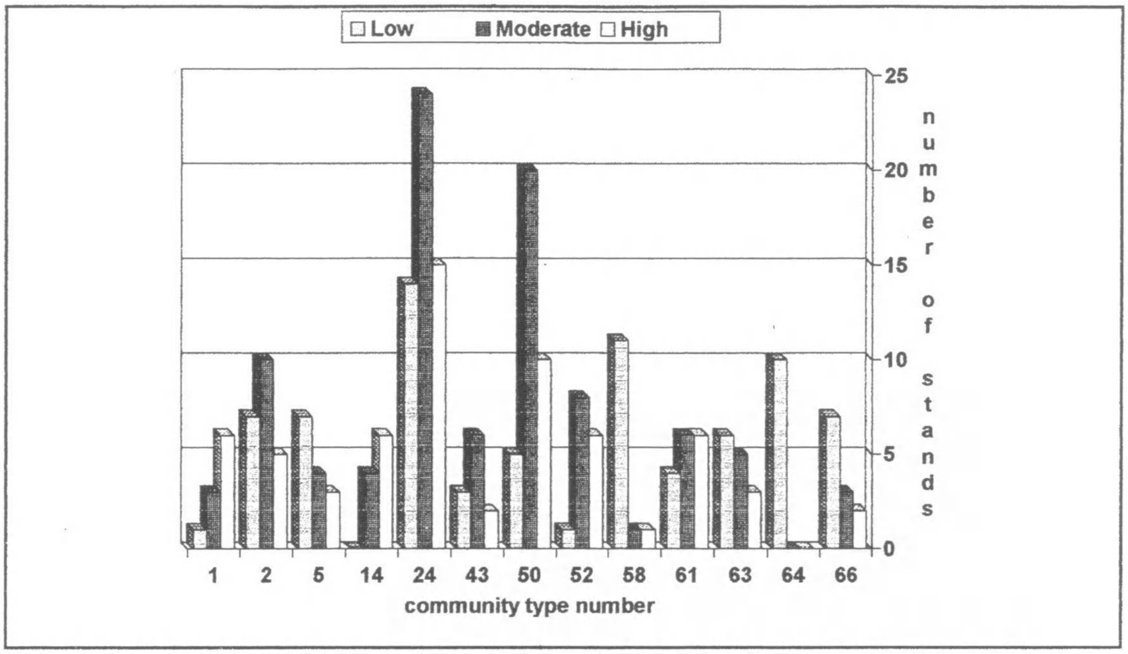

Fig. 9. Number of aspen stands in the major aspen community types with high, moderate, and low ungulate impacts (X^2=70.06, p<.000) Gardiner RD, Gardiner, MT.

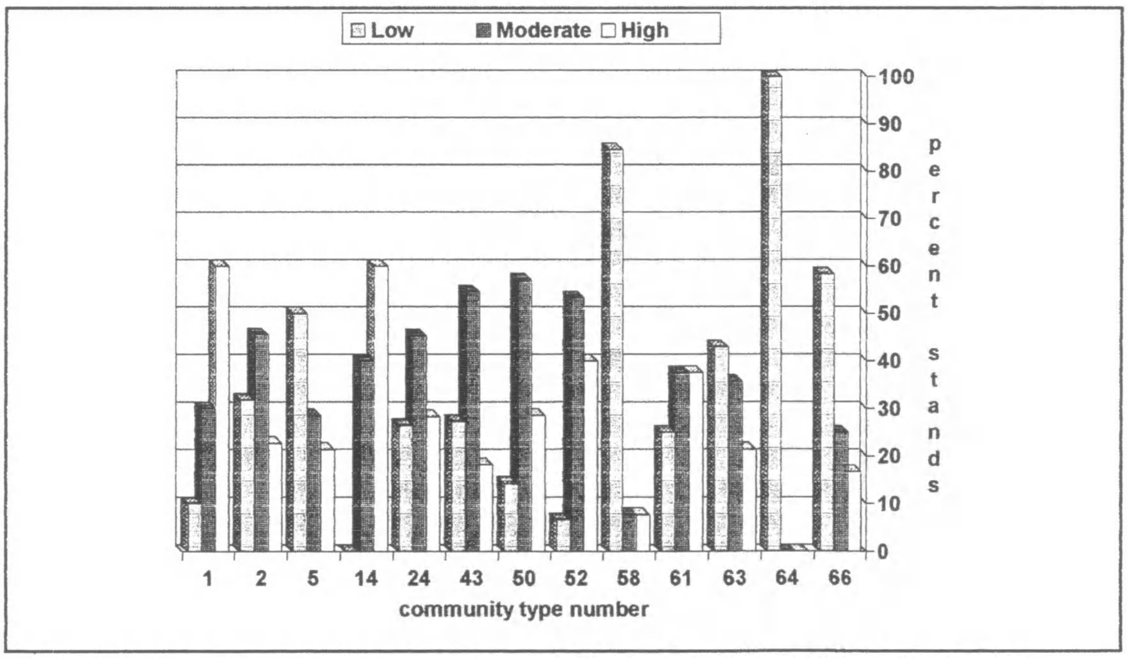

Fig. 10. Percent of stands in the major community types with low, moderate, and high ungulate impacts (X^2=70.06, p<.000). Gardiner RD, Gardiner, MT.

[1] Community type numbers Appendix A, Table 4

community types 60% were in the high ungulate impact category, compared to an overall community average of 31% in the high category.

When the major community types were grouped into either scree or non-scree community types I found a significant difference (chi sq. = 40.5, df = 2, p < .000) in the proportions of aspen stands in the ungulate impact categories (Table 5, in Appendix A) (Fig. 11 & 12). Of the scree communities, 91% of the stands had low ungulate impacts compared to only 26% of the non-scree communities.

II. Ungulate impacts and distance from major roads or human habitations

This analysis considered all aspen stands except those stands located in snow accumulation areas and scree community types. Limited access in these stands would restrict most ungulate use thereby confounding the analysis. Ungulate impact on aspen stands as a function of distance from main roads or human habitations was not independent (chi-sq. = 10.1, df = 2, p < .007) (Table 6, in Appendix A) (Fig. 13 & 14). Aspen stands located within 500 m of main roads or human habitations had a higher proportion of stands with low ungulate impacts, 31%, as compared to 17% for aspen stands located greater than 500 m. Whereas, aspen stands located greater than 500 m from main roads or human habitations had a higher proportion of stands with moderate ungulate impacts, 48%, compared to 31% for aspen stands located less than 500 m. The proportion of aspen stands with high ungulate impacts was similar for stands less than and for stands greater than 500 m, 39% and 35% respectively.

III. Ungulate impacts on allotment versus non-allotment lands

In order to confine the analysis to aspen stands accessible to cattle, scree community types and aspen stands on slopes greater than 47% were excluded from the analysis. I concluded that location, i.e. allotment or non-allotment, and ungulate impact category were not independent (chi sq. = 10.3, df = 2, p < .006) (Table 7, in Appendix A) (Fig. 15 & 16). The proportions of aspen stands in the low ungulate

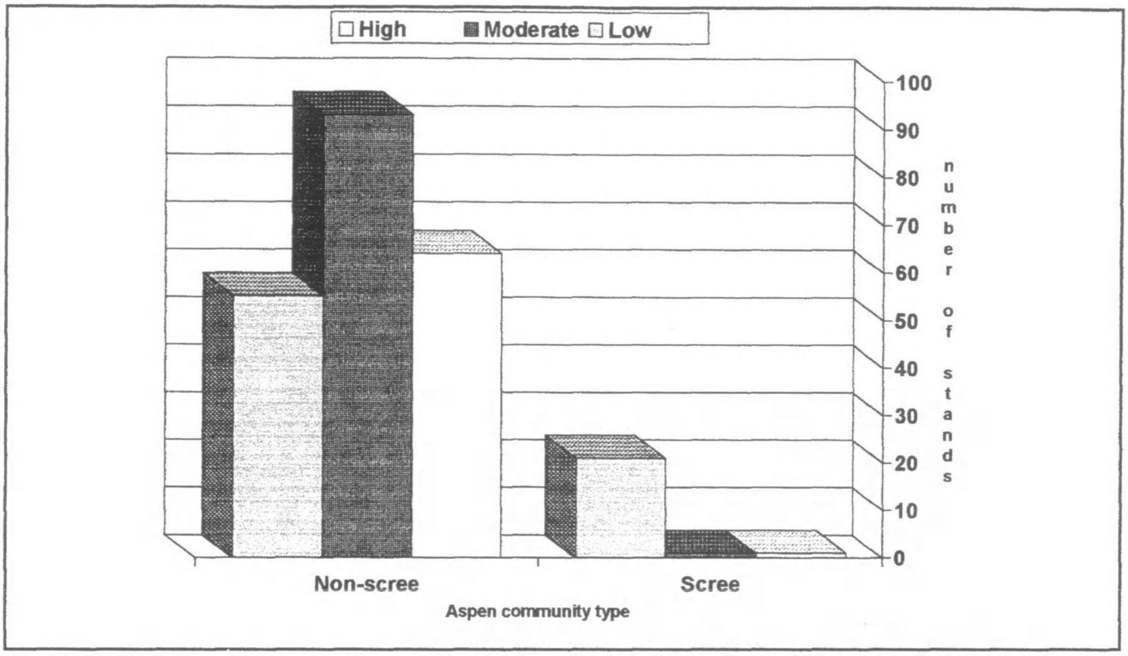

Fig. 11. Number of aspen scree and non-scree stands in the low, moderate, and high ungulate impact categories (X^2=40.56, p<.000). Gardiner RD, Gardiner, Mt.

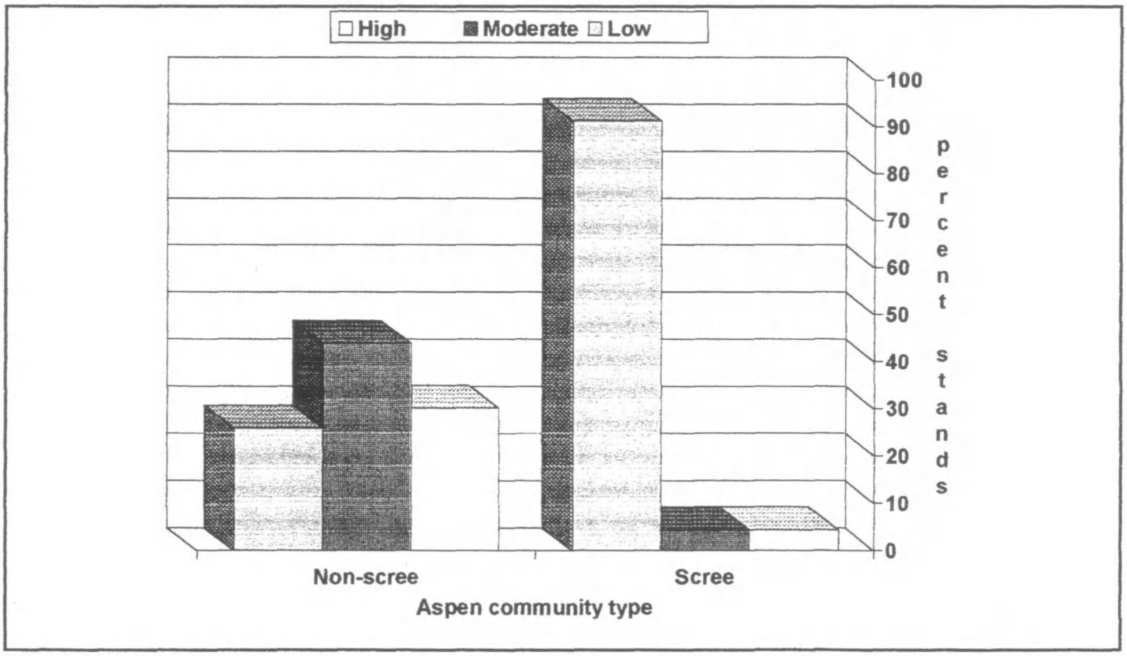

Fig. 12. Percent scree and non-scree aspen stands in the low, moderate, and high ungulate impact categories (X^2=40.56, p<.000). Gardiner RD, Gardiner, MT.

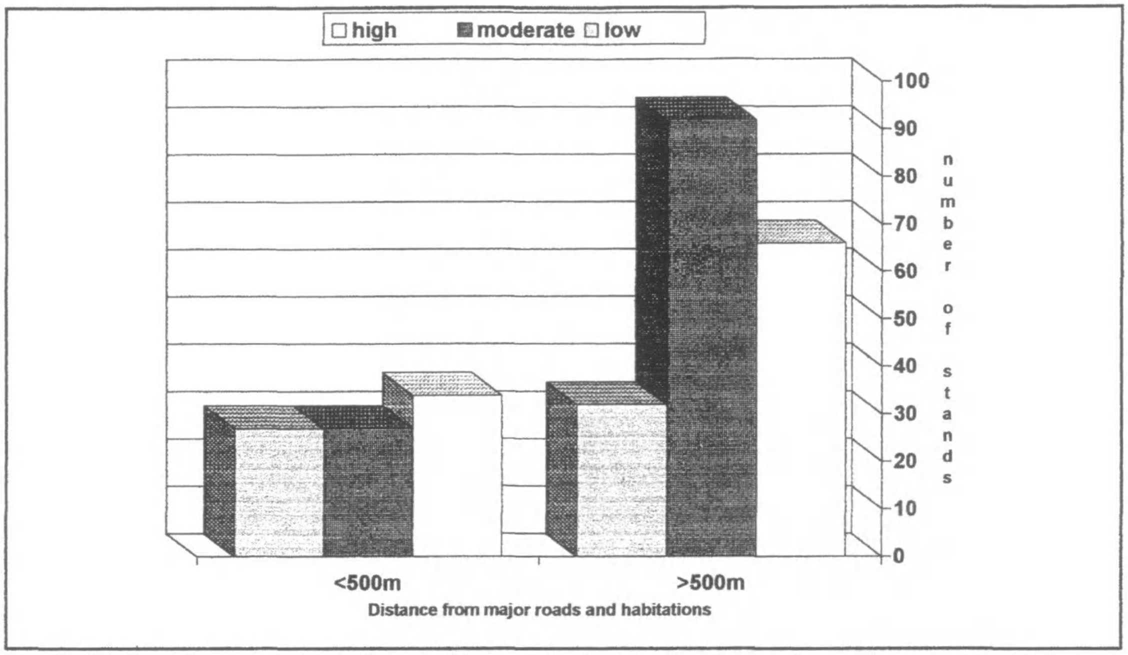

Fig. 13. Number of aspen stands in the ungulate impact categories by distance from main roads or habitations (X^2=10.10, p<.006). Gardiner RD, Gardiner, MT.

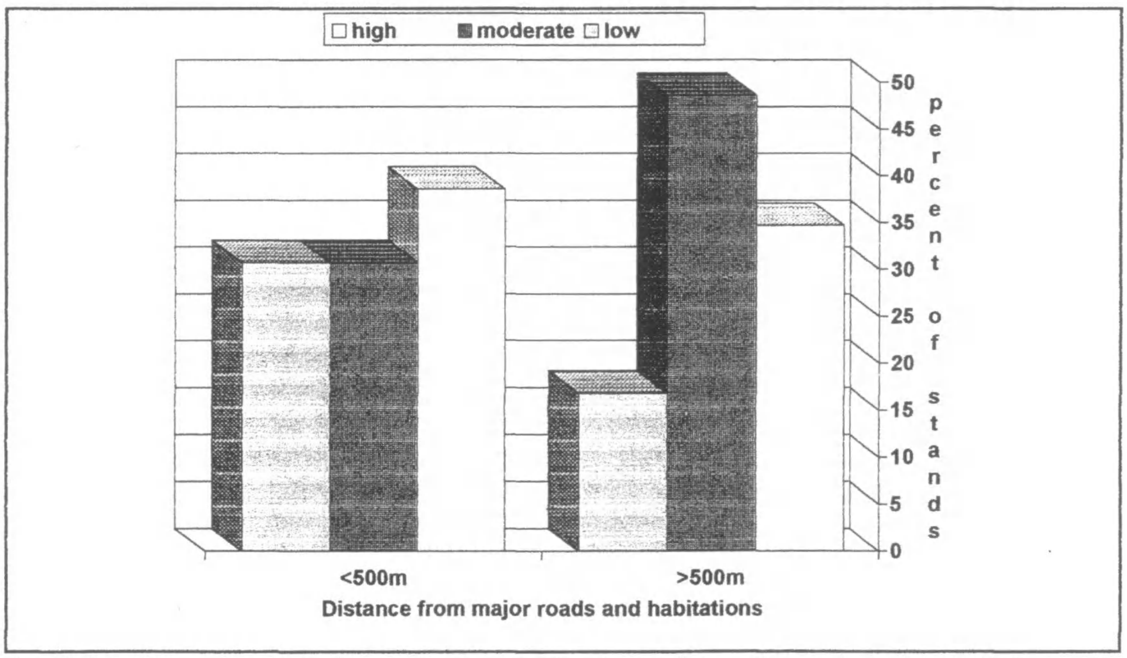

Fig. 14. Percent aspen stands in the ungulate impact categories by distance from main roads or habitations (X^2=10.10, p<.006). Gardiner RD, Gardiner, MT.

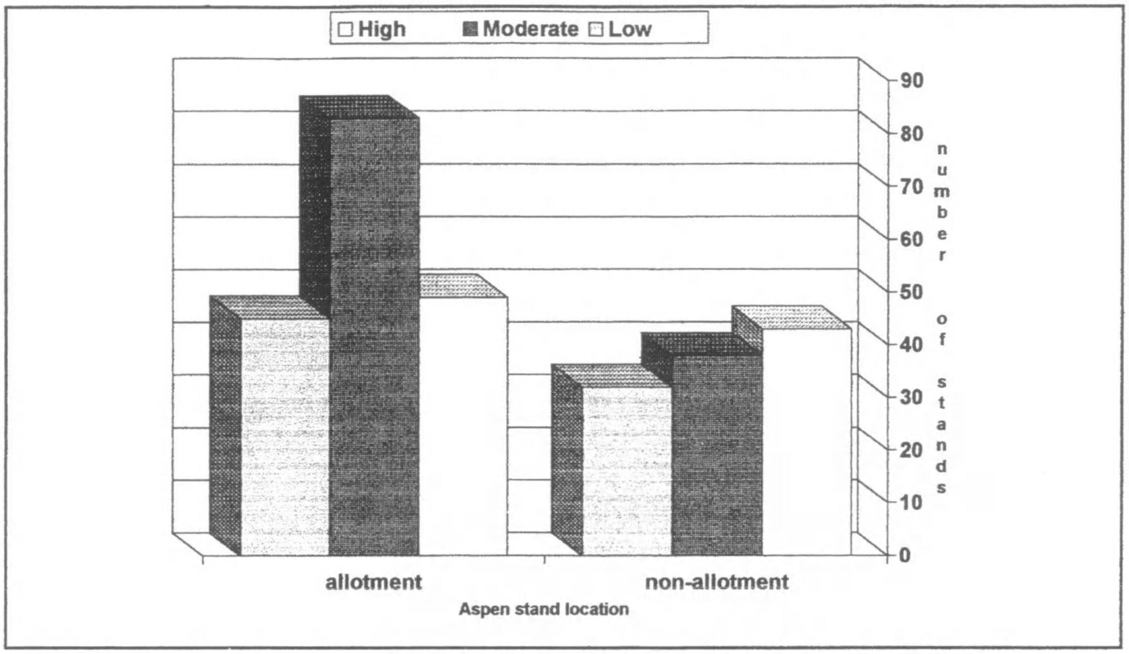

Fig. 15. Number of aspen stands in the ungulate impact categories on allotment versus non-allotment lands (X^2=10.33, p<.006). Gardiner RD, Gardiner, MT.

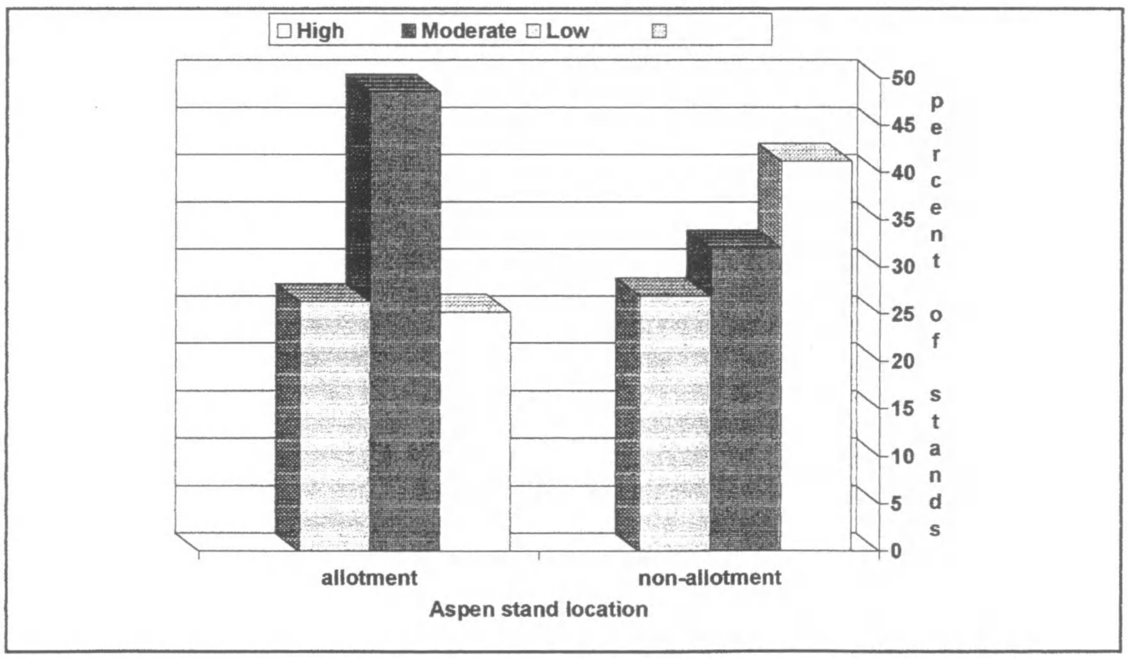

Fig. 16. Percent aspen stands in the ungulate impact categories on allotment versus non-allotment lands (X^2=10.33, p<.006). Gardiner RD, Gardiner, MT.

impact category was the same for allotment and non-allotment lands, 26%. However, for the moderate ungulate impact category there was a significantly greater proportion of aspen stands on allotment lands, averaging 49% and 32% respectively. And aspen stands on non-allotment lands had a significantly greater proportion of stands in the high ungulate use category, 41%, than occurred on allotment lands, 25%. In summary, the highest proportion of stands on non-allotment lands were in the high ungulate impact category whereas on allotment lands the highest proportion occurred in the moderate ungulate impact category.

