Elk effects on sagebrush-grassland after fire on Yellowstones Northern Range
by Reyer Jan Rens

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

Abstract:
There continues to be concern for the shrub communities of the Northern Yellowstone Winter Range (NYWR). This concern for the decline of big sagebrush (Artemisia tridentata Nutt.) began during the first half of the twentieth century. It is not well understood how these communities will recover from the wildfires of 1988. Intense levels of herbivory allowed under the National Park Service (NPS) policy of natural regulation has generated additional concern. It was my objective to determine the effect of elk browsing on shrub community recovery from fire on the Black-tailed Deer Plateau of the NYWR. The null hypotheses I tested were: 1) that the shrubs of a mountain big sagebrush (A. t. vaseyana [Rydb.] Beetle) habitat type will recover from fire at the same rate with or without elk browsing, and 2) that elk herbivory would have no effect on the herbaceous component of this habitat type, regardless of bum treatment. I sampled 12 sites. Significant differences were found in the development of protected and browsed shrubs. Big sagebrush measurements were taken in and out of exclosures at 5 environmentally paired, protected and browsed sites dominated by sagebrush. Big sagebrush canopy cover at the 5 sites averaged 20.0% with protection and 9.7% where browsed ($P < 0.01$). Individual plants produced 76% more grams of forage for winter where protected ($P < 0.01$). Big sagebrush densities were not different ($P < 0.01$). Sprouting shrubs, rubber rabbitbrush (Chrysothamnus nauseosus (Pallas ex Pursh) Britt.), green rabbitbrush (C. viscidiflorus (Hook) Nutt.) and gray horsebrush (Tetradymia canescens DC.) made up a smaller part of the community and generally responded the same as big sagebrush. Coverages for all herbaceous species, perennial grasses, forbs, Idaho fescue (Festuca idahoensis Elmer), bluebunch wheatgrass (Agropyron spicatum (Pursh) Gould), and other grass species were compared by treatment. Some small differences were found in herbaceous components. Impacts on shrub communities from cumulative and interactive effects of wildfire and intense herbivory have implications for many NYWR values.

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A thesis submitted in partial fulfillment
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APPROVAL

of a thesis submitted by

Reyer Jan Rens

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

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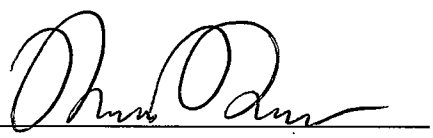
Signature 

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ABSTRACT

There continues to be concern for the shrub communities of the Northern Yellowstone Winter Range (NYWR). This concern for the decline of big sagebrush (*Artemisia tridentata* Nutt.) began during the first half of the twentieth century. It is not well understood how these communities will recover from the wildfires of 1988. Intense levels of herbivory allowed under the National Park Service (NPS) policy of natural regulation has generated additional concern. It was my objective to determine the effect of elk browsing on shrub community recovery from fire on the Black-tailed Deer Plateau of the NYWR. The null hypotheses I tested were: 1) that the shrubs of a mountain big sagebrush (*A. t. vaseyana* [Rydb.] Beetle) habitat type will recover from fire at the same rate with or without elk browsing, and 2) that elk herbivory would have no effect on the herbaceous component of this habitat type, regardless of burn treatment. I sampled 12 sites. Significant differences were found in the development of protected and browsed shrubs. Big sagebrush measurements were taken in and out of exclosures at 5 environmentally paired, protected and browsed sites dominated by sagebrush. Big sagebrush canopy cover at the 5 sites averaged 20.0% with protection and 9.7% where browsed ($P \leq 0.01$). Individual plants produced 76% more grams of forage for winter where protected ($P \leq 0.01$). Big sagebrush densities were not different ($P \leq 0.01$). Sprouting shrubs, rubber rabbitbrush (*Chrysothamnus nauseosus* (Pallas ex Pursh) Britt.), green rabbitbrush (*C. viscidiflorus* (Hook) Nutt.) and gray horsebrush (*Tetradymia canescens* DC.) made up a smaller part of the community and generally responded the same as big sagebrush. Coverages for all herbaceous species, perennial grasses, forbs, Idaho fescue (*Festuca idahoensis* Elmer), bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Gould), and other grass species were compared by treatment. Some small differences were found in herbaceous components. Impacts on shrub communities from cumulative and interactive effects of wildfire and intense herbivory have implications for many NYWR values.

CHAPTER 1

INTRODUCTION

Ungulates rely heavily on sagebrush (*Artemisia* L.) habitat types for winter foraging on the Northern Yellowstone Winter Range (NYWR) (Wambolt and McNeal 1987, Wambolt 1996, Wambolt 1998, Wambolt and Sherwood 1999). Dominant big sagebrush (*A. tridentata*) taxa on the NYWR are basin big sagebrush (*A. t.* Nutt. *tridentata*), Wyoming big sagebrush (*A. t. wyomingensis* Beetle and Young), and mountain big sagebrush (*A. t. vaseyana* [Rydb.] Beetle). All three are non-sprouting after disturbance such as fire. Wildfire at least temporarily eliminates these taxa (Wambolt et al. 1999). The 1988 wildfires renewed and escalated concern for sagebrush communities on the NYWR.