CHAPTER II: Ungulate Impacts on understory vegetation

I. Grass community types

Scree community types and aspen stands located on slopes greater than 47% were excluded from this analysis due to their limited accessibility to cattle (Mackie 1970). This study found no significant difference between the proportion of aspen grass community types on allotment lands compared to non-allotment lands (chi-sq. = .001, df = 1, $p < .981$) (Table 8, in Appendix A) (Fig. 17 & 18). Grass community types comprised 23% of the community types on both allotment and non-allotment lands. Non-grass community types made up the remaining 77% on both allotment and non-allotment lands.

II. Grazing/trampling sensitive and resistant species on allotment versus non-allotment lands

Sensitive species

Aspen scree communities and stands on slopes greater than 47% were not included in this analysis due to limited access to cattle. The relationship between the proportion of aspen stands with grazing and/or trampling sensitive species and location, i.e. allotment versus non-allotment lands, was not independent (chi-sq. = 7.1,

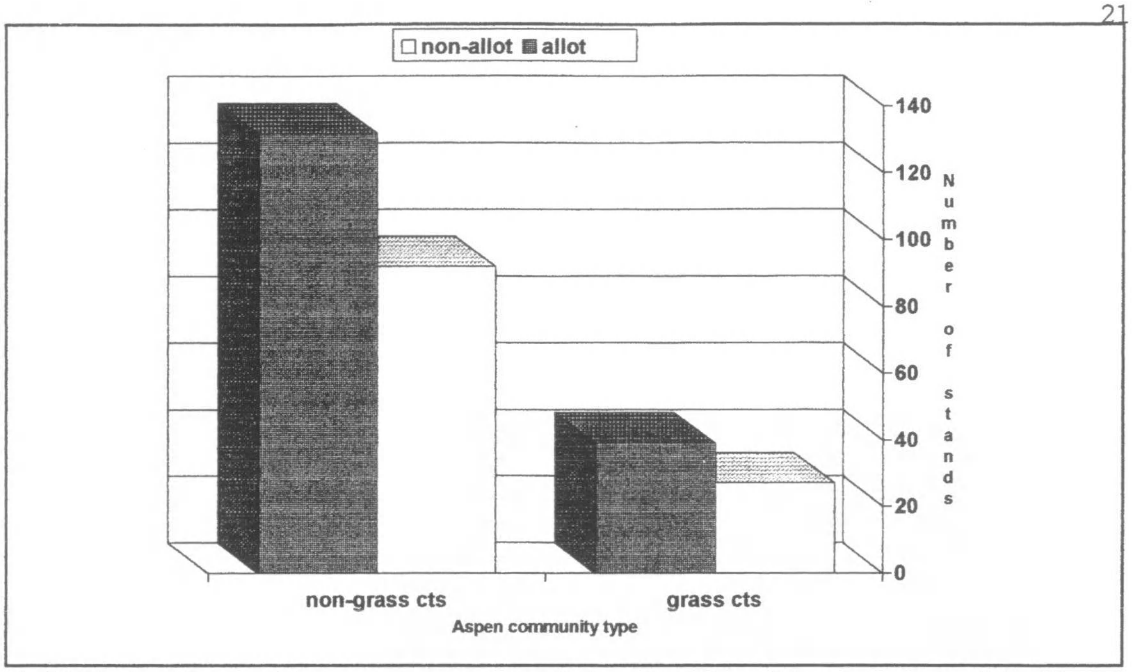

Fig. 17. Number of grass and non-grass aspen community types located on allotment versus non-allotment lands (X^2=.001, p<.981) Gardiner RD, Gardiner, MT.

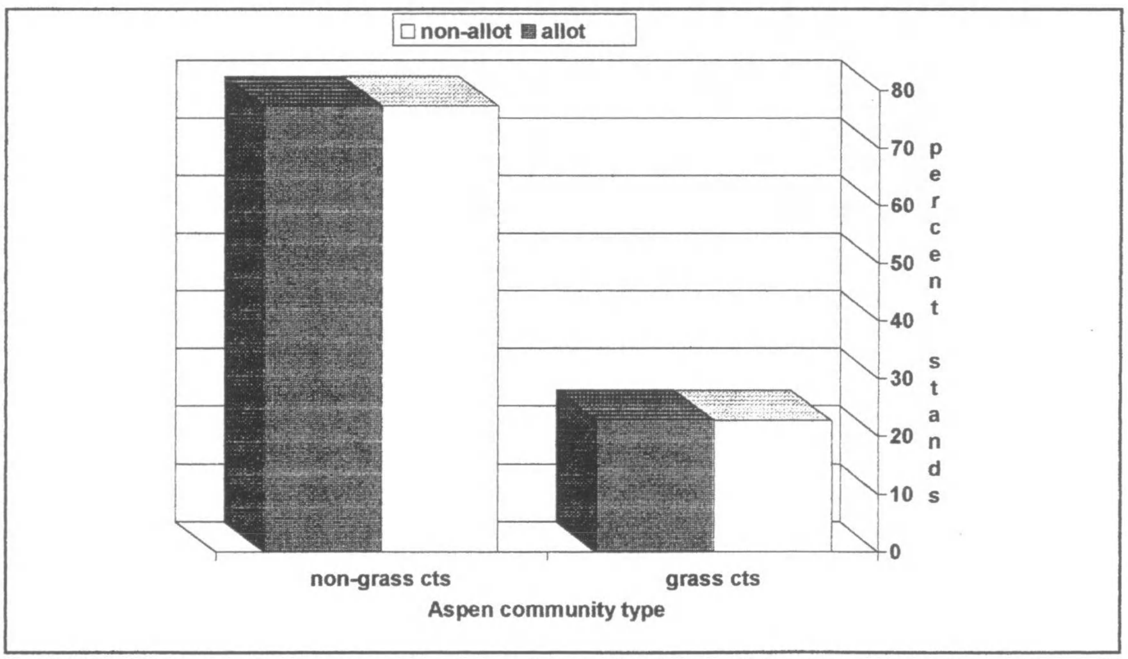

Fig. 18. Percent grass and non-grass aspen community types located on allotment versus non-allotment lands (X^2=.001, p<.981) Gardiner RD, Gardiner, MT.

df = 1, p < .008) (Table 9, in Appendix A) (Fig. 19 & 20). There was a significant greater proportion of aspen stands with grazing / trampling sensitive forbs on non-allotment lands. On non-allotment lands 82% of the aspen stands contained grazing / trampling sensitive species compared to 68% on allotment lands.

I also found the mean canopy coverage of the grazing / trampling sensitive species was significantly higher in the non-allotment aspen stands compared to allotment aspen stands (pooled variances t = 4.9, df=213, p < .000) (Table 10, in Appendix A). Non-allotment aspen communities with sensitive species had a mean canopy coverage of 22.9% for the sensitive species compared to 9.6% for the allotment stands.

Resistant species

The relationship between the proportion of aspen stands with grazing and/or trampling resistant species and location, i.e. allotment versus non-allotment was not independent. There was a significantly greater proportion of aspen stands with grazing / trampling resistant species located on allotment lands as compared to non-allotment lands (chi-sq = 8.9, df = 1, p < .003) (Table 11, in Appendix A) (Fig. 21 & 22). On allotments 97% of the aspen stands had grazing / trampling resistant species compared to 88% of the stands on non-allotment lands.

Mean canopy coverage of the grazing / trampling resistant species was also significantly greater in aspen stands located on allotments compared to non-allotment stands (pooled variances t = 6.2, df = 269, p < .000) (Table 12, in Appendix A). Allotment aspen stands with grazing / trampling resistant species had a mean canopy coverage of 60.4% of resistant species compared to a mean canopy coverage of 39.9% on non-allotment lands.

III. Mean canopy coverage of graminoids, forbs, and shrubs

The mean forb canopy coverage in aspen stands on allotment lands was less

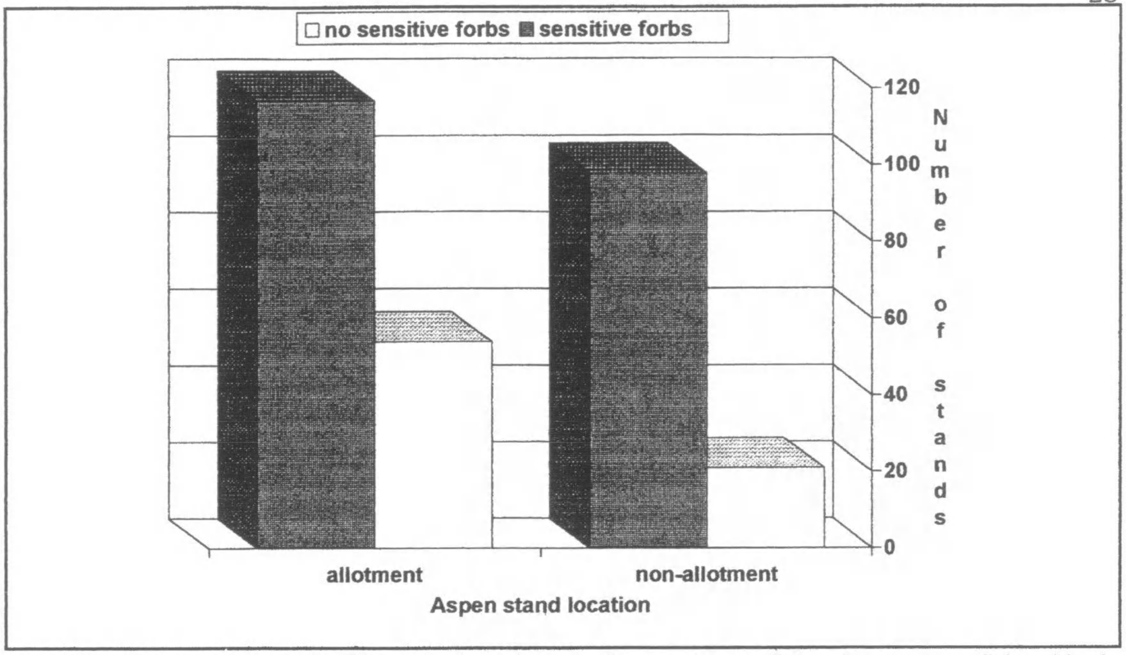

Fig. 19. Number of aspen stands with grazing/trampling sensitive species on allotment versus non-allotment lands (X^2=7.10, p<.008) Gardiner RD, Gardiner, MT.

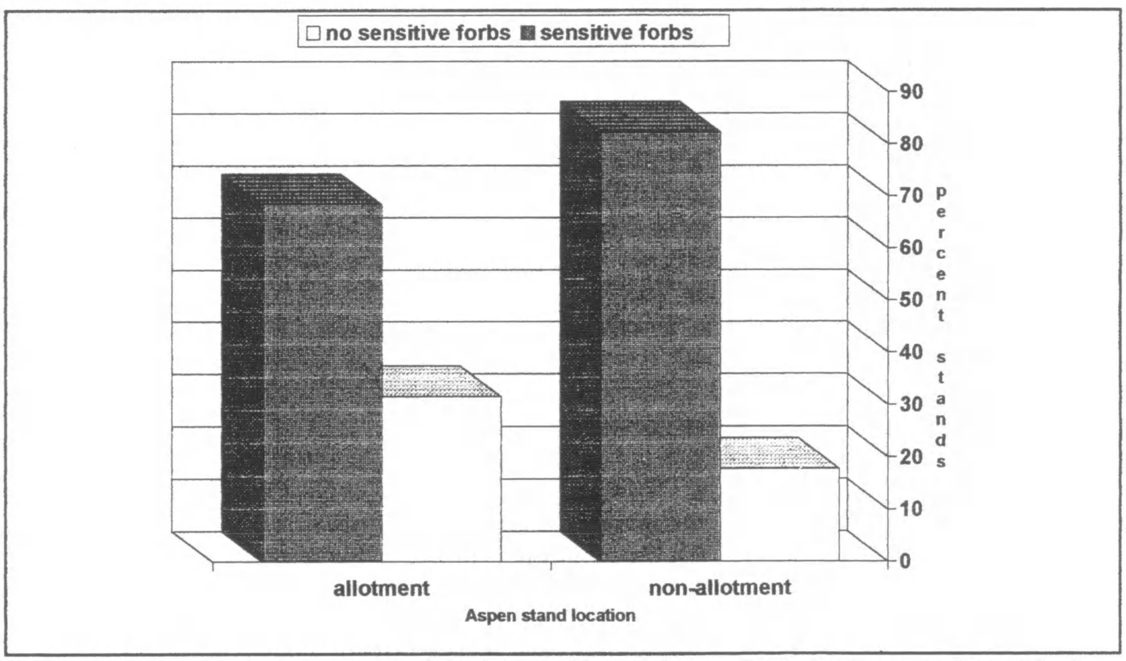

Fig. 20. Percent aspen stands with grazing/trampling sensitive species on allotment versus non-allotment lands (X^2=7.10, p<.008) Gardiner RD, Gardiner, MT.

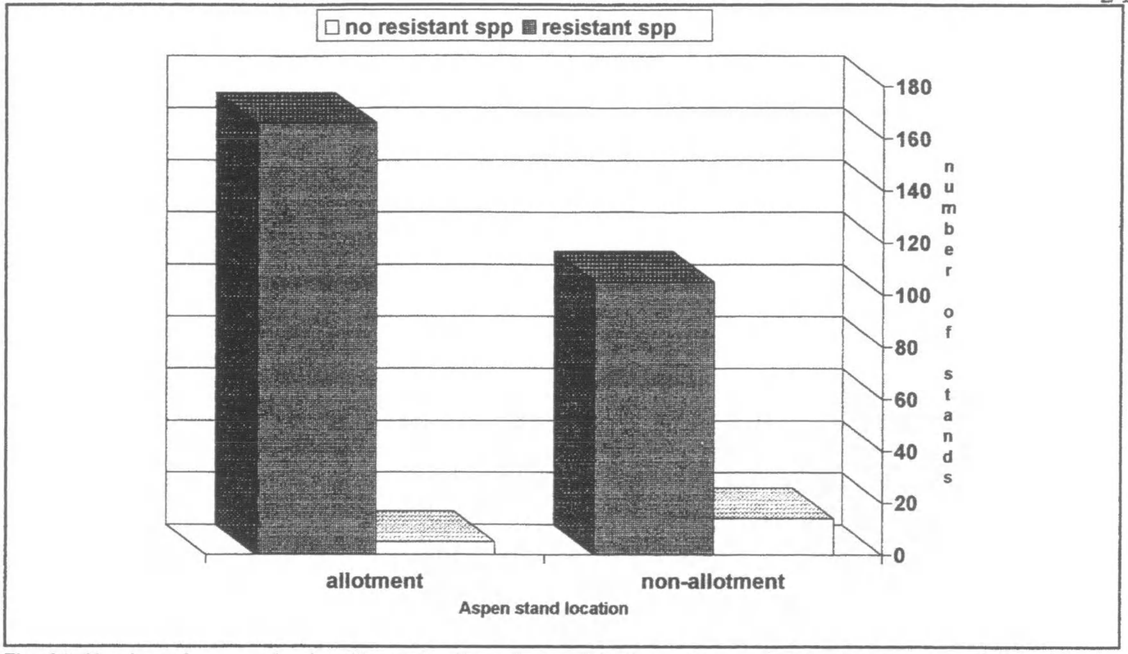

Fig. 21. Number of aspen stands with grazing/trampling resistant species on allotment versus non-allotment lands (X^2=8.96, p<.003) Gardiner RD, Gardiner, MT.

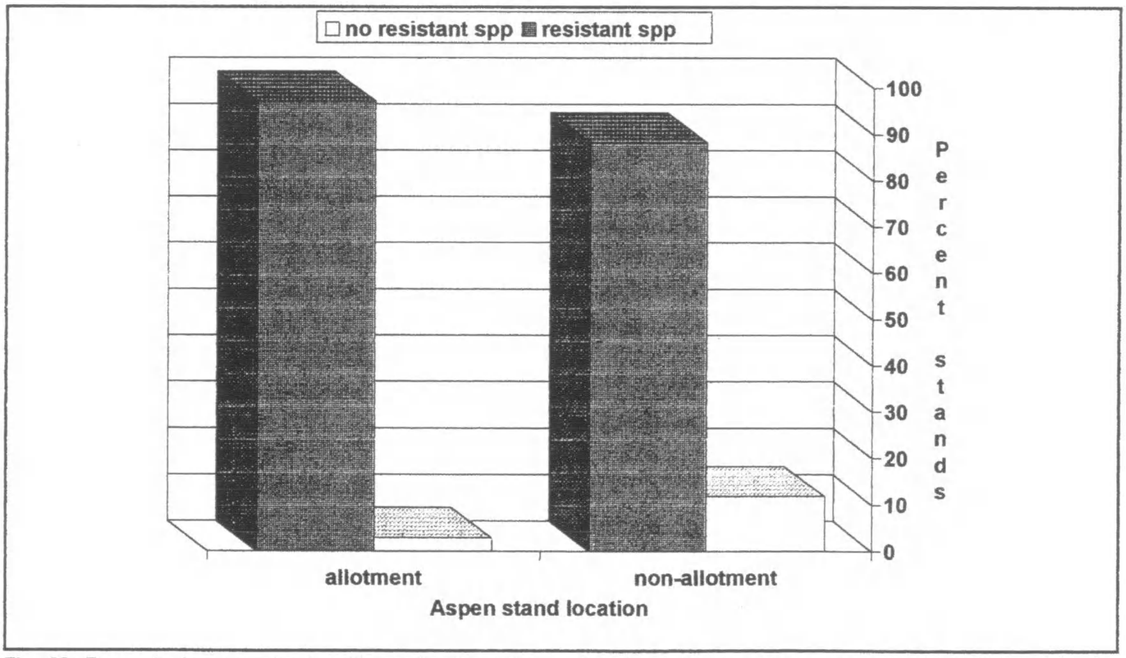

Fig. 22. Percent of aspen stands with grazing/trampling resistant species on allotment versus non-allotment lands (X^2=8.96, p<.003) Gardiner RD, Gardiner, MT.

than forb canopy coverage on non-allotment lands, 44.2% and 69.2% respectively, a statistically significant difference (pooled variances $t = 6.2$, $df=286$, $p < .000$) (Table 13, in Appendix A).

Conversely, I found a significant difference in mean graminoid canopy coverage in aspen stands located on non-allotment lands versus allotment lands, averaging 75.7% and 82.3% respectively (pooled variance $t = 2.7$, $df = 286$, $p < .008$) (Table 13, in Appendix A).

There was not a significant difference (pooled variances $t = 1.3$, $df = 280$, $p < .189$) in mean shrub canopy coverage in aspen stands located on allotment lands versus non-allotment lands (Table 13, in Appendix A). The mean canopy coverage for graminoids on allotment lands was 33.3% compared to 37.7% for non-allotment lands.

Chapter III. Aspen stand recruitment

I. Aspen stand recruitment and community type

Aspen community type and stand recruitment were not independent (chi-sq. = 49.5, $df = 12$, $p < .000$) (Table 14, in Appendix A) (Fig. 23 & 24). POTR/SCREE c.t.s and POTR-PSME/SCREE c.t.s had the highest proportion of stands with recruitment, averaging 85% and 70% respectively. POTR-PSME/CARU c.t.s and POTR-PIEN/SMST c.t.s had the lowest proportion of stands with recruitment, averaging 7% and 6% respectively. When the aspen communities were grouped into scree or non-scree community types the overall proportion of stands with recruitment for scree communities was 78% compared to 22% for non-scree communities (Table 15, in Appendix A) (Fig. 25 & 26).

II. Aspen stand recruitment and ungulate impacts

A. Kay's criterion

When all the aspen stands were included in the analysis the relationship between recruitment and ungulate impacts was not independent (chi-sq = 49.5, $df = 2$,

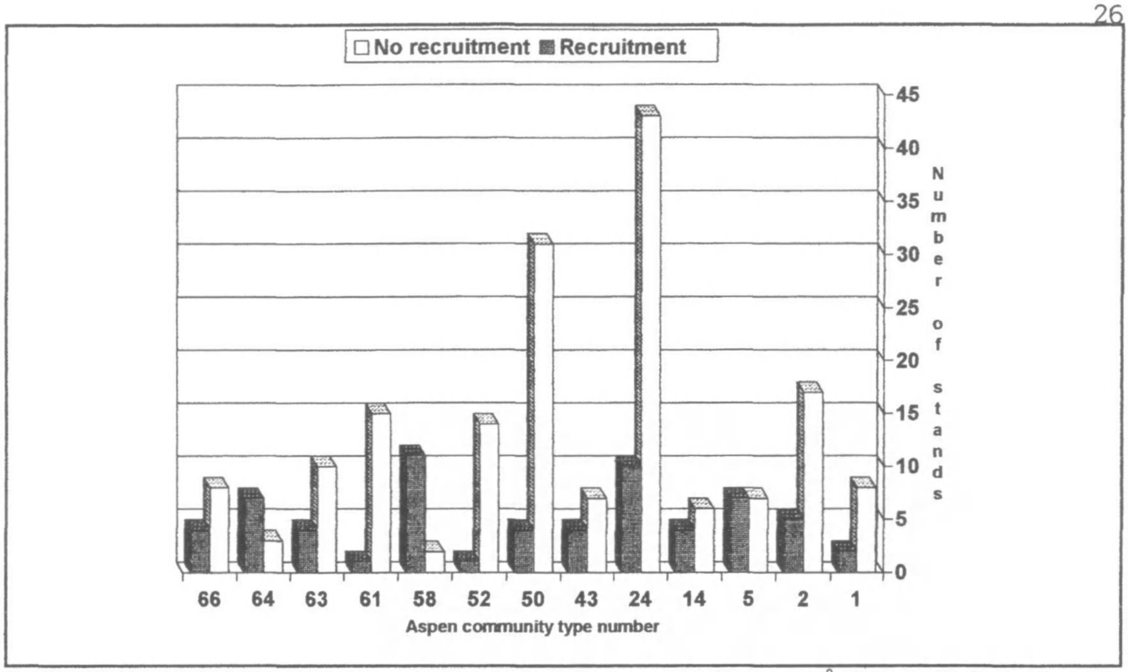

Fig. 23. Number of stands with recruitment for the major aspen community types (X^2=49.54, p<.000) Gardiner RD, Gardiner, MT.

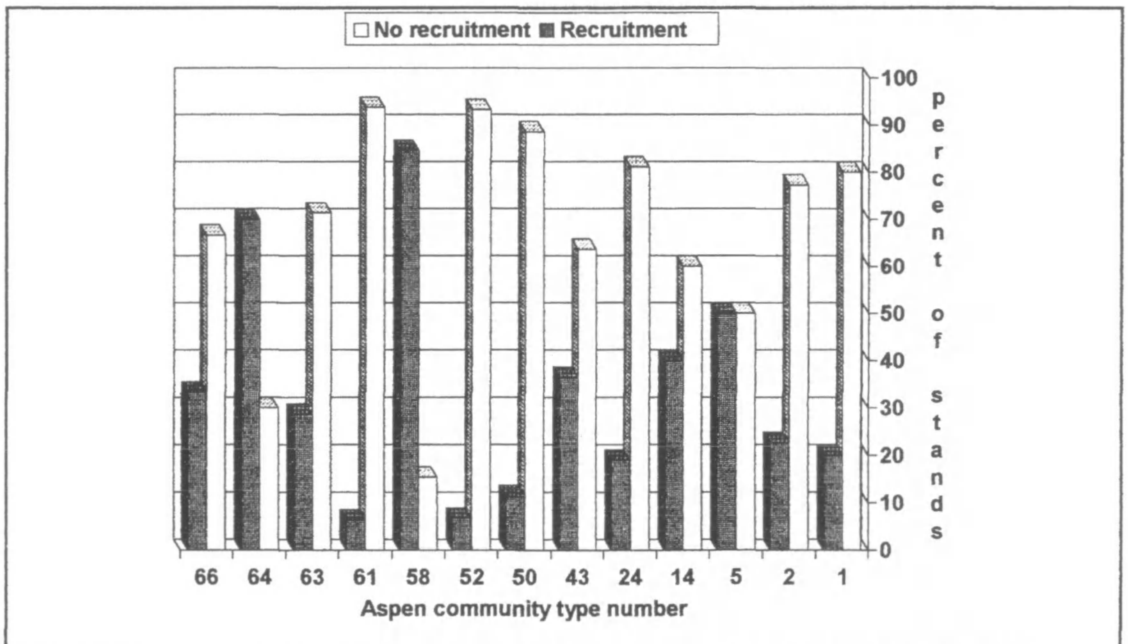

Fig. 24. Percent stands with recruitment for the major aspen community types (X^2=49.54, p<.000) Gardiner RD, Gardiner, MT.

[1] Aspen community type code numbers (Table 4, in Appendix A).

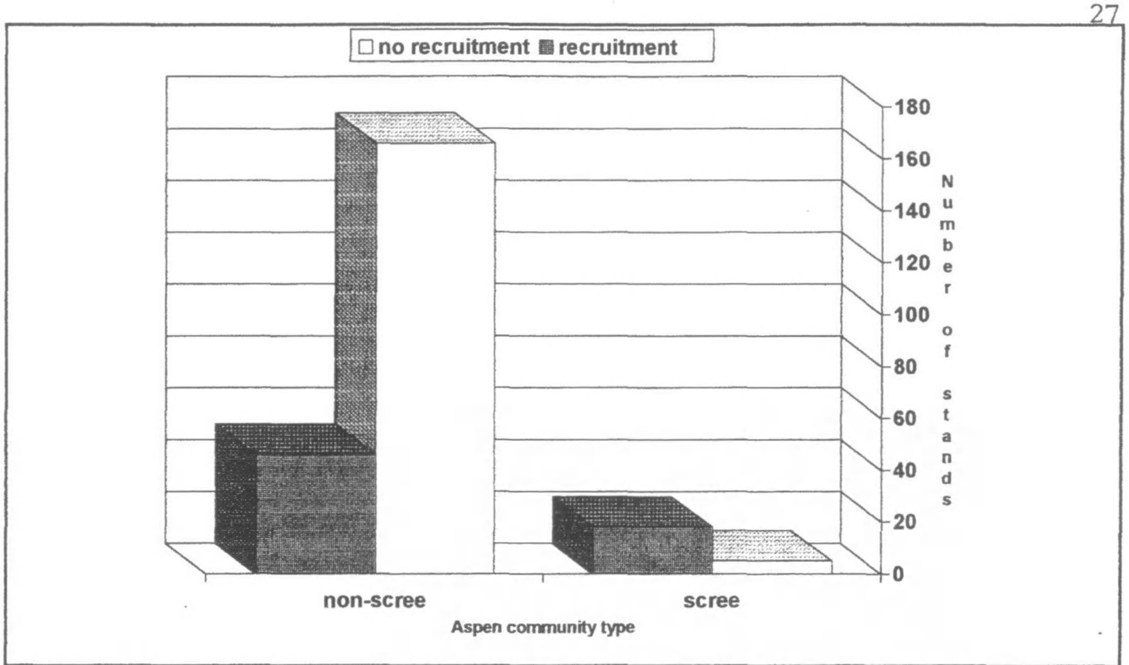

Fig. 25. Number of scree and non-scree communities with recruitment (X^2=33.50, p<.000) Gardiner RD, Gardiner, MT.

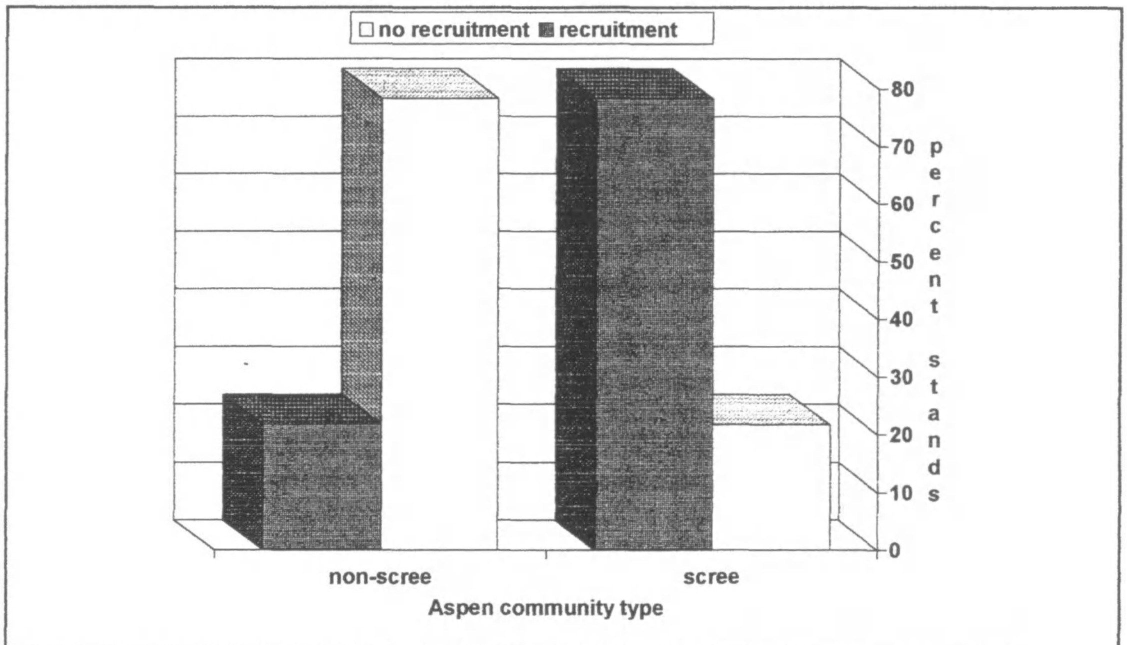

Fig. 26. Percent of aspen scree and non-scree community types with recruitment (X^2=33.50, p<.000) Gardiner RD, Gardiner, MT.

p < .000) (Table 16, in Appendix A) (Fig. 27 & 28). Aspen stands with low ungulate impacts had a significantly greater proportion of stands with recruitment than stands with high ungulate impacts, 47% compared to 10%. Only 14% of the aspen stands in the moderate ungulate impact classification met Kay's criterion for recruitment.

When the analysis was restricted to the more accessible stands (non-scree community types, stands not in snow accumulation areas, and stands on slopes less than 47%) the relationship between recruitment and ungulate impact was not independent (chi-sq. = 16.9, df = 2, p < .000) (table 17, in Appendix A) (Fig. 29 & 30). Aspen stands with high ungulate impacts had a significantly lower proportion of stands with recruitment than stands with low ungulate impacts, 10% and 30% respectively. While 10% of the aspen stands with moderate ungulate impacts had recruitment.

B. Recruitment stem production criterion

When all the aspen stands were analyzed the relationship between recruitment and ungulate impacts was not independent (chi-sq. = 55.7, df = 6, p < .000) (Table 18, in Appendix A) (Fig. 31 & 32). Aspen stands with low ungulate impacts had a significantly greater proportion of stands in the in the (rec => 1) category than aspen stands with high ungulate impacts, 47% compared to 10%. Conversely, aspen stands with high ungulate impacts had a significantly greater proportion of stands in the (rec = 0) and in the (0 < rec =< .5) categories than aspen stands with low ungulate use, 58% and 21% compared to 26% and 15% respectively.

When the analysis was restricted to the more accessible stands (non-scree community types, stands not in snow accumulation areas, and stands on slopes less than 47%) the relationship between recruitment and ungulate impacts was not independent (chi-sq. = 19.4, df = 6, p < .003) (Table 19, in Appendix A) (Fig. 33 & 34). Aspen stands with low ungulate impacts had a greater proportion of stands in the (rec => 1) or the (.5 < rec < 1) categories than stands with moderate or high ungulate use,

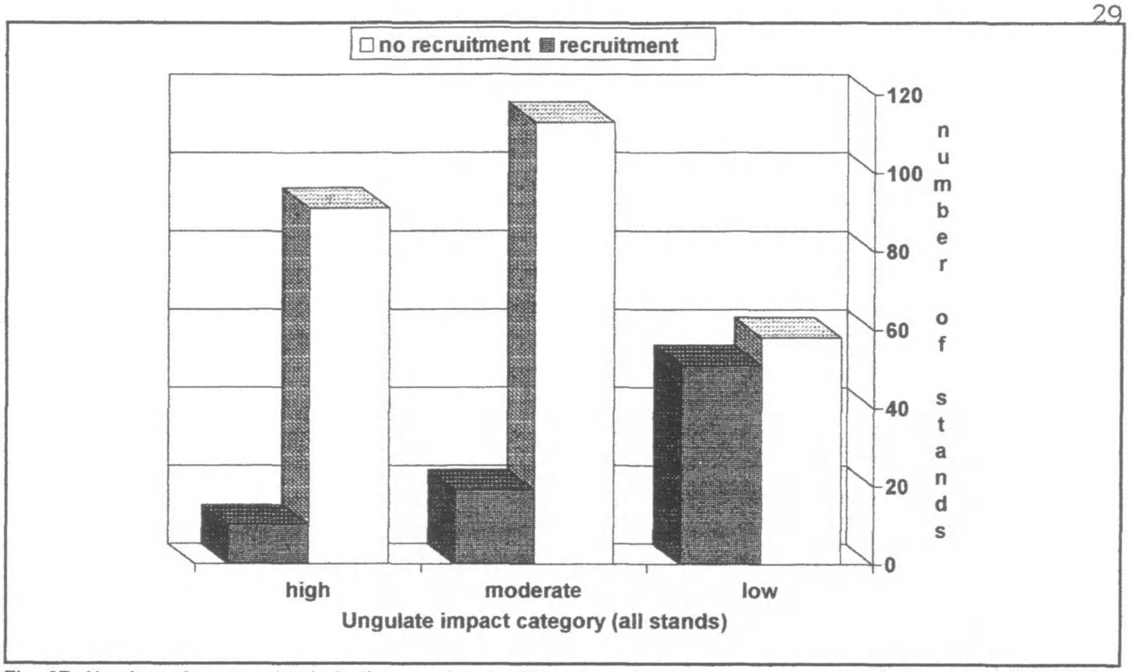

Fig. 27. Number of aspen stands in the ungulate impact categories with recruitment (all stands included)(X^2=49.52, p<.000) Gardiner RD, Gardiner, MT.

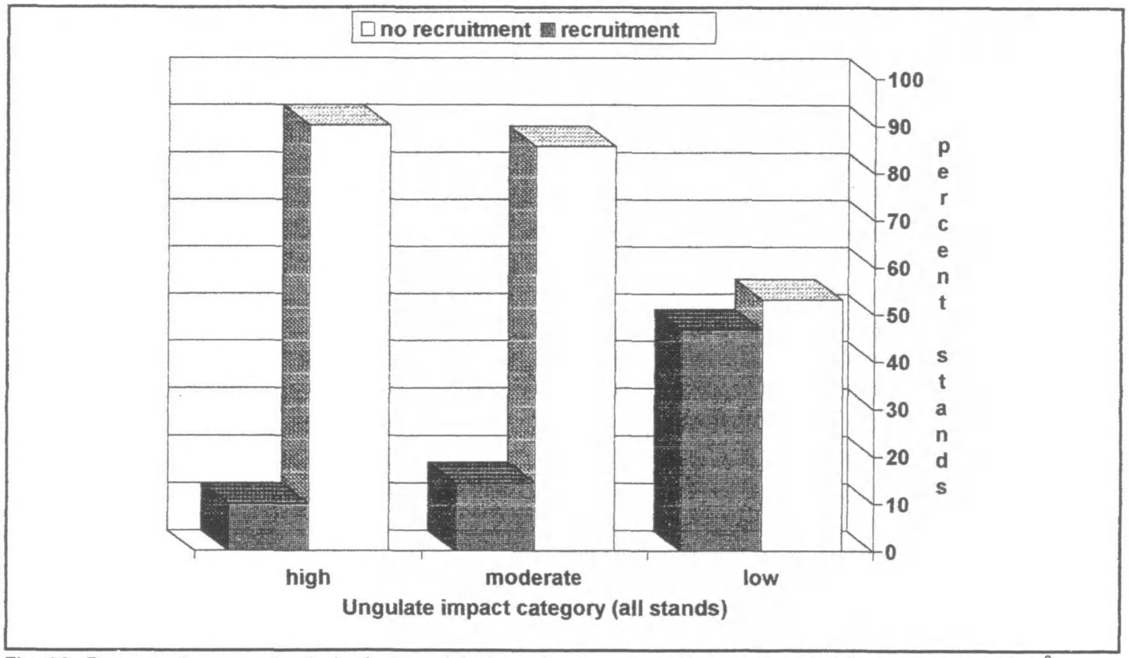

Fig. 28. Percent of aspen stands in the ungulate impact categories with recruitment (all stands included)(X^2=49.52, p<.000) Gardiner RD, Gardiner, MT.

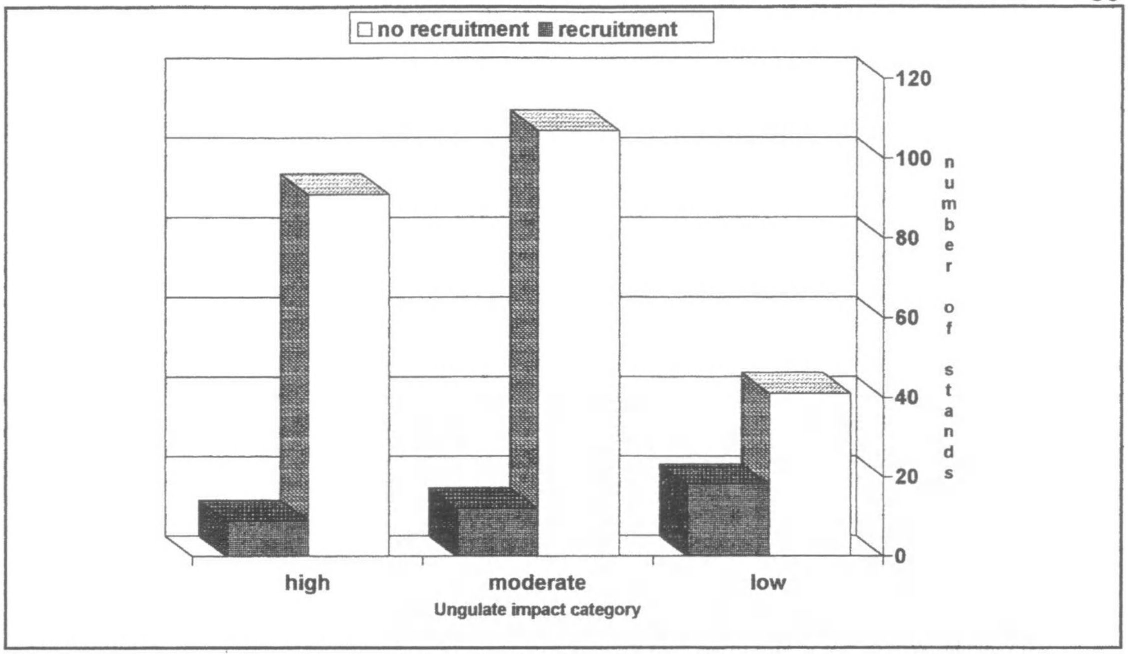

Fig. 29. Number of stands in the ungulate impact categories with recruitment (scree, snow, and on slopes > 47% excluded)(X^2=16.92, p<.000) Gardiner RD, Gardiner, MT.

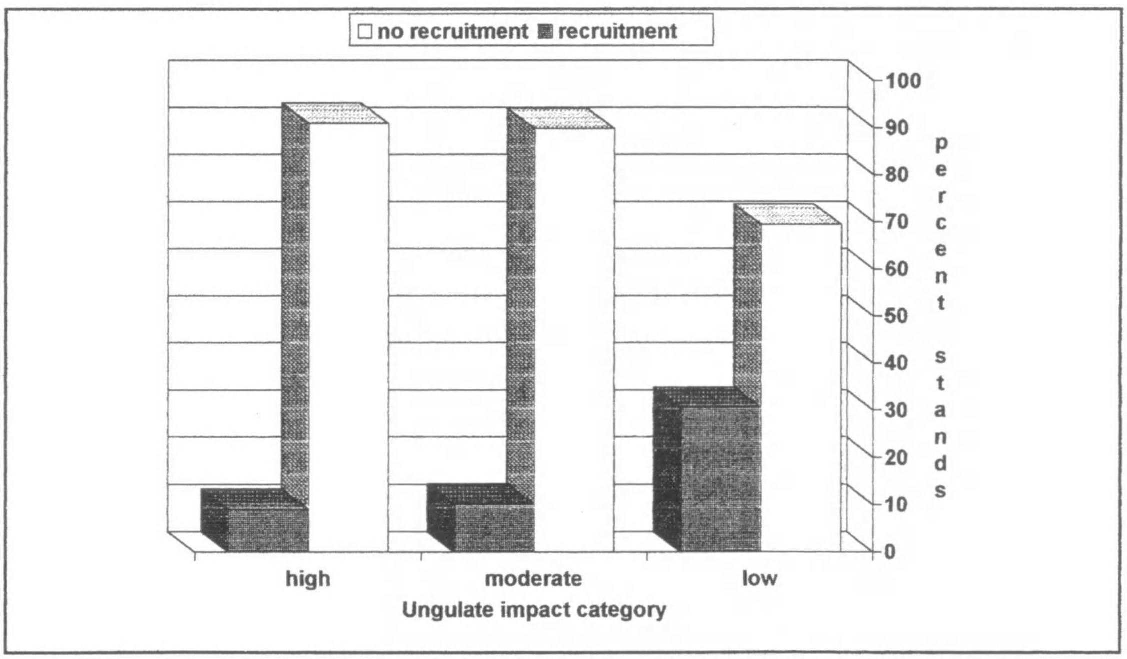

Fig. 30. Percent aspen stands in the ungulate impact categories with recruitment (snow,scree, and on slopes > 47% excluded)(X^2=16.92, p<.000) Gardiner RD, Gardiner, MT.

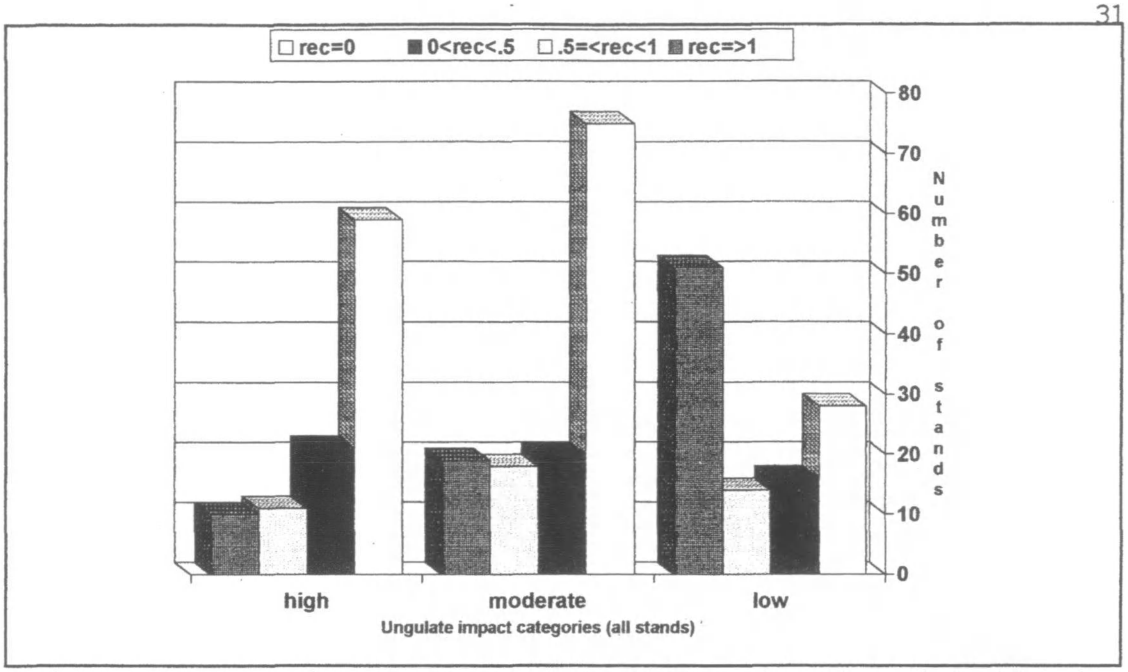

Fig. 31. Number of aspen stands in the ungulate impact categories with recruitment stem production (all stands included)(X^2=55.67, p<.000) Gardiner RD, Gardiner, MT.

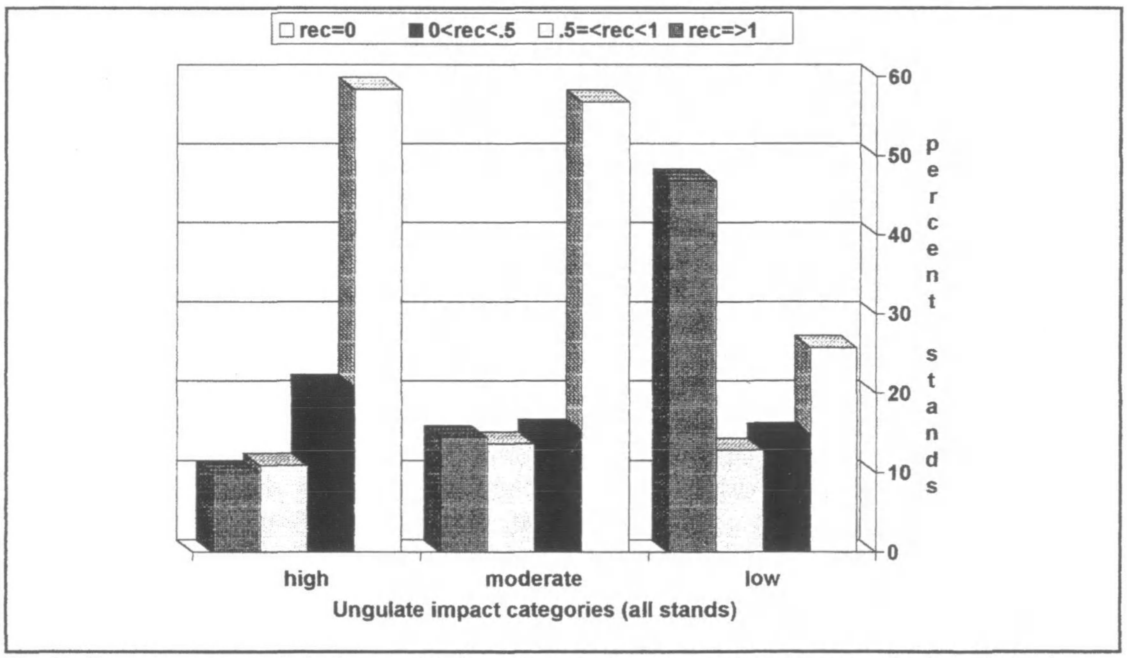

Fig. 32. Percent aspen stands in the ungulate impact categories with recruitment stem production (all stands included)(X^2=55.67, p<.000) Gardiner RD, Gardiner, MT.

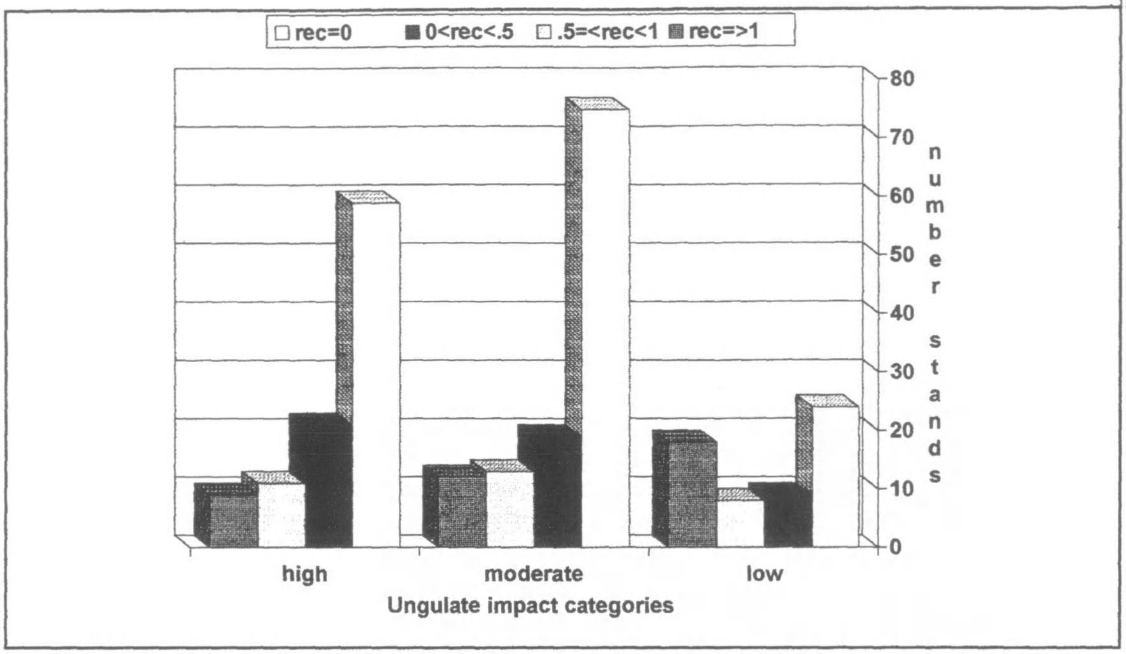

Fig. 33. Number of stands with recruitment stem production by ungulate impacts (scree, snow and on slopes >47% excluded)(X^2=19.43, p<.003) Gardiner RD, Gardiner, MT.

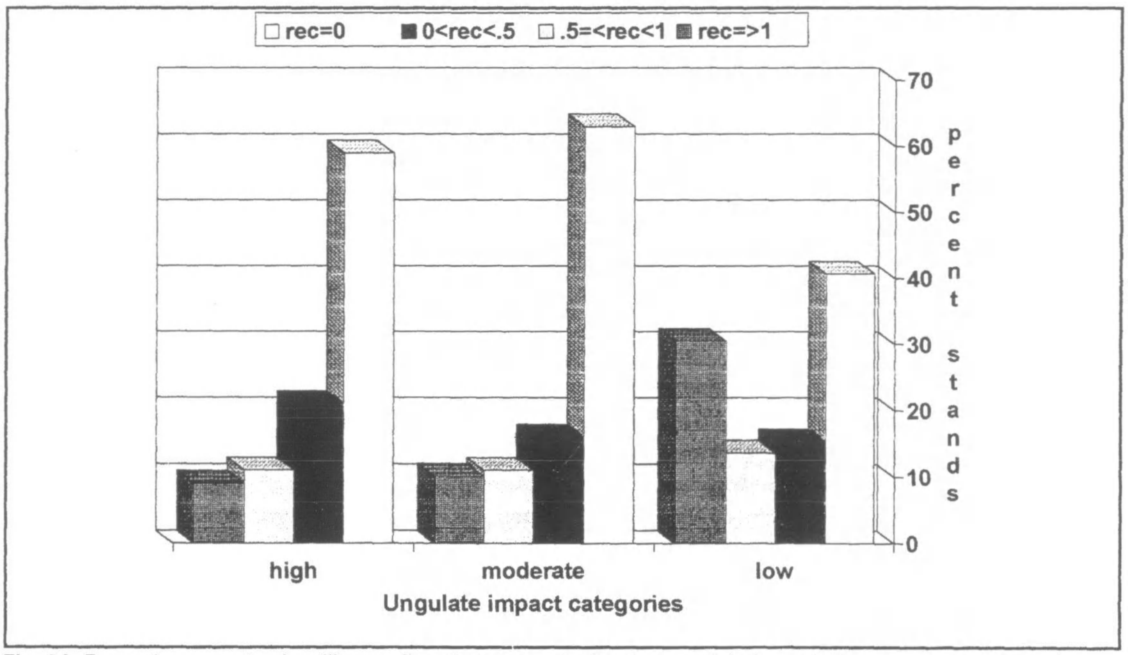

Fig. 34. Percent aspen stands with recruitment stem production by ungulate impacts (scree, snow and on slopes >47% excluded)(X^2=19.43, p<.003) Gardiner RD, Gardiner, MT.

31% and 14%, compared to 10% and 11% for moderate impacts, and 9% and 11% for high impacts. Furthermore, aspen stands with low ungulate impacts had lower proportions of stands in the (rec = 0) and in the (0 < rec =<.5) categories than stands with high and moderate ungulate impacts, 41% and 15%, compared to 63% and 16% for moderate impacts, and 59% and 21% for high ungulate impacts.

III. Aspen recruitment on allotment versus non-allotment lands

A. Kay's criterion

The relationship between aspen recruitment and location on allotment versus non-allotment lands was not independent (chi-sq. = 11.0, df = 1, $p < .002$) (Table 20) (Fig. 35 & 36). Aspen stands located on non-allotment lands had a greater proportion of stands with recruitment (28%) than stands on allotment lands (12%). Sixty one percent of the aspen stands with recruitment occurred on non-allotment lands.

B. Recruitment stem production criterion

I determined the relationship between location and recruitment was significantly different (chi-sq. = 70.0, df = 3, $p < .000$) (Table 21, in Appendix A) (Fig. 37 & 38). Aspen stands in the (rec=> 1) category comprised 28% of the stands on non-allotment lands compared to 12% on allotment lands. Aspen stands in the (.5<=rec<1) category comprised 24% of the stands on non-allotment lands compared to 5% on the allotment lands. Aspen stands in the (0<rec<.5) category constituted 25% of the non-allotment aspen stands and only 12% of the allotment stands. Conversely, 71% of the aspen stands on allotment lands were in the (rec=0) category compared to 23% of the non-allotment stands.

Even though aspen stands on non-allotment lands had a significantly greater proportion of stands with high ungulate use (Chapter I, part III) non-allotment lands produced greater proportions of aspen stands with recruitment in the high, moderate and low impact categories. Non-allotment aspen stands with low ungulate impacts had

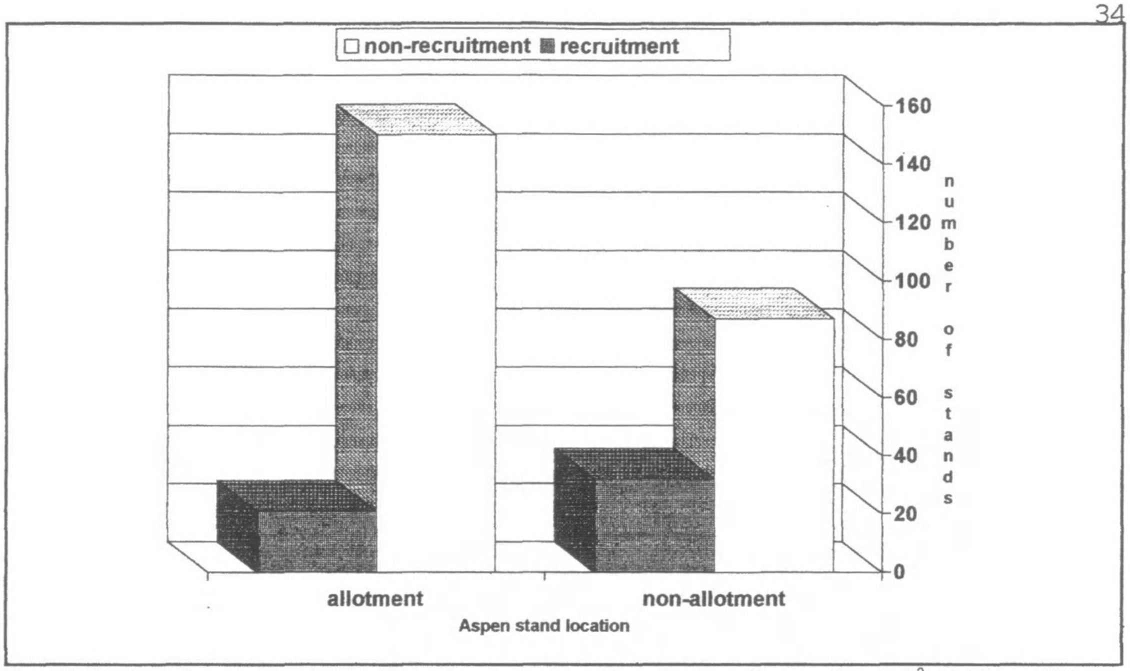

Fig. 35. Number of aspen stands on allotment versus non-allotment lands with recruitment (X^2=11.05, p<.002) Gardiner RD, Gardiner, MT.

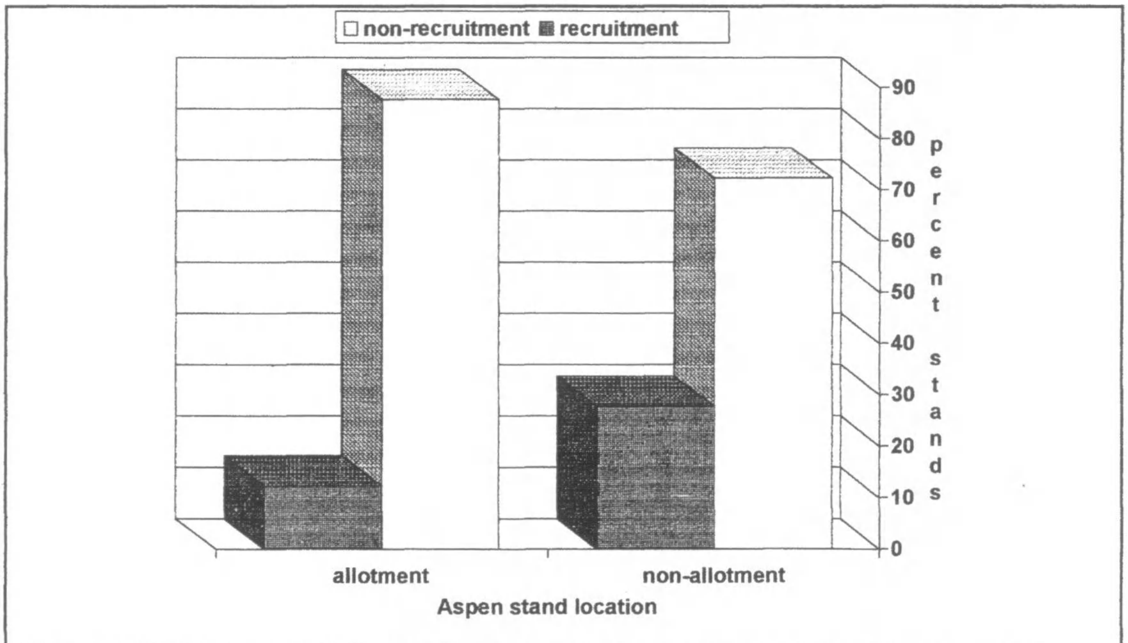

Fig. 36. Percent aspen stands on allotment versus non-allotment lands with recruitment (X^2=11.05, p<.002) Gardiner RD, Gardiner, MT.

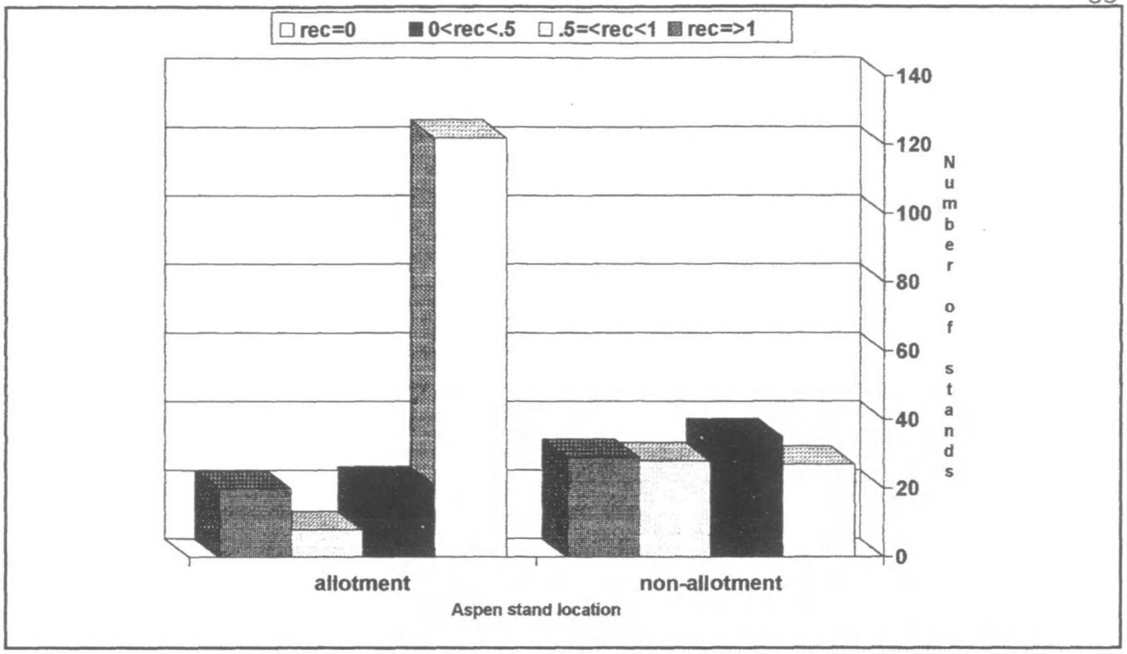

Fig. 37. Number of aspen stands on allotment and non-allotment lands with recruitment stem production (X^2=70.09, p<.000) Gardiner RD, Gardiner, MT.

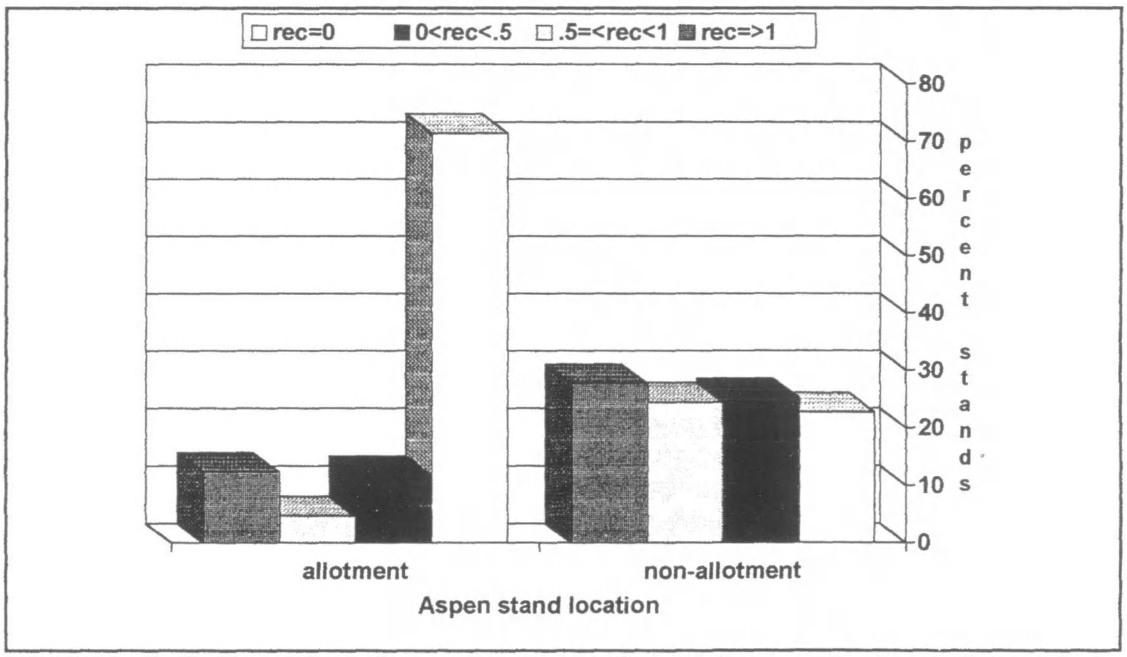

Fig. 38. Percent of aspen stands on allotment and non-allotment lands with recruitment stem production (X^2=70.09, p<.000) Gardiner RD, Gardiner, MT.

a higher proportion of stands in both the (.5<=rec<1) category (22% compared to 9%) and in the (rec=>1) category (56% compared to 29%) than allotment stands (Fig. 39 & 40) (Table 22, in Appendix A). When compared to allotment stands, the non-allotment aspen stands with moderate ungulate impacts had a higher proportion of stands in the (0<rec<.5) category, 29% versus 10%, in the (.5<=rec<1) category, 32% versus 5%, and in the (rec=>1) category, 21% and 10% respectively (Fig. 41 & 42) (Table 23, in Appendix A). Finally, when compared to allotment stands, the non-allotment aspen stands with high ungulate impacts had a higher proportion of stands in the (.5<=rec<1) category, 20% compared to 0%, and in the (rec=>1) category, 14% and 0% respectively (Fig. 43 & 44) (Table 24, in Appendix A).

IV. Aspen stand recruitment and distance from major roads or human habitations

A. Kay's criterion

I concluded the relationship between distance from main roads or human habitations and proportion of aspen stands with recruitment was not independent (chi-sq. = 12.9, df = 1, p < .000) (Table 25, in Appendix A) (Fig. 45 & 46). Aspen stands located within 500 m of main roads or human habitations had a significantly higher proportion of stands with recruitment compared to stands located greater than 500 m, 25% versus 9%.

B. Recruitment stem production criterion

I found the relationship between recruitment category and distance was not independent (chi-sq. = 37.3, df = 3, p < .000) (Table 26, in Appendix A) (Fig. 47 & 48). Aspen stands located within 500 m of main roads or human habitations had significantly higher proportions in the (0<rec<.5), (.5<=rec<1), and in the (rec=>1) categories. Conversely, the aspen stands located greater than 500 m had a significantly greater proportion of stands in the (rec=0) recruitment category.

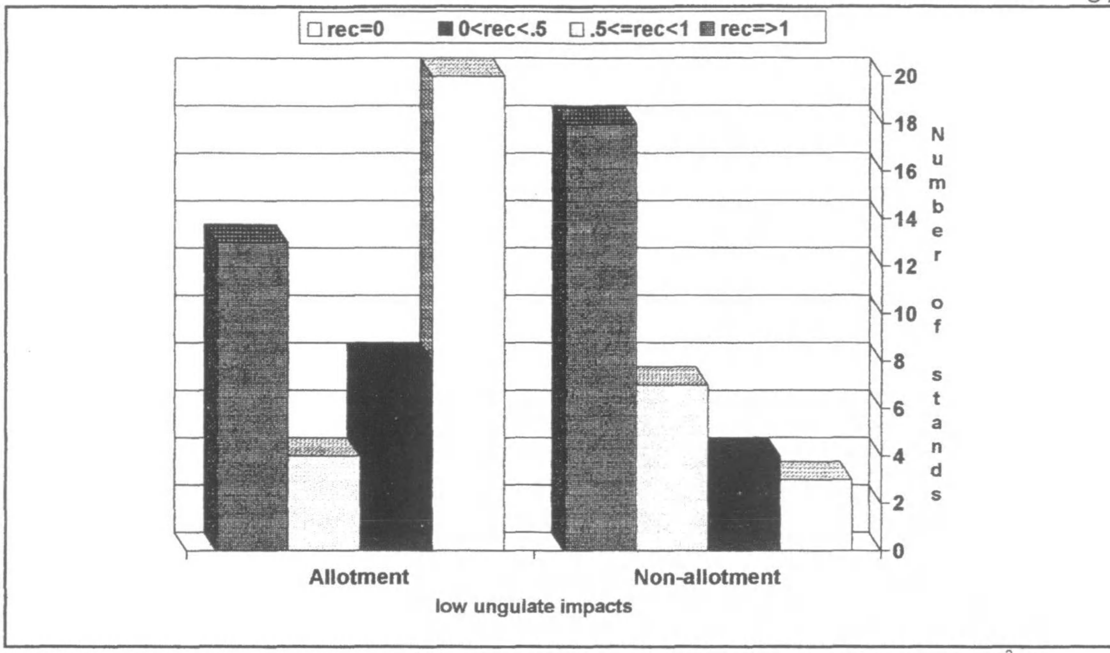

Fig. 39. Recruitment stem production on allotment or non-allotment lands with low ungulate impacts (X^2=13.72, p<.000) Gardiner RD, Gardiner, MT.

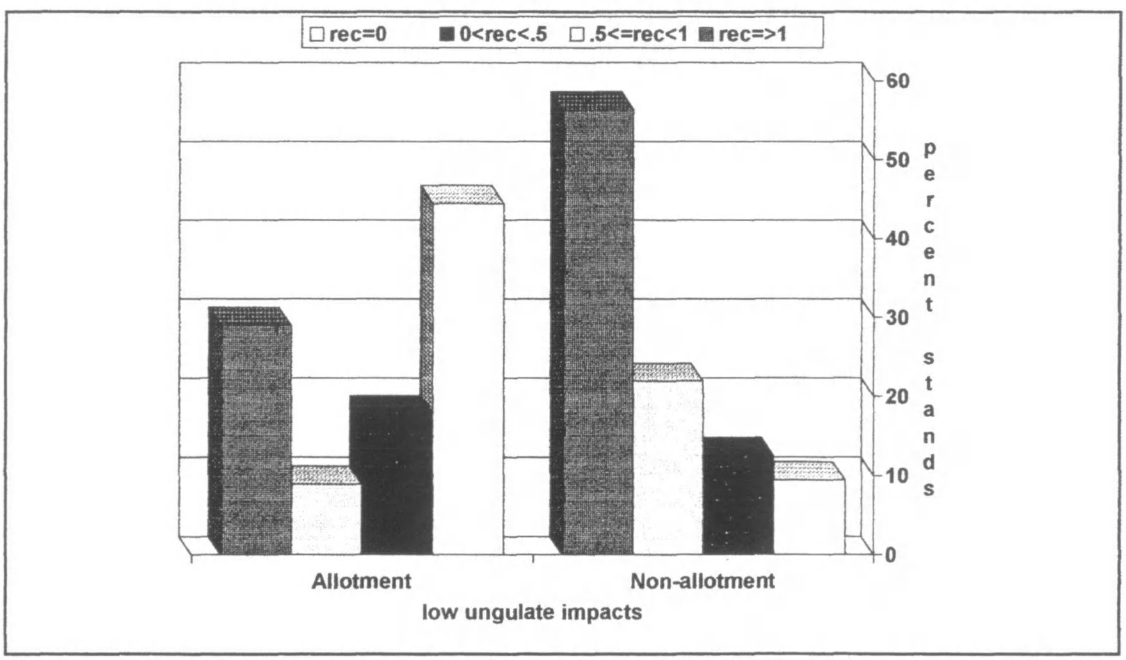

Fig. 40. Percent recruitment stem production on allotment or non-allotment lands with low ungulate impacts (X^2=13.72, p<.000) Gardiner RD, Gardiner, MT.

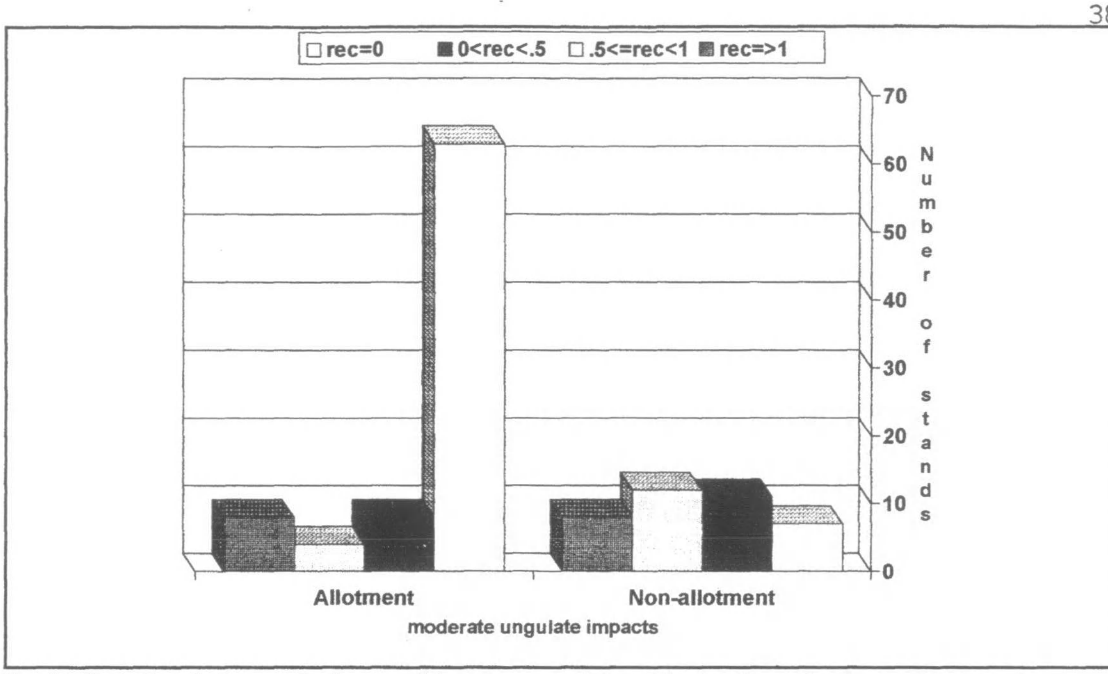

Fig. 41. Recruitment stem production on allotment or non-allotment lands with moderate ungulate impacts (X^2=37.76, p<.000) Gardiner RD, Gardiner, MT.

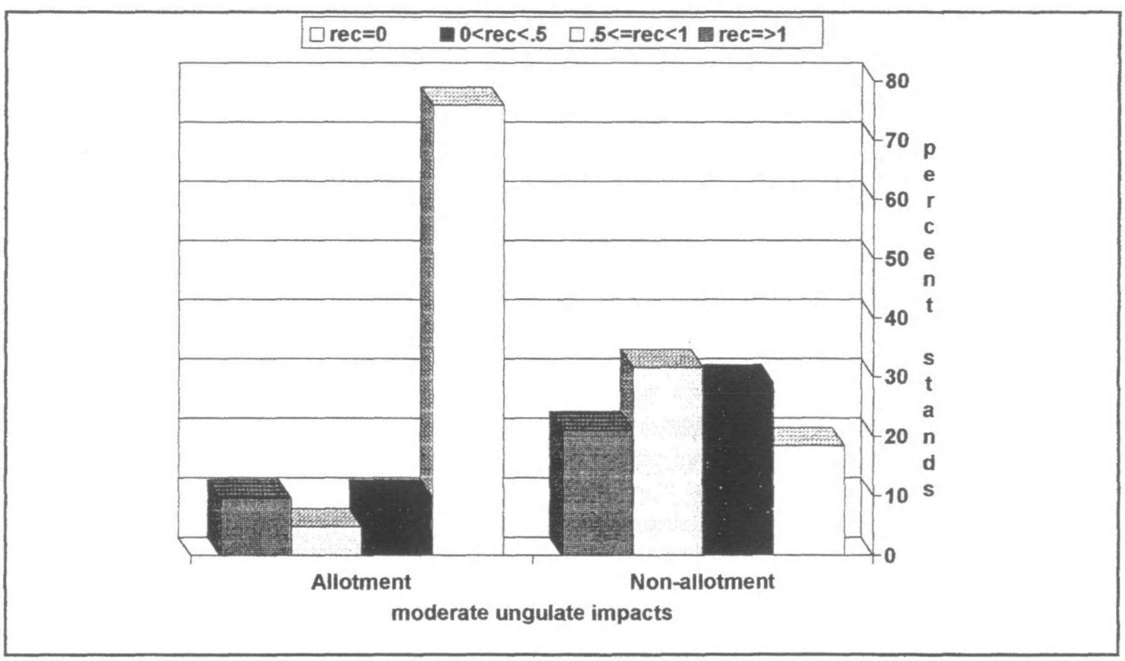

Fig. 42. Percent recruitment stem production on allotment or non-allotment lands with moderate ungulate impacts (X^2=37.76, p<.000) Gardiner RD, Gardiner, MT.

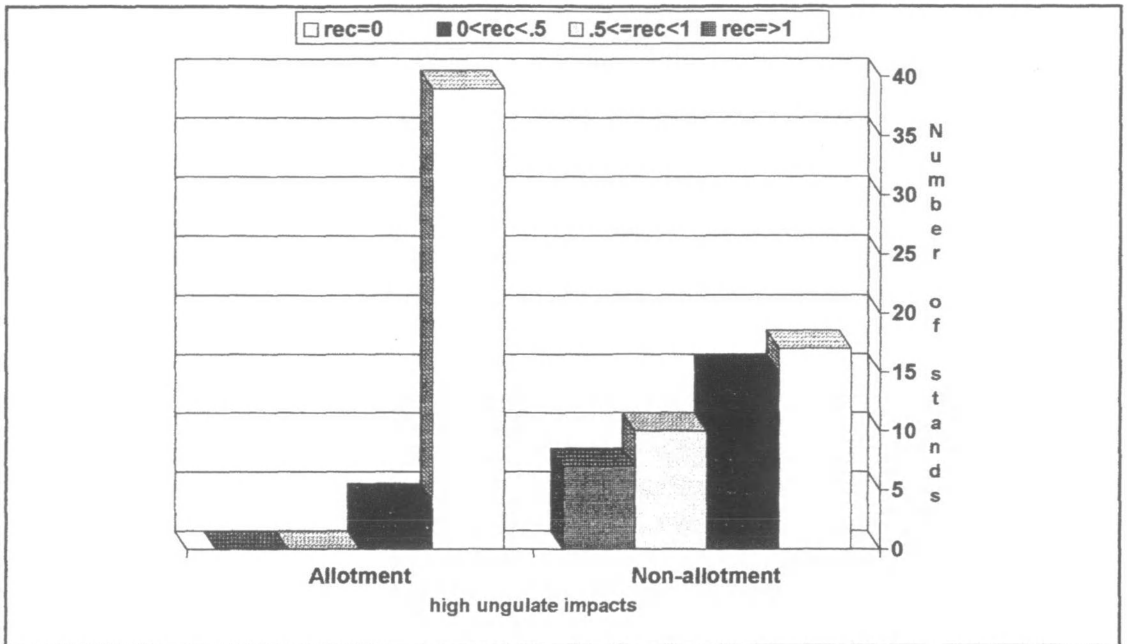

Fig. 43. Recruitment stem production on allotment or non-allotment lands with high ungulate impacts (X^2=31.76, p<.000) Gardiner RD, Gardiner, MT.

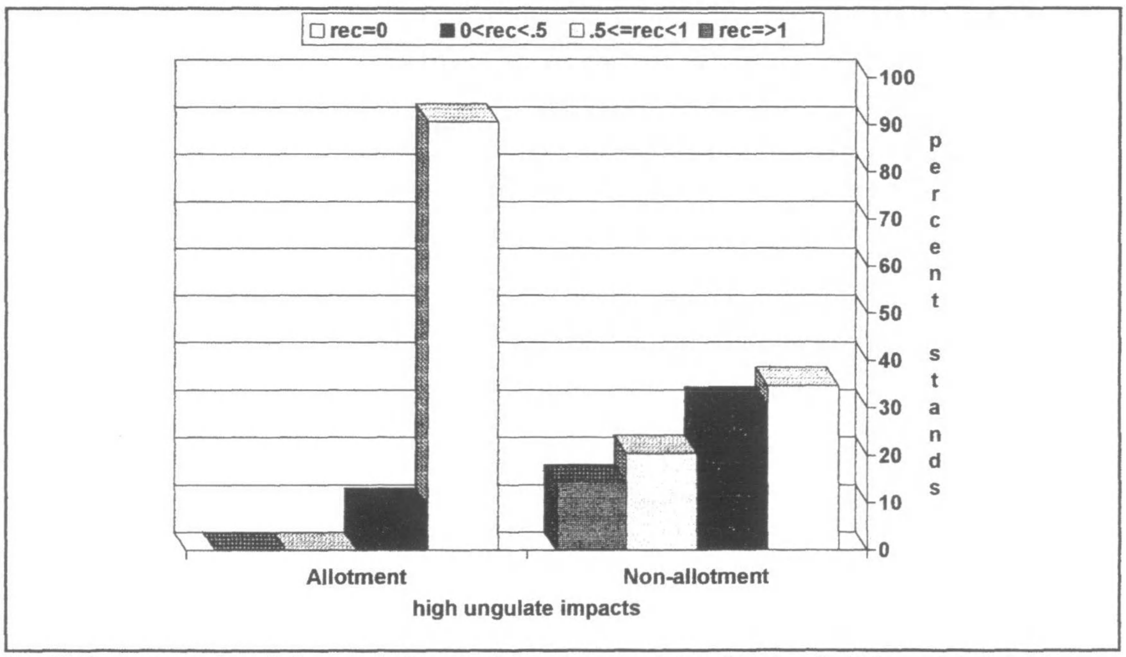

Fig. 44. Percent recruitment stem production on allotment or non-allotment lands with high ungulate impacts (X^2=31.76, p<.000) Gardiner RD, Gardiner, MT.

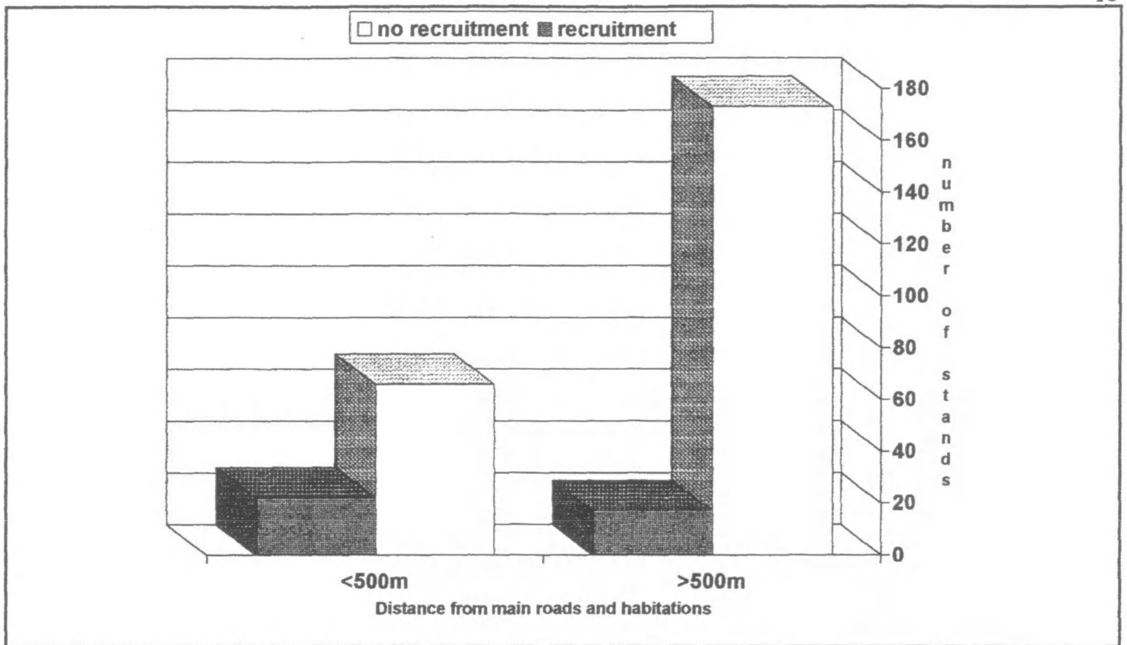

Fig. 45. Aspen stands with recruitment by distance from main roads or human habitations (X^2=12.85, p<.000) Gardiner RD, Gardiner, MT.

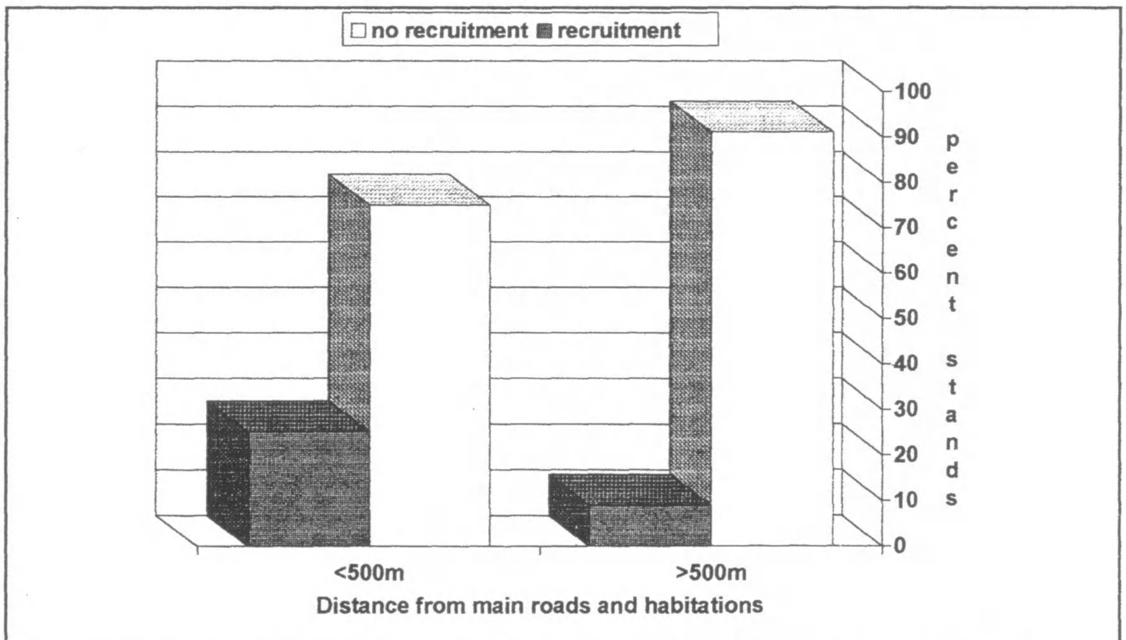

Fig. 46. Percent aspen stands with recruitment by distance from main roads or human habitations (X^2=12.85, p<.000) Gardiner RD, Gardiner, MT.

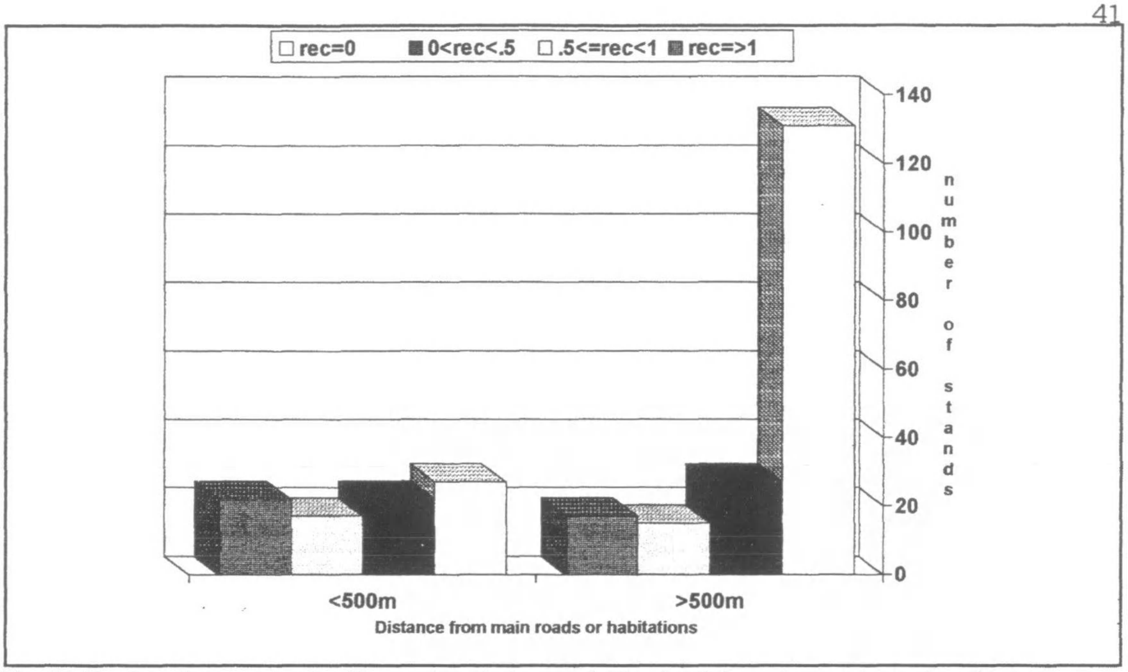

Fig. 47. Number of aspen stands with recruitment stem production by distance from main roads or human habitations (X^2=37.33, p<.000) Gardiner RD, Gardiner, MT.

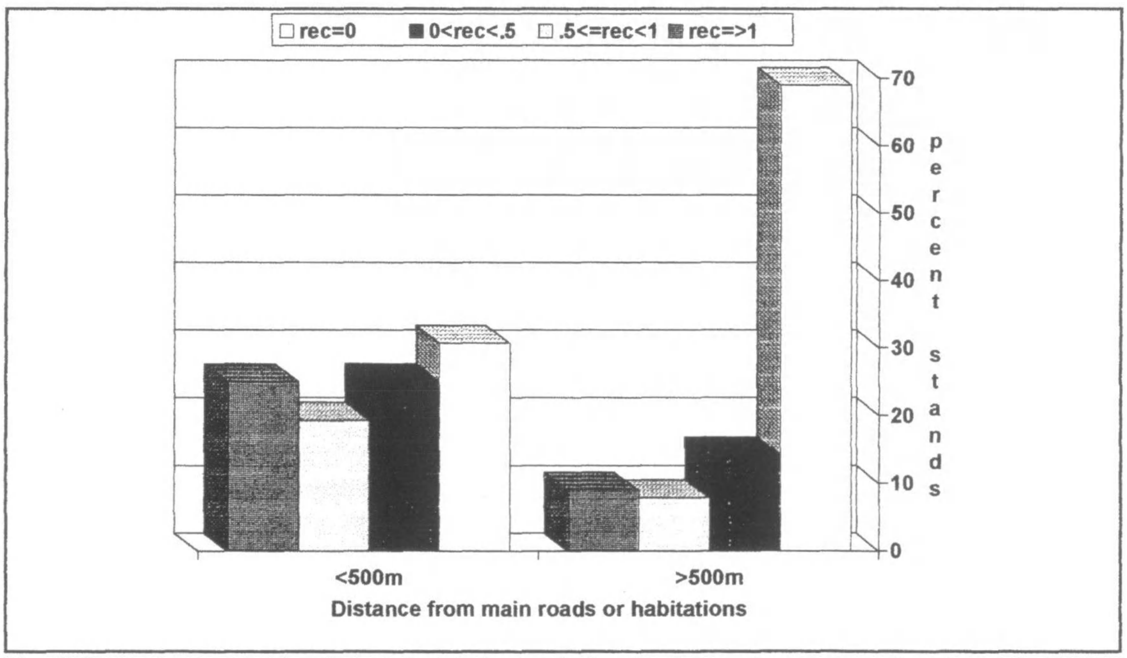

Fig. 48. Percent aspen stands with recruitment stem production by distance from main roads or human habitations (X^2=37.33, p<.000) Gardiner RD, Gardiner, MT.

Summarily, these figures indicate aspen communities closer than 500 m are producing recruitment stems whereas the communities greater than 500 m are not.

DISCUSSION

Ungulate impacts

On the western portion of the Gardiner Ranger District the aspen scree community types (POTR/SCREE c.t.s and POTR-PSME/SCREE c.t.s) are being impacted less than the other community types. Apparently this is due to the rocky substrate limiting ungulate access to these stands. The limited access to scree community types is evident through less bole scaring, less extensive bole scarring, and less browse hedging within the aspen stands.

POTR/TALL FORB c.t.s and POTR/ARTR c.t.s had higher proportions of stands with high ungulate impacts. It is possible the higher ungulate impacts are due to these aspen community types being located on aspects and in areas which received greater use by wintering ungulates. Aspen communities located within 500 m of main roads or human habitations also exhibited lower ungulate impacts. Other studies have noted elk avoidance of roads and human activity (Lyon et al. 1985, Ward et al. 1973, Edge and Marcum 1985) which probably accounts for the lower ungulate impacts on these aspen stands.

Aspen communities on allotment and non-allotment lands differed in the proportions of ungulate impacts. Both locations had the same proportion of stands with low ungulate impacts, 26%. However, more of the aspen stands on allotment lands were in the moderate ungulate impact category, 49%, whereas on the non-allotment lands the greatest number of stands were in the high ungulate use category, 41%.

Ungulate impacts and understory vegetation

Similar proportions of aspen-grass community types occurred on both allotment

and non-allotment lands. Both locations had 23% aspen-grass community types.

Significant differences did exist in understory vegetation composition between allotment and non-allotment lands. Aspen stands on allotment lands had a lower proportion of aspen stands with grazing / trampling sensitive species (*Heracleum lanatum, Epilobium angustifolium,* and *Thalictrum* spp.) than non-allotment lands, 68% compared to 82%. Furthermore, for the aspen communities which contained the grazing / trampling sensitive species, the mean canopy coverage of those species was significantly less on allotment versus non-allotment lands, 10% compared to 23%.

Conversely, there was a significantly greater proportion of aspen communities with grazing / trampling resistant species (*Poa pratensis, Phleum pratense, Calamagrostis rubescens,* and *Fragaria* spp.) on allotment lands (97%) compared to non-allotment lands (88%). In addition, for the aspen communities which contained the grazing/trampling resistant species, the mean canopy coverage of those species was significantly greater on allotment lands (60%) than on non-allotment lands (40%).

Differences in the mean canopy coverage for graminoid, forb, and shrub understory vegetation were evident. There was a significantly greater mean canopy coverage of graminoids on allotment lands. Mean graminoid canopy coverage was 82% on allotment lands versus 76% on non-allotment lands.

Conversely, significantly less mean forb canopy coverage was noted in aspen stands on allotment lands when compared to non-allotment stands, 44% and 70% respectively. Other studies have also noted a decrease in herbaceous coverage under grazing (Kay 1990, Mueggler and Bartos 1977, Sampson 1919). These studies suggested the decreased herbaceous cover, hence less competition, would result in an increase in aspen regeneration. This study did not reach the same conclusion probably because the high levels of ungulate browsing suppress regeneration.

Aspen stands on allotment lands had a lower mean shrub canopy coverage but

not significantly lower, 38% compared to 33% for aspen stands on non-allotment land. Mueggler and Bartos (1977) recorded a significant reduction in shrub coverage under grazing. Even though the difference in shrub canopy coverage was not statistically significant it should be noted that the difference does exist. Also, the difference in graminoid canopy coverage, albeit statistically significant, was relatively small. I would recommend the shrub and graminoid canopy differences be monitored for future trends.

Aspen community recruitment

Aspen scree community types had significantly higher proportions of stands with recruitment than non-scree community types. This difference was most likely due to ungulate exclusion, based on the the ungulate impact results, and possibly because these stands enjoy limited competition from other tree species in the rocky substrate. POTR-PSME/CARU c.t.s and POTR-PIEN/SMST c.t.s had the lowest proportion of stands with recruitment. The low recruitment in these particular community types hypothetically could be due, in part, to the advanced seral condition of some of these community types rather than ungulate use.

Ungulate impacts and recruitment stem production were not independent. Aspen communities with low ungulate impacts produced more recruitment stems and were more likely to meet Kay's recruitment requirement (i.e. recruitment/non-recruitment => 1) than stands in the moderate or high ungulate impact categories.

Aspen stands located on non-allotment lands had a greater proportion of stands with Kay's measure of recruitment and produced more recruitment stems than stands on allotment lands. Even though non-allotment aspen stands had a higher proportion of stands in the high ungulate impact category, the aspen stands on non-allotment lands produced greater proportions of stands with recruitment stems in all ungulate impact categories. Thus, cattle grazing appears to have had an additive effect on

areas of current cattle activity (Mackie 1970, Leege 1984) it is possible that cattle grazing during the summer and early fall, followed by elk use in winter and early spring, is responsible for lower recruitment stem production within allotment stands. The results also indicate the methods used to measure ungulate impacts were more sensitive to wild ungulate use than cattle use, i.e. bark stripping, scarring extent, and browse hedging are more a result of wild ungulate use than cattle use. Establishing exclosures to eliminate cattle use, but not wild ungulate use, in the allotment stands should be used to address this question.

Aspen located within 500 m of main roads or human habitations had a higher proportion of stands producing recruitment stems. Consequently, the aspen stands within 500 m were more likely to met Kay's recruitment criterion. Whereas aspen stands farther than 500 m had the highest proportion of stands not producing any recruitment stems (i.e. rec=0) and not meeting Kay's recruitment criterion. Numerous studies have noted the ability of aspen to produce recruitment size stems in areas of light ungulate utilization and not in areas of high ungulate use (Kay 1984, 1987, 1990, Krebil 1972, Gruell and Loope 1974, Mueggler and Bartos 1977).

SUMMARY

Ungulate impacts, chiefly by elk and cattle on the study area, are having an adverse effect on aspen recruitment. This is evidenced by the lower proportion of aspen stands with recruitment in non-scree community types, in stands with moderate and high ungulate impacts, and in aspen stands located farther than 500 m from main roads and human habitations. Conversely, aspen stands with lower ungulate impacts, in scree community types, and in aspen stands located within 500 m of main roads and human habitations exhibit a higher proportion of stands with recruitment. Cattle impacts appears to be additive to wild ungulate use, thereby further reducing aspen recruitment on allotment lands.

Allotments had a greater proportion of aspen stands with grazing / trampling resistant species than non-allotments. In addition, the mean canopy coverage of the grazing / trampling resistant species was significantly greater in the allotment stands than in the non-allotment stands.

Non-allotment lands had higher proportions of stands with grazing / sensitive species. In addition, the mean canopy coverage of grazing / trampling sensitive species was significantly greater in non-allotment stands.

There was also greater mean canopy coverage of forbs and shrubs in non-allotment stands than in allotment stands. However, the shrub differences were not statistically significant. There was a significantly greater graminoid canopy coverage in allotment stands. These understory vegetation differences potentially are attributable to the additive grazing effect of cattle on the allotment lands. If these differences are a result of current ungulate pressure the differences may become greater over time. However, it is also possible these differences are the result of historically higher cattle stocking rates. If this is true the differences potentially might decrease over time. Therefore, these vegetative parameters should continue to be monitored for future trends.

Yellowstone National Park elk census counts report an overall increase in elk numbers since the 1970's which are at substantially higher levels than for most of the 20th century. As elk populations increase, or remain at current levels, we can expect the ungulate impacts to the Gardiner RD aspen stands to also increase. Girdling has been noted as an effective method of reducing aspen coverage (Schier and Smith 1979). Bole scarring may, over time, sufficiently girdle the trees thereby reducing the overall vigor and reproductive success of the aspen stands. Bark stripping also provides avenues for pathogen entry (Krebil 1972, Patton and Jones 1977, Hinds and Krebil 1975). Thus, ungulates may indirectly contribute to decreased vigor, lower

recruitment, and increased aspen mortality. Current levels of ungulate use, both cattle and wildlife, have resulted in low aspen recruitment and therefore, further deterioration and demise of aspen clones on the Gardiner Ranger District is expected to occur.

During the winter of 1994-95 gray wolves were reintroduced to the Greater Yellowstone Ecosystem (GYE) as a "nonessential experimental" population. The repatriation of this predator has initiated speculation on the impact of the wolves on ungulate populations and ultimately, the plant communities within the GYE. YNP biologists previously have regarded wolf predation as a "... nonessential adjunct to the natural regulation process..." (Cole 1971, Houston 1982). Hence, according to YNP biologists, wolf reintroduction should have a negligible effect on ungulate populations. Other researchers report predators are able to suppress ungulate populations to levels below the ecological carring capacity (carring capacity determined by food resources) under certain conditions (Messier 1991, 1994, Kay and White 1994 in press). However, in some national park settings predators have been unsuccessful in limiting ungulate populations due to a combination of ungulate habituation to humans and predator avoidance of human activities (Kay and White 1994 in press).

The prognosis for GYE aspen communities, under current Forest Service, Park Service, and Fish, Wildlife & Parks management objectives and/or mandates, is continued deterioration and demise of existing clones , changes in aspen understory compositions from grazing/trampling sensitive species toward grazing/trampling resistant species, decreased overall canopy coverage of forbs in allotment stands, and a concurrent increase in graminoids within allotment stands.

The combined effects of low aspen recruitment, changes in understory species composition, and changes in aspen and understory canopy coverage potentially have a deleterious effects on the numerous wildlife species which utilize the diverse synusia associated with aspen communities (Flack 1976, Gullion 1984, Hobbs et al. 1981, Kay

1994c, Tew 1970, Hungerford 1970, Leckenby et al. 1982). Efforts to regenerate aspen and other deciduous vegetation in areas of moderate to high ungulate use will most likely be unsuccessful unless intensive management methods are used, e.g. fencing, herbivore repellents, or barrier falling. Management efforts should be directed toward aspen communities in areas of limited ungulate use, i.e. near roads and human habitations, scree communities, and on non-allotment lands.

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Appendix A: Figures and Tables

TABLE 1. Cattle allotments, grazing systems, season, and numbers for the Gardiner RD, Gardiner, MT within the aspen study area.

Allotment	Grazing system	Season	Numbers
Slip & Slide	4 pasture rest rotation	6/16 to 10/15	300 head (reduced by 120 head 1991)
Wigwam	2 pasture deferred	6/16 to 9/30	56 term; 20 private
Canyon	3 pasture deferred	6/16 to 10/15	100 head for 30 days
Green Lake	3 pasture deferred	6/16 to 10/15	117 head
Lion	4 pasture rest rotation	6/16 to 10/15	53 term; 42 private
Cottonwood	season long	6/16 to 10/15	41 head (non-use since 1988)
Cedar Cr.	3 pasture deferred	6/16 to 10/15	27 term; 15 private (non-use since 1983)
Little Trail Cr.	1 pasture	6/16 to 10/15	19 head (non-use since 1978)
Mill Cr.	1 pasture season long	6/16 to 10/15	13 term; 14 private
Section 22	1 pasture season long (Mill Cr. and Section 22 are now operated a 2 pasture deferred)	6/16 to 10/15	22 head
Park (Mol Heron)	3 pature deferred	7/1 to 10/15	20 term; 130 private
Park (Beattie Cr.)	1 pasture	6/16 to 6/30; 10/6 to 11/5	4 head on/off
Tom Miner-Ramshorn	4 pasture deferred	7/1 to 10/15	126 term; 134 private (reduced by 30 head 1992)
Horse Cr.-Reeder	5 pasture deferred	7/1 to 9/30	106 term; 14 private
Eagle Cr.	Homestead livestock use	varied	non use since 1930's

TABLE 2. Foliar Canopy Cover Class as per USDA Forest Service Ecosystem Classification Handbook FSH 12/87 R-1 Supp 1.

Code	Class Range	Midpoint
T	0.1< 1%	0.5%
P	1 < 5%	3.0%
1	5 <15%	10.0%
2	15 <25%	20.0%
3	25 <35%	30.0%
4	35 <45%	40.0%
5	45 <55%	50.0%
6	55 <65%	60.0%
7	65 <75%	70.0%
8	75 <85%	80.0%
9	85 <95%	90.0%
F	95 <100%	97.5%

TABLE 3. Summary Chi-square statistics for the major aspen communities in the ungulate impact categories on the Gardiner RD, Gardiner, MT. [1] Aspen community type code numbers (see Table 4, in Appendix A).

Ungulate Impact Frequency Exected Residual Row % Col. %	Potr/ Tall Forb 1[1]	Potr/ Syal/ Tall Forb 2	Potr/ Syal/ Caru 5	Potr/ Artr 14	Potr/ Saspp 24	Potr-Abla/ Syal/ Thoc 43	Potr-Pame/ Syal 50	Potr-Pame/ Caru 52	Potr/ Scree 58	Potr-Pien/ Smst 61	Potr-Pame/ Saspp 63	Potr-Pame/ Scree 64	Potr-Pien/ Saspp 66	Total Col %
Low Impact														
Frequency	1	7	7	0	14	3	5	1	11	4	6	10	7	76
Exected	3.2	7.1	4.5	3.2	17.1	3.6	11.3	4.9	4.2	5.2	4.5	3.2	3.8	32.3
Residuals	-1.24	-.04	1.16	-1.80	-.76	-.30	-1.88	-1.75	3.31	-.52	.69	3.76	1.58	
Row %	1.3	9.2	9.2	0.0	18.4	4.0	6.6	1.3	14.5	5.3	7.9	13.2	9.2	
Col. %	10.0	31.8	50.0	0.0	26.4	27.3	14.3	6.7	84.6	25.0	42.9	100.0	58.3	
Moderate Impact														
Frequency	3	10	4	4	24	6	20	8	1	6	5	0	3	94
Exected	4	8.8	5.6	4	21.2	4.4	14	6	5.2	6.4	5.6	4	4.8	40.0
Residuals	-.50	-.40	-.68	.00	.61	.76	1.60	.82	-1.84	-.16	-.25	-2.00	-.82	
Row %	3.2	10.6	4.3	4.3	25.5	6.4	21.3	8.5	1.1	6.4	5.3	0.0	3.2	
Col. %	30.0	45.5	28.6	40.0	45.3	54.6	57.1	53.3	7.7	37.5	35.7	0.0	25.0	
High Impact														
Frequency	6	5	3	6	15	2	10	6	1	6	3	0	2	65
Exected	2.8	6.1	3.9	2.8	14.7	3.0	9.7	4.1	3.6	4.4	3.9	2.8	3.3	27.7
Residuals	1.94	-.44	6.0	1.94	.09	-.60	.10	.91	-1.37	.75	-.44	-1.68	-.72	
Row %	9.2	7.7	4.62	9.2	23.1	3.1	15.4	9.2	1.5	9.2	4.6	0.0	3.1	
Col. %	60.0	22.7	21.43	60.0	28.3	18.2	28.6	40.0	7.7	37.5	21.4	0.0	16.7	
Total	10	22	14	10	53	11	35	15	13	16	14	10	12	235
Row %	4.3	9.4	6.0	4.3	22.6	4.7	14.9	6.7	5.5	6.8	6.0	4.3	5.1	100.0

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI SQ	70.061	24	.000

TABLE 4. Definitions of major aspen community type abbreviations and numbers. Adapted and modified from Mueggler, W.F. 1976. Aspen Community Types of the Intermountain Region. USDA For. Serv. Gen. Tech. Rep. INT-250. Intermtn. For. and Range Res. Sta., Ogden, UT. Aspen community numbers 58, 61, 64, and 66 are additional aspen community types defined on the Gardiner RD for uniqueness or management considerations (see Appendix D).

Name	Abbreviation	Community number
Populus tremuloides/ Tall Forb	POTR/TALL FORB	1
Populus tremuloides/Symphoricarpos albus/ Tall Forb	POTR/SYAL/TALL FORB	2
Populus tremuloides/Symphoricarpos albus/ Calamagrostis rubescens	POTR/SYAL/CARU	5
Populus tremuloides/ Artemisia tridentata	POTR/ARTR	14
Populus tremuloides/Salix spp.	POTR/SASP	24
Populus tremuloides-Abies lasiocarpa/ Symphoricarpos albus/ Thalictrum occidentalis	POTR-ABLA/SYAL/THOC	43
Populus tremuloides-Pseudotsuga menziesii/ Symphoricarpos albus	POTR-PSME/SYAL	50
Populus tremuloides-Pseudotsuga menziesii/ Calamagrostis rubescens	POTR-PSME/CARU	52
Populus tremuloides/ Scree	POTR/SCREE	58
Populus tremuloides-Picea engelmannii/ Smilacina stellata	POTR-PIEN/SMST	61
Populus tremuloides-Pseudotsuga menziesii/ Salix spp.	POTR-PSME/SASP	63
Populus tremuloides-Pseudotsuga menziesii/ Scree	POTR-PSME/SCREE	64
Populus tremuloides-Picea engelmannii/ Salix spp.	POTR-PIEN/SASP	66

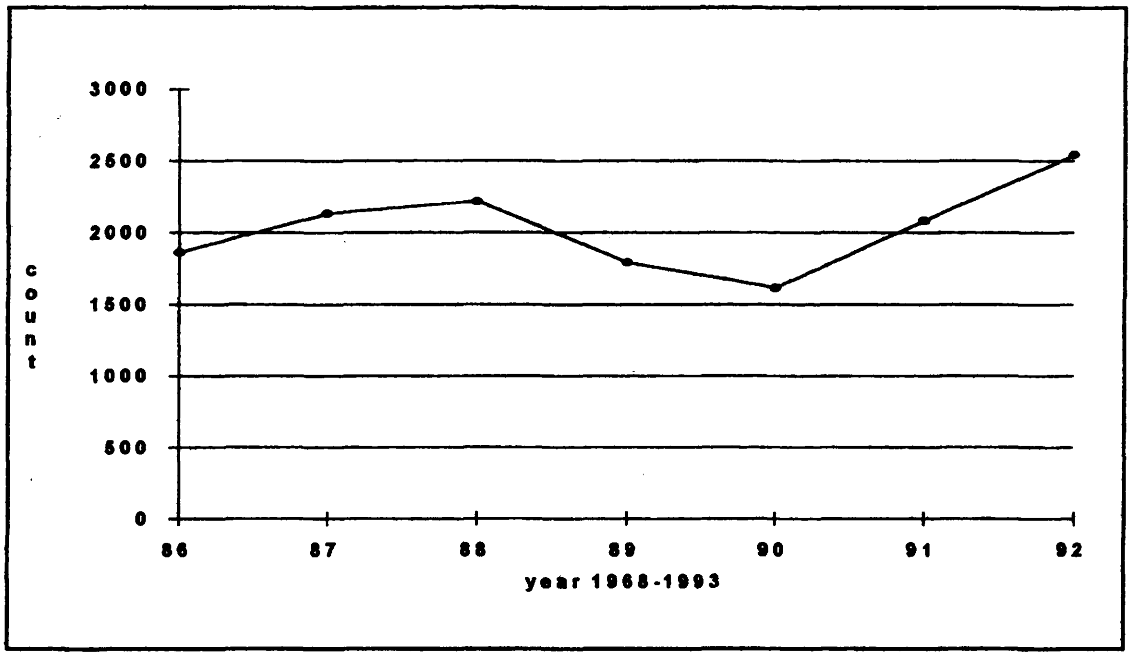

Fig. 4. Mule deer census counts for the Nothern Winter Range north of Yellowstone National Park. Data was adapted from aerial censuses taken by the Northern Range Cooperative Working Group (YNP, USFS, and Montana FW & P).

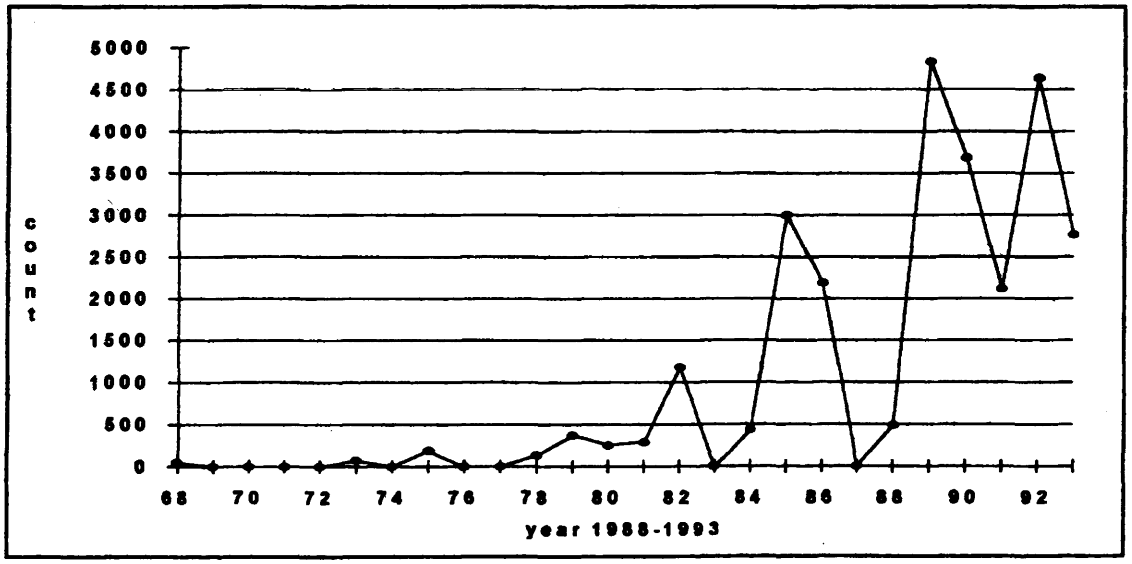

Fig. 3. Elk census counts for the Northern Winter Range north of Yellowstone National Park. Counts for Tom Miner have been included. No census was taken for 1969, 1970, 1971, 1972, 1974, 1976, 1977, 1983, and 1987 for either areas. Census numbers for 1968, 1973, 1975, 1978, 1979, 1980, 1981, and 1984 are for Tom Miner only. Data was adapted from aerial censuses taken by the Northern Range Cooperative Working Group (YNP, USFS, and Montana FW & P).

TABLE 5. Summary chi-square statistics for scree and non-scree communities in low, moderate, and high ungulate impact categories. Gardiner RD, Gardiner, MT.

Ungulate Impact Frequency Expected Residuals Row % Col %	Scree communities	Non-scree communities	Total Col %
Low Impact			
Frequency	21	55	76
Expected	7.4	68.6	332.3
Residuals	4.97	-1.64	
Row %	27.6	72.4	
Col %	91.3	25.9	
Moderate Impact			
Frequency	1	93	94
Expected	9.2	84.8	40.0
Residuals	-2.70	.89	
Row %	1.1	98.9	
Col %	4.4	43.9	
High Impact			
Frequency	1	64	65
Expected	6.4	58.6	27.6
Residuals	-2.13	.70	
Row %	1.5	98.5	
Col %	4.4	30.2	
Total	23	212	235
Row %	9.8	90.2	100.0

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI SQ	40.519	2	.000

TABLE 6. Summary chi-square statistics for low, moderate and high ungulate impact categories in aspen stands less than and greater than five hundred meters of main roads and human habitations. On the Gardiner RD, Gardiner, MT.

Ungulate Impacts Frequency Expected Residuals Row % Col %	Less than 500 meters from main roads and human habitations	Greater than 500 meters from main roads and human habitations	Total Col %
Low Impact			
Frequency	27	32	59
Expected	18.68	40.32	21.22
Residuals	1.93	-1.31	
Row %	45.76	54.24	
Col %	30.68	16.84	
Moderate Impact			
Frequency	27	92	119
Expected	37.67	81.33	42.81
Residuals	-1.74	1.18	
Row %	22.69	77.31	
Col %	30.68	48.62	
High Impact			
Frequency	34	66	190
Expected	31.65	68.35	35.97
Residuals	.42	-.28	
Row %	34.00	66.00	
Col %	38.64	34.74	
Total	88	190	278
Row %	31.65	68.35	100.00

TEST STATISTICS	VALUE	DF	PROB
PEARSON CHI-SQ	10.104	2	.006

TABLE 7. Summary chi-square statisitcs for low, moderate, and high ungulate impact categories in aspen communities located on allotment versus non-allotment lands. Gardiner RD, Gardiner, MT.

Ungulate Impacts Frequency Expected Residuals Row % Col %	Aspen communities on allotment lands	Aspen communities on Non-allotment lands	Total Col %
Low Impact Frequency Expected Residuals Row % Col %	 45 45.40 -.06 58.44 26.32	 32 31.60 .07 41.56 26.89	 77 26.55
Moderate Impact Frequency Expected Residuals Row % Col %	 83 71.35 1.38 68.60 48.54	 38 49.65 -1.65 31.40 31.93	 121 41.72
High Impact Frequency Expected Residuals Row % Col %	 43 54.25 -1.53 46.74 25.15	 49 37.75 1.83 53.26 41.18	 92 31.72
Total Row %	171 58.97	119 41.03	290 100.0

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI SQ	10.330	2	.006

TABLE 8. Summary chi-square statistics comparing grass and non-grass aspen community type occurrence on allotment versus non-allotment lands. Gardiner RD, Gardiner, MT.

Allotment Status Frequency Expected Residuals Row % Col %	Non-grass community types	Grass community types	Total Col %
Non-allotment Frequency Expected Residuals Row % Col %	 92 91.92 .01 77.31 41.07	 27 27.08 -.02 22.69 40.91	 119 41.03
Allotment Frequency Expected Residuals Row % Col %	 132 132.08 -.01 77.19 58.93	 39 38.92 .01 22.81 59.09	 171 58.97
Total Row %	224 77.24	66 22.76	290 100.0

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI-SQ	.001	1	.981

TABLE 9. Summary chi-square statistics comparing occurrence of aspen communities with grazing/trampling sensitive forbs (*Heracleum lanatum, Epilobium angustifolium,* and *Thalicturm spp.*) on allotment versus non-allotment lands. Gardiner RD, Gardiner, MT.

Allotment Status Frequency Expected Residuals Row % Col %	Aspen communities with out grazing sensitive species.	Aspen communities with grazing sensitive species.	Total Col %
Non-allotment Frequency Expected Residuals Row % Col %	 21 30.78 -1.76 17.65 28.00	 98 88.22 1.04 82.35 45.58	 119 41.03
Allotment Frequency Expected Residuals Row % Col %	 54 44.22 1.47 31.58 72.00	 117 126.78 -.87 68.42 54.42	 171 58.97
Total Row %	75 25.86	215 74.14	290 100.0

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI-SQ	7.103	1	.008

TABLE 10. Mean canopy coverage for grazing/trampling sensitive species (*Heracleum lanatum, Epilobium angustifolium,* and *Thalictrum spp.*) in aspen communities on allotment versus non-allotment lands on the Gardiner R D, Gardiner, MT.

Allotment stands Mean (SEM)	Non-allotment stands Mean (SEM)
9.6 (1.2)	22.9 (2.5)

pooled variance t = 4.943, df=213, p < .000

TABLE 12. Mean canopy coverage for grazing/trampling resistant species (*Poa pratensis, Phleum pratense, Calamagrostis rubescens,* and *Fragaria spp.*) in aspen communities on allotment versus non-allotment lands on the Gardiner R D, Gardiner, MT.

Allotment stands Mean (SEM)	Non-allotment stands Mean (SEM)
60.4 (2.3)	39.9 (2.3)

pooled variance t = 6.181, df=269, p < .000

TABLE 13. Mean canopy coverage of grasses, forbs and shrubs in aspen communities located on allotment versus non-allotment lands on the Gardiner R D, Gardiner, MT.

Vegetation lifeform	Allotment stands Mean (SEM)	Non-allotment stands Mean (SEM)
Grass	82.3 (1.9)	75.7 (2.5)
Forb	44.2 (2.0)	69.2 (3.4)
Shrub	33.3 (2.1)	37.7 (3.3)

grasses: pooled variance t = 2.675, df=286, p < .008
forbs: pooled variance t = 6.222, df=286, p < .000
shrubs: pooled variance t = 1.316, df=286, p < .189

TABLE 11. Summary chi-square statistics comparing occurrence of aspen communities with grazing/trampling resistant species *(Poa pratensis, Phleum pratense, Calamagrostis rubescens,* and *Fragaria* spp.*)* on allotment versus non-allotment lands. Gardiner RD, Gardiner MT.

Allotment status Frequency Expected Residuals Row % Col %	Aspen communities without grazing resistant species	Aspen communities with grazing resistant species	Total Col %
Non-allotment Frequency Expected Residuals Row % Col %	 14 7.80 2.22 11.76 73.68	 105 111.20 -.59 88.24 38.75	 119 41.03
Allotment Frequency Expected Residuals Row % Col %	 5 11.20 -1.85 2.92 26.32	 166 159.80 .49 97.08 61.25	 171 58.97
Total Row %	19 6.55	271 93.45	290 100.00

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI-SQ	8.958	1	.003

TABLE 14. Summary chi-square statistics for aspen recruitment in the major aspen community types. Gardiner RD, Gardiner, MT.
[1] Aspen comunity type code numbers (see Table 4 in Appendix A).

Recruitment Frequency Expected Residuals Row % Col %	Potr/ Tall Forb 1[1]	Potr/ Syal/ Tall Forb 2	Potr/ Syal/ Caru 5	Potr/ Artr 14	Potr/ Saspp 24	Potr- Albia/ Syal/ Thoc 43	Potr- Psme/ Syal 50	Potr- Psme/ Caru 52	Potr/ Scree 58	Potr/ Pien/ Smst 61	Potr- Psme/ Saspp 63	Potr- Psme/ Scree 64	Potr/ Pien/ Saspp 66	Total Col %
No Recruitment Frequency Expected Residuals Row % Col %	 8 7.28 .27 4.68 80.00	 17 16.01 .25 9.94 77.27	 7 10.19 -1.00 4.09 50.00	 6 7.28 -.47 3.51 60.00	 43 38.57 .71 25.15 81.13	 7 8.00 -.35 4.09 63.64	 31 25.47 1.10 18.13 88.57	 14 10.91 .93 8.19 93.33	 2 9.46 -2.43 1.17 15.38	 15 11.64 .98 8.77 93.75	 10 10.19 -.06 5.85 71.43	 3 7.28 -1.59 1.75 30.00	 8 8.73 -.25 4.68 66.67	 171 72.77
Recruitment Frequency Expected Residuals Row % Col %	 2 2.72 -.44 3.13 20.00	 5 5.99 -.41 7.81 22.73	 7 3.81 1.63 10.94 50.00	 4 2.72 .77 6.25 40.00	 10 14.43 -1.17 15.63 18.87	 4 3.00 .58 6.25 36.36	 4 9.53 -1.79 6.25 11.43	 1 4.09 -1.53 1.56 6.67	 11 3.54 3.96 17.19 84.62	 1 4.36 -1.61 1.56 6.25	 4 3.81 .10 6.25 28.57	 7 2.72 2.59 3.13 70.00	 4 3.27 .40 6.25 33.33	 64 27.23
Total Row %	10 4.26	22 9.36	14 5.96	10 4.26	53 22.55	11 4.68	35 14.89	15 6.38	13 5.53	16 6.81	14 5.96	10 4.26	12 5.11	235 100

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI-SQ	49.544	12	.000

TABLE 15. Summary chi-square statistics comparing aspen recruitment in scree and non-scree aspen community types. Gardiner RD, Gardiner, MT.

Recruitment Status Frequency Expected Residuals Row % Col %	Scree aspen community types	Non-scree aspen community types	Total Col %
No recruitment Frequency Expected Residuals Row % Col %	 5 16.74 -2.87 2.92 21.74	 166 154.26 .94 97.08 78.30	 171 72.77
Recruitment Frequency Expected Residuals Row % Col %	 18 6.26 4.69 28.13 78.26	 46 57.74 -1.54 71.88 21.70	 64 27.23
Total Row %	23 9.79	212 90.21	235 100.00

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI-SQ	33.498	1	.000

TABLE 16. Summary chi-square statistics comparing aspen community recruitment (Kay's criterion) in low, moderate, and high ungulate impact categories. Gardiner RD, Gardiner, MT.

Ungulate impact Frequency Expected Residuals Row % Col %	Recruitment ratio fraction (recruitment/ non-recruitment) rec < 1	Recruitment ratio fraction (recruitment/ non-recruitment) rec => 1	Total Col %
Low Impact			
Frequency	58	51	109
Expected	83.50	25.50	31.87
Residuals	-2.79	5.05	
Row %	53.21	46.79	
Col %	22.14	63.75	
Moderate Impact			
Frequency	113	19	132
Expected	101.12	30.88	38.60
Residuals	1.18	-2.14	
Row %	85.61	14.39	
Col %	43.13	23.75	
High Impact			
Frequency	91	10	101
Expected	77.37	23.63	29.53
Residuals	1.55	-2.80	
Row %	90.10	9.90	
Col %	34.73	12.50	
Total	262	80	342
Row %	76.61	23.39	100.00

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI-SQ	49.519	2	.000

TABLE 17. Summary chi-square statistics comparing aspen community recruitment (Kay's criterion) in low, moderate, and high ungulate impact categories. Scree communities, communities in snow accumulation areas, and communities on slopes > 47% were excluded from this analysis. Gardiner RD, Gardiner, MT.

Ungulate Impact Frequency Expected Residuals Row % Col %	Recruitment ratio fraction (recruitment/ non-recruitment) rec < 1	Recruitment ratio fraction (recruitment/ non-recruitment) rec => 1	Total Col %
Low Impact Frequency Expected Residuals Row % Col %	 41 50.72 -1.37 69.49 17.15	 18 8.28 3.28 30.51 46.15	 59 21.22
Moderate Impact Frequency Expected Residuals Row % Col %	 107 102.31 .46 89.92 44.77	 12 16.69 -1.15 10.08 30.77	 119 42.81
High Impact Frequency Expected Residuals Row % Col %	 91 85.97 .54 91.00 38.08	 9 14.03 -1.34 9.00 23.08	 100 35.97
Total Row %	239 85.97	39 14.03	278 100.00

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI-SQ	16.918	2	.000

Table 18. Summary chi-square statistics comparing aspen community recruitment (recruitment stem production criterion) in low, moderate, and high ungulate impact categories. All stands were included in this analysis. Gardiner RD, Gardiner, MT.

Ungulate Impacts Frequency Expected Residuals Row % Col %	Recruitment ratio fraction (recruitment/ non-recruitment) rec=0	Recruitment ratio fraction (recruitment/ non-recruitment) 0<rec<.5	Recuitment ratio fraction (recruitment/ non-recruitment) .5<=rec<1	Recruitment ratio fraction (recritment/ non-recruitment) rec=>1	Total Col %
Low Impact					
Frequency	28	16	14	51	109
Expected	51.63	18.17	13.70	25.50	31.87
Residuals	-3.29	-.51	.08	5.05	
Row %	25.69	14.68	12.84	46.79	
Col %	17.28	28.07	32.56	63.73	
Moderate Impact					
Frequency	75	20	18	19	132
Expected	62.53	22.00	16.60	30.88	38.60
Residuals	1.58	-.43	.34	-2.14	
Row %	56.82	15.15	13.64	14.39	
Col %	46.30	35.09	41..86	23.75	
High Impact					
Frequency	59	21	11	10	101
Expected	47.84	16.83	12.70	23.63	29.53
Residuals	1.61	1.02	-.48	-2.80	
Row %	58.42	20.79	10.89	9.90	
Col %	36.42	36.84	25.58	12.50	
Total	162	57	43	80	342
Row %	47.37	16.67	12.57	23.39	100.00

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI-SQ	55.667	6	.000

TABLE 19. Summary chi-square statistics comparing aspen community recruitment (recruitment stem production criterion) in low, moderate, and high ungulate impact categories. Scree communities, communities in snow accumulation areas, and communities on slopes >47% were excluded from this analysis. Gardiner RD, Gardiner, MT.

Ungulate Impacts Frequency Expected Residuals Row % Col %	Recruitment ratio fraction (recruitment/ non-recruitment) rec=0	Recruitment ratio fraction (recruitment/ non-recruitment) 0<rec<.5	Recuitment ratio fraction (recruitment/ non-recruitment) .5<=rec<1	Recruitment ratio fraction (recritment/ non-recruitment) rec=>1	Total Col %
Low Impact					
Frequency	24	9	8	18	59
Expected	33.53	10.40	6.79	6.79	21.22
Residuals	-1.65	-.43	.46	3.38	
Row %	40.68	15.25	13.56	30.51	
Col %	15.19	18.37	25.00	46.15	
Moderate					
Impact	75	19	13	12	119
Frequency	67.63	20.97	13.70	16.69	42.81
Expected	.90	-.43	-.19	-1.15	
Residuals	63.03	15.97	10.992	10.08	
Row %	47.47	38.78	40.63	30.77	
Col %					
High Impact					
Frequency	59	21	11	9	100
Expected	56.83	17.63	11.51	14.03	35.97
Residuals	.29	.80	-.15	-1.34	
Row %	59.00	21.00	11.00	9.00	
Col %	37.34	42.86	34.38	23.08	
Total	158	49	32	39	278
Row %	56.83	17.63	11.51	14.03	100.0

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI-SQ	19.432	6	.003

TABLE 20. Summary chi-square statistics comparing aspen community recruitment (Kay's criterion) on allotment versus non-allotment lands. Gardiner RD, Gardiner, MT.

Allotment Status Frequency Expected Residuals Row % Col %	Recruitment ratio fraction (recruitment stems/non-recruitment stems) rec < 1	Recruitment ratio fraction (recruitment stems/non-recruitment stems) rec => 1	Total Col %
Non-allotment Frequency Expected Residuals Row % Col %	 86 96.84 -1.10 72.27 36.44	 33 22.16 2.30 27.73 61.11	 119 41.03
Allotment Frequency Expected Residuals Row % Col %	 150 139.16 .92 87.72 63.56	 21 31.84 -1.92 12.28 38.89	 171 58.97
Total Row %	237 81.38	53 18.62	290 100.0

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI-SQ	11.05	1	.002

TABLE 21. Summary chi-square statistics comparing aspen community recruitment (recruitment stem production criterion) on allotment versus non-allotment lands. Gardiner RD, Gardiner, MT.

Allotment Status Frequency Expected Residuals Row % Col %	Recruitment ratio fraction (recruitment/ non-recruitment) rec=0	Recruitment ratio fraction (recruitment/ non-recruitment) 0<rec<.5	Recuitment ratio fraction (recruitment/ non-recruitment) .5<=rec<1	Recruitment ratio fraction (recritment/ non-recruitment) rec=>1	Total Col %
Non-allotment Frequency Expected Residuals Row % Col %	 27 61.14 -4.37 22.69 18.12	 30 20.52 2.09 25.21 60.00	 29 15.18 3.55 24.37 78.38	 33 22.16 2.30 27.73 61.11	 119 41.03
Allotment Frequency Expected Residuals Row % Col %	 122 87.86 3.64 71.35 81.88	 20 29.48 -1.75 11.70 40.00	 8 21.82 -2.96 4.68 21.62	 21 31.84 -1.92 12.28 38.89	 171 58.97
Total Row %	149 51.38	56 17.24	36 12.76	49 18.62	290 100.0

TEST STATISTICS	VALUE	DF	PROB
PEARSON CHI-SQ	70.09	3	.000

TABLE 22. Summary chi-square statistics comparing aspen community recruitment in allotment versus non-allotment aspen stands in the low ungulate impact category. Gardiner RD, Gardiner, MT.

Low ungulate impacts

Allotment Status Frequency Expected Residuals Row % Col %	Recruitment ratio fraction (recruitment/ non-recruitment) rec=0	Recruitment ratio fraction (recruitment/ non-recruitment) 0<rec<.5	Recuitment ratio fraction (recruitment/ non-recruitment) .5<=rec<1	Recruitment ratio fraction (recritment/ non-recruitment) rec=>1	Total Col %
Non-allotment Frequency Expected Residuals Row % Col %	 3 9.56 -2.12 9.38 13.04	 4 4.99 -.44 12.50 33.33	 7 4.57 1.14 21.88 63.64	 18 12.88 1.43 56.25 58.06	 32 41.56
Allotment Frequency Expected Residuals Row % Col %	 20 13.44 1.79 44.44 86.96	 8 7.01 .37 17.78 66.67	 4 6.43 -.96 8.89 36.36	 13 18.12 -1.20 28.89 41.94	 45 58.43
Total Row %	23 29.87	12 15.58	11 14.29	31 40.26	77 100.0

TEST STATISTICS	VALUE	DF	PROB
PEARSON CHI-SQ	13.719	3	.003

TABLE 23. Summary chi-square statistics comparing aspen community recruitment in allotment versus non-allotment aspen stands in the moderate ungulate impact category. Gardiner RD, Gardiner, MT.

Moderate ungulate impacts

Allotment Status Frequency Expected Residuals Row % Col %	Recruitment ratio fraction (recruitment/ non-recruitment) rec=0	Recruitment ratio fraction (recruitment/ non-recruitment) 0<rec<.5	Recuitment ratio fraction (recruitment/ non-recruitment) .5<=rec<1	Recruitment ratio fraction (recritment/ non-recruitment) rec=>1	Total Col %
Non-allotment Frequency Expected Residuals Row % Col %	7 21.96 -3.20 18.42 10.00	11 5.97 2.06 28.95 57.89	12 5.02 3.11 31.58 75.00	8 5.02 1.33 21.05 50.00	38 31.40
Allotment Frequency Expected Residuals Row % Col %	63 48.02 2.16 75.90 90.00	8 13.03 -1.39 9.64 42.11	4 10.98 -2.11 4.82 25.00	8 10.98 -.90 9.64 50.00	45 68.60
Total Row %	70 57.85	19 15.70	16 13.22	16 13.22	121 100.0

TEST STATISTICS	VALUE	DF	PROB
PEARSON CHI-SQ	37.761	3	.000

TABLE 24. Summary chi-square statistics comparing aspen community recruitment in allotment versus non-allotment aspen stands in the high ungulate impact category. Gardiner RD, Gardiner, MT.

High ungulate impacts

Allotment Status Frequency Expected Residuals Row % Col %	Recruitment ratio fraction (recruitment/ non-recruitment) rec=0	Recruitment ratio fraction (recruitment/ non-recruitment) 0<rec<.5	Recuitment ratio fraction (recruitment/ non-recruitment) .5<=rec<1	Recruitment ratio fraction (recritment/ non-recruitment) rec=>1	Total Col %
Non-allotment Frequency Expected Residuals Row % Col %	17 29.83 -2.35 34.69 30.36	15 10.12 1.53 30.61 78.95	10 5.33 2.03 20.41 100.00	7 3.73 1.69 14.29 100.00	49 53.26
Allotment Frequency Expected Residuals Row % Col %	39 26.17 2.51 90.70 69.64	4 8.88 -1.64 9.30 21.05	0 4.67 -2.16 .00 .00	0 3.27 -1.81 .00 .00	43 46.74
Total Row %	56 60.87	19 20.65	10 10.87	7 7.61	92 100.0

TEST STATISTICS	VALUE	DF	PROB
PEARSON CHI-SQ	31.755	3	.000

TABLE 25. Summary chi-square statistics comparing aspen community recruitment (Kay's criterion) less than 500 m from main roads or human habitations versus greater than 500 m. Gardiner RD, Gardiner, MT.

Distance Frequency Expected Residuals Row % Col %	Recruitment ratio fraction (recruitment stems/non-recruitment stems) rec<1	Recruitment ratio fraction (recruitment stems/non-recruitment stems) rec=>1	Total Col %
Less than 500m Frequency Expected Residuals Row % Col %	 66 75.65 -1.11 75.00 27.62	 22 12.35 2.75 25.00 56.41	 88 31.65
Greater than 500m Frequency Expected Residuals Row % Col %	 173 163.35 .76 91.05 72.38	 17 26.65 -1.87 8.95 43.59	 190 68.35
Total Row %	239 85.97	39 14.03	278 100.0

TEST STATISTICS	VALUE	DF	PROB
PEARSON CHI-SQ	12.850	1	.000

TABLE 26. Summary chi-square statistics for aspen community recruitment categories by distance from major roads or human habitations. Gardiner RD, Gardiner, MT.

Distance Frequency Expected Residuals Row % Col %	Recruitment ratio fraction (rec. stems/ non-rec. stems) rec=0	Recruitment ratio fraction (rec. stems/ non-rec. stems) 0<rec<.5	Recruitment ration fraction (rec. stems/ non-rec. stems) .5<=rec<1	Recruitment ration fraction (rec. stems/ non-rec. stems) rec=>1	Total Col %
Less than 500m Frequency Expected Residuals Row % Col %	27 50.01 -3.25 30.68 17.09	22 15.51 1.65 25.00 44.90	17 10.13 2.16 19.32 53.13	22 12.35 2.75 25.00 56.41	88 31.65
Greater than 500m Frequency Expected Residuals Row % Col %	131 107.99 2.21 68.95 82.91	27 33.49 -1.12 14.21 55.10	15 21.87 -1.47 7.89 46.88	17 26.65 -1.87 8.95 43.59	190 68.35
Total Row %	158 56.83	49 17.63	32 11.51	39 14.03	278 100.0

TEST STATISTIC	VALUE	DF	PROB
PEARSON CHI-SQ	37.333	3	.000

Appendix B: Maps and Forms

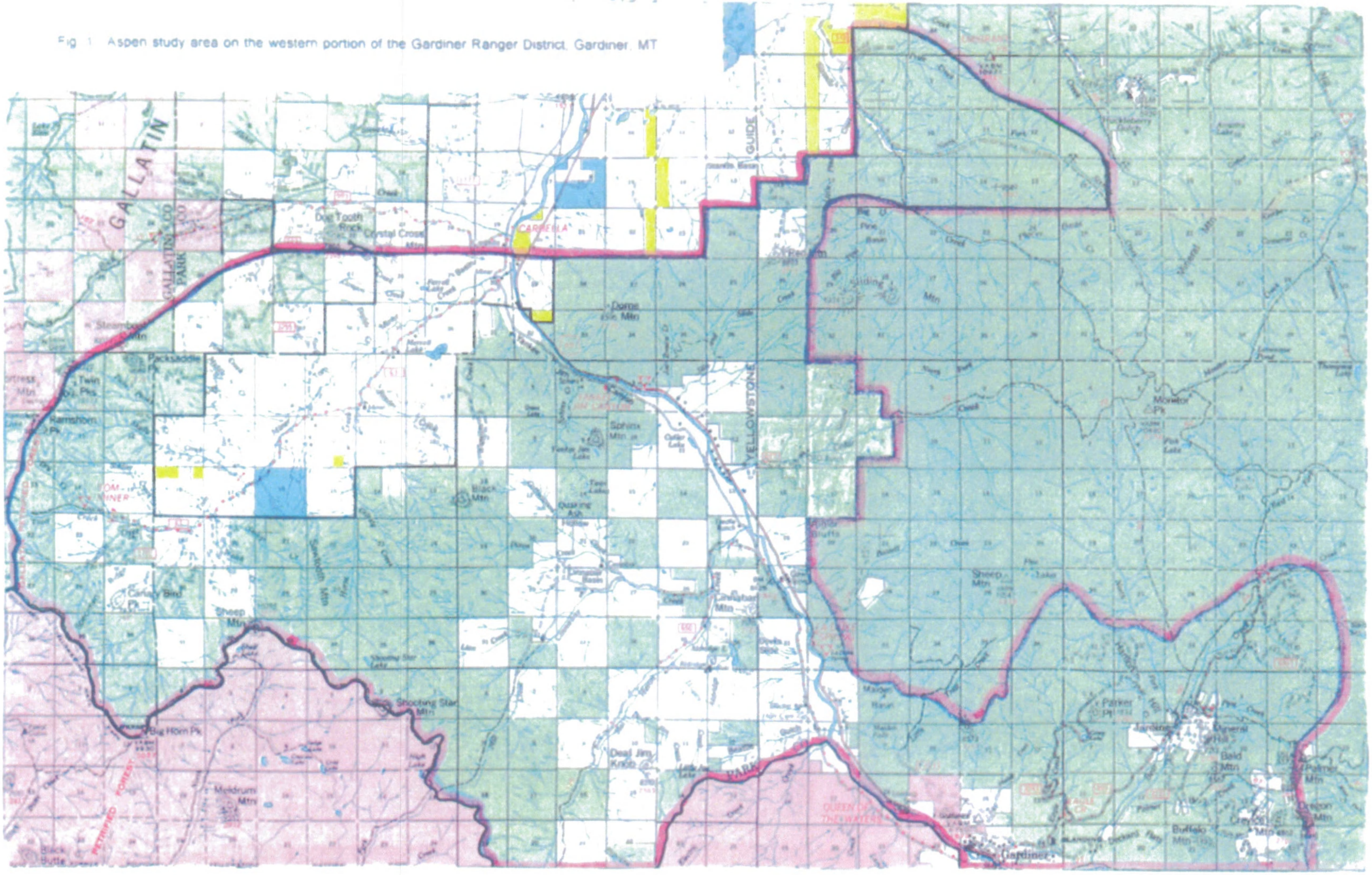

Fig. 1. Aspen study area on the western portion of the Gardiner Ranger District, Gardiner, MT

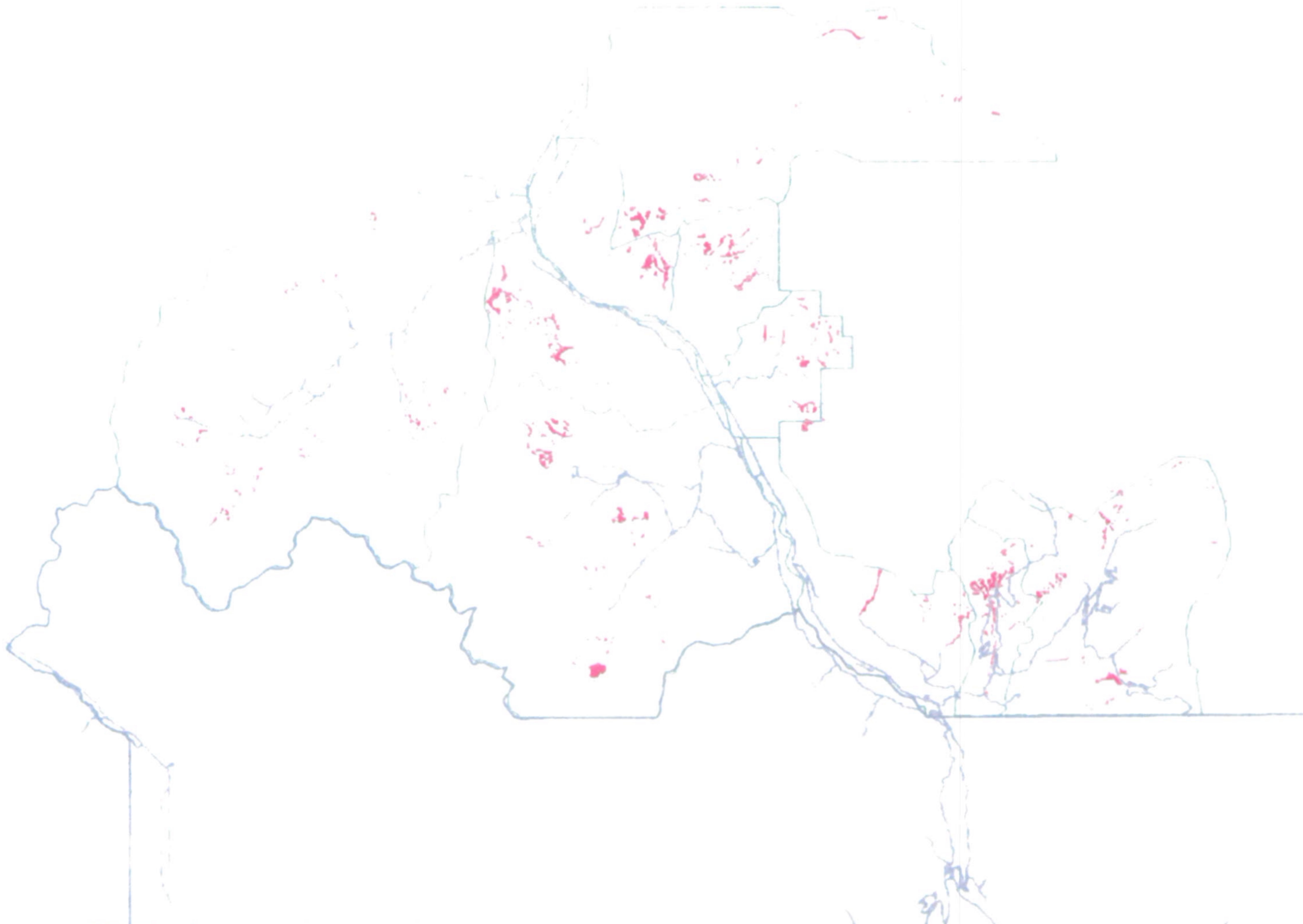

Fig. 2. GIS map of the aspen stands, roads, and drainages on the study area. Gardiner RD, Gardiner, MT.

```
IDENTIFICATION AND LOCATION:
                Fo  D  P   Yr  D   Plt
F1 KEY ID _ _ _ _ _ _ _ _ _ _ _     F2 Examiner _______________  F3 Edit _
   Survey    Mo     Day    Project#      Plot Types        PltRL    PltW
F4|_ _ _| F5|_ _| F6|_ _| F7|_ _ _ _|F8|_ _ _ _ _ _ _ _ _|F9|_ _ _|F10|_ _ _|
F11 GS Quad |_ _ _ _ _ _ _ _| F12 Quad scale |_ _ _ _ _ _ _|
F13 Quad Name |_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _|
F14 Photo ID |_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _|
F15 Photo Scale |_ _ _ _ _ _ _|
F16-18 Range: Allotment |_ _ _ _ _| Map Unit |_ _ _| Extension |_ _|
F19 Landtype Assoc. |_ _ _ _ _ _ _ _ _ _| F20 Landtype |_ _ _ _ _ _ _ _ _ _ _|
F21 Forest Mgmt. Area |_ _ _ _ _ _ _| F22 Forest Cap. Area |_ _ _ _ _ _ _|

ENVIRONMENTAL FEATURES:
F23 Elev. |_ _ _ _ _| F24 Asp. |_ _ _| F25 Slope |_ _| F26 Parent Mat. |_ _|
F27 Physiographic Position |_ _| F28 Soil |_ _-_ _|

VEGETATION STRUCTURE:
F29 St |_| F30 Ct |_ _ _| F31 Ht |_ _ _ _ _ _|
F32 Cover Type |_ _ _ _| |_ _| F33 Aspen Stand Physiognomy |_|
F34 Conifers present and reproducing successfully |_|
BAF |_ _| * No. trees |_ _| = F35 Basal Area |_ _ _|
F36 DBH Dom (Conifer if present) |_ _ _| F37 DBH Dom Aspen |_ _ _|
F38 Total Tree Cover |_| F39 Total Aspen Cover |_|
F40 Mature |_| F41 Pole |_| F42 Sapling |_| F43 Seedling |_|
F44 Total Shrub Cover |_| F45 Tall |_| F46 Mid |_| F47 Low |_|
F48 Dead Regen. |_ _ _ _ _| F49 Dead Down |_ _ _ _ _|
F50 Total Recruitment Stems |_ _ _ _ _|
F51 Total Nonrecruitment Stems |_ _ _ _ _| F52 Ratio (Rec./Nonrec.) |_|

ANIMAL USE AND DISTRUBANCE HISTORY:
F53-58 Animal Use Evidence: 1 |_| 2 |_| 3 |_| 4 |_| 5 |_| 6 |_|
F59 Bole Scarring |_| F60 Browse Hedging |_| F61 Scarring Extent |_|
                   Type   I  Freq  Yr  Seas                    Type   I  Freq  Yr  Seas
F62-66 Dis. 1 |_ _ _| _ | _ | _ _ | _ | F67-71 Dis. 2 |_ _ _| _ | _ | _ _ | _ |
F72-76 Dis. 3 |_ _ _| _ | _ | _ _ | _ | F77-81 Dis. 4 |_ _ _| _ | _ | _ _ | _ |

COMMENTS:
F82 COMMENT1: ________________________________________________
              ________________________________________________
              ________________________________________________

F83 COMMENT2: ________________________________________________
              ________________________________________________
              ________________________________________________
              ________________________________________________
```

Fig. 49. Field form for recording aspen study data. Gardiner RD, Gardiner, MT.

Appendix C: Bolescars and Browsing Classes

Fig. 5. Low degree of bole scarring on aspen. Predominantly caused by ungulates scraping the bark from the boles with their teeth. On the Gardiner RD, Gardiner, MT.

Fig. 6. Moderate degree of bole scarring on aspen. Predominantly caused by ungulates scraping the bark from the boles with their teeth. Gardiner RD, Gardiner, MT

Fig. 7. High degree of bole scarring on aspen. Predominantly caused by ungulates scraping the bark from the boles with their teeth. Gardiner RD, Gardiner, MT.

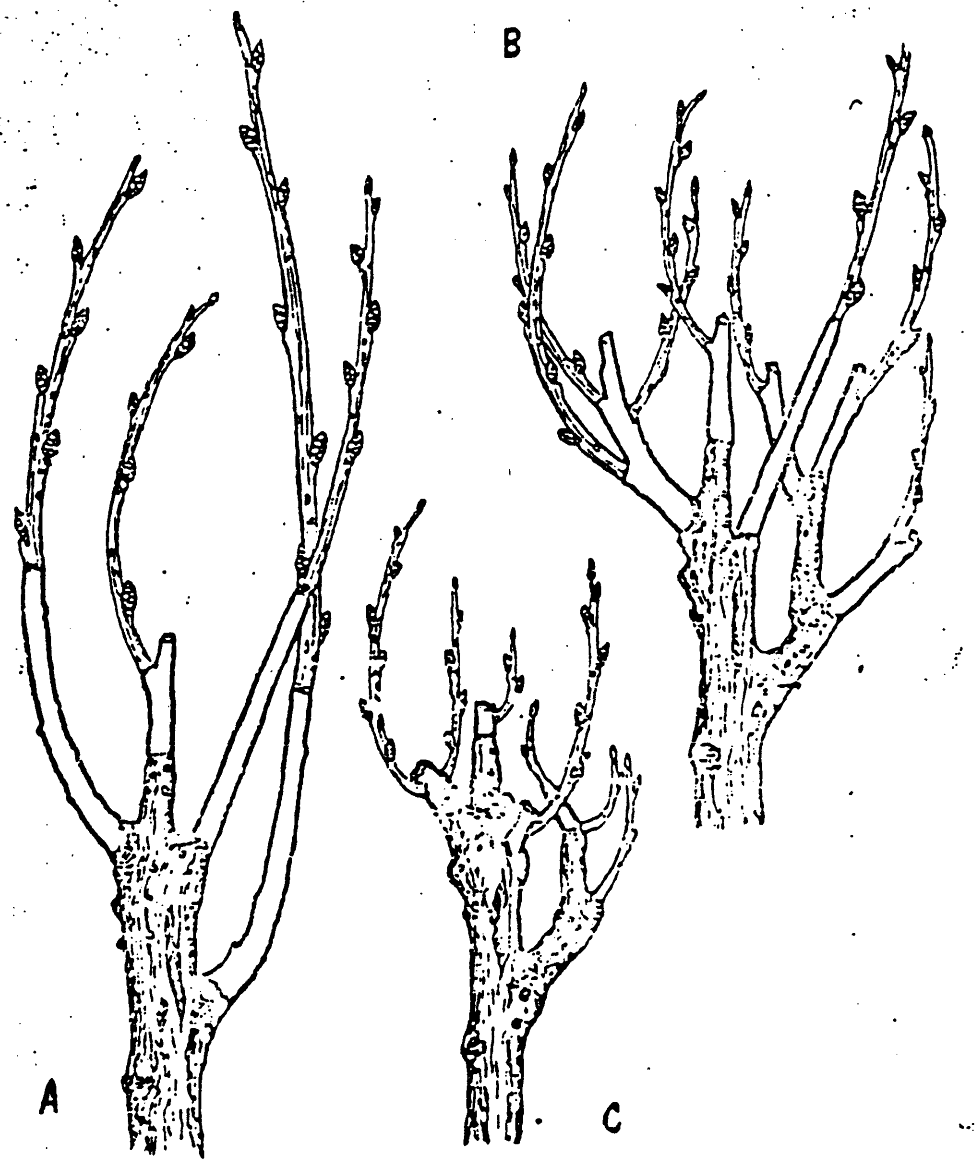

Fig. 8. Degrees of hedging A. low, B. moderate, and C. high. Adapted from Peek 1981. Range 453 handout on shrub measurements. Univ. of Montana, Missoula, MT.

Appendix D: Additional Aspen Community Types

Additional Aspen Community Types classified on the Gardiner Ranger District

I. Aspen Scree Community Types:

Aspen scree community types are typlified by aspen community growing in talus slopes or rock fields.

1) Populus tremuloides/ Scree (POTR/SCREE c.t.s)

These communities have an overstory of aspen dominated by aspen. Conifers are either incidentals or represented by less than 10% canopy coverage. The understory is characterized by sparse vegetation in a rock substrate.

2) Populus tremuloides-Psuedotsuga menziesii (POTR-PSME/SCREE c.t.s)

These communities have an overstory dominated by Douglas fir (*Psuedotsuga menziesii*) mixed with aspen. The understory is characterized by sparse vegetation in a rock substrate. In some of these communities there exists heavy accumulations of fallen Douglas fir needles occasionally combined with shed branches and moss.

3) Populus tremuloides/Abies lasiocarpa (POTR-ABLA/SCREE c.t.s)

These community types have an overstory dominated by Subalpine fir (*Abies lasiocarpa*) mixed with aspen. The understory is characterized by sparse vegetation in a rock substrate.

II. Aspen-Picea Community Types:

These community types were located at low elevations (5000-6000 ft.) in riparian areas. These communities are found along riparian areas where the forest-sagebrush ecotone occurs. The aspen and spruce (*Picea engelmannii*) exist in these areas because of subirrigation. These community types were recognized as being eventually seral to Pfister's PIEN habitat types (Pfister et al. 1972). Therefore, to maintain consistancy with Pfister classification system I named these community types with respect to the eventual climax vegetation.

1) POTR-PIEN/SMST c.t.s

These community types are seral to the PIEN/SMST habitat type. Understory is characteristic of the PIEN/SMST habitat type (Pfister et al. 1972).

2) POTR-PIEN/EQAR c.t.s

These mesic community types are seral to the PIEN/EQAR habitat type. Understory is characteristic of the PIEN/EQAR habitat type (Pfister et al. 1972).

III. Aspen-Juniper Community Types:

1) POTR/JUSC c.t.s

This community type occurred at the lowest elevation where aspen occured 5000-5500 ft. These communities occupied dry sites on south to south-west slopes often where stream courses disappeared or entered sagebrush dominated slopes. They were occasionally found associated with seeps on south to south-west slopes at low to mid elevations. The overstory consisted of aspen and western juniper (*Juniperus scopulorum*). The understory was commonly dominated by grasses (*Poa pratensis, Elymus cinerius,* and *Festuca idahoensis*). These communities are possibly grazing disclimaxes due to livestock and/or wintering ungulates.

IV. Aspen-Willow Community Types:

1) Populus tremuloides/Salix spp. (POTR/SASP c.t.s)

This riparian community type is typically associated with streams, seeps, and areas of high water tables. Aspen stands with greater than 10% canopy coverage of Salix spp. were grouped into this community type.

2) Populus tremuloides-Psuedotsuga menziesii/Salix spp. (POTR-PSME/SASP c.t.s)

This community type is POTR/SASP c.t.s which have a great than 10% canopy coverage of Douglas fir.

3) Populus tremuloides-Picea englemannii/Salix spp. (POTR-PIEN/SASP c.t.s)

This community type is POTR/SASP c.t.s which have greater than 10% canopy coverage of Spruce.