Effects of large ungulates on the NYWR have been debated since at least the 1920's. Biologists focused most on woody plants, primarily aspen (*Populus tremuloides* Michx.) and willows (*Salix* L.). There has been little concern for the decline of sagebrush on the NYWR over the last 35 years. During the early twentieth century, sagebrush communities within Yellowstone National Park (YNP) received much attention (Rush 1932, Wright and Thompson 1935, Cahalane 1943, Kittams 1950). In response, the National Park Service (NPS) constructed 10 exclosures in 1957 and 1962 partially to study the relationships between ungulate foraging and sagebrush. This was during a period of high elk (*Cervus elaphus nelsoni* Bailey) numbers on the NYWR. Eight of these exclosures still exist; 4 of which are totally in sagebrush habitat types, and all have

significant portions within a sagebrush habitat type. Two burned completely during the large Yellowstone fires of 1988. These exclosures on the Black-tailed Deer Plateau contain primarily a mountain big sagebrush habitat type.

Recently, the relationship between ungulate foraging and sagebrush taxa on the NYWR has received increasing attention. Investigations have determined mechanisms that influence browsing patterns on sagebrush and intensity of use by ungulates (Personius et al. 1987, Striby et al. 1987, Wambolt and McNeal 1987, Bray et al. 1991, Wambolt et al. 1994, Singer and Renkin 1995, Wambolt 1996). These mechanisms are unique to sagebrush taxa and sagebrush-herbivore interactions on the NYWR (Wambolt 1998). Intense browsing has reduced big sagebrush populations on the NYWR (Wambolt 1996, Wambolt and Sherwood 1999, Wambolt et al. 1999). Loss of big sagebrush habitat can impact numerous wildlife populations (Welch 1997, 1999) and may cause long term reductions in some wildlife populations. Big sagebrush is particularly important for ungulates during winter as a nutritious forage (Welch and McArthur 1979) and for thermal and security cover. Given the importance of big sagebrush to wildlife, natural resource managers need to understand the dynamics of big sagebrush communities following fire, especially on ranges like the NYWR where browsing is intense.

Fire interacts with ungulate herbivory to influence vegetative community dynamics. This interaction is not well understood. This study was conducted to examine the interaction of fire with herbivory on community recovery. My objective was to investigate shrub and herbaceous community recovery on the Black-tailed Deer Plateau of the NYWR following the 1988 Yellowstone fires and under intense browsing. I did

this by comparing shrub and herbaceous parameters between sites protected or unprotected from ungulate foraging on a portion of the NYWR burned in 1988.

CHAPTER 2

LITERATURE REVIEW

Importance of Big Sagebrush to Wildlife

Big sagebrush taxa dominate the largest vegetation type on the NYWR (Houston 1982). Sagebrush habitats that remain relatively free of snow during the winter are important winter foraging areas for ungulates on the NYWR (Wambolt and McNeal 1987, Wambolt 1996, Wambolt 1998, Wambolt and Sherwood 1999). Big sagebrush habitats on the NYWR may include basin big sagebrush, Wyoming big sagebrush, and/or mountain big sagebrush. Stands of big sagebrush types vary by site and microsite conditions from nearly pure stands of 1 taxon to mixed stands. Ungulates on the NYWR utilize all 3 taxa to differing extents but prefer mountain big sagebrush as a forage (Wambolt 1996).

Among ungulates, big sagebrush-grassland plant community types are particularly important to antelope (Barmore 1980, Norland et al. 1996), mule deer (*Odocoileus hemionus* ssp. *hemionus*) (Julander and Low 1976, Hobbs and Spowart 1984, Welch and Wagstaff 1992), and elk (McNeal 1984). These habitats provide important cover and forage during winter when other forages are less nutritious and unavailable (McNeal 1984, Welch and McArthur 1986, Welch and Wagstaff 1992). Ungulates meet protein requirements for maintenance of approximately 5.5-6.0% during winter (Nelson and Leege 1982) in part by consuming big sagebrush which maintains a crude protein level of approximately 12% (Welch and McArthur 1979). Winter protein content in Yellowstone

elk rumens averaged 9.3% when percent crude protein of commonly used grass species and sedge species is < 4% and < 5% respectively (Houston 1982). Concurrently, bluebunch wheatgrass, the dominant grass of relatively snow-free portions of the NYWR, does not meet minimum protein requirements for gestation during fall and winter (Wambolt et al. 1997, Nelson and Leege 1982). Big sagebrush also has the highest digestibility among browse plants on the NYWR (Striby et al. 1987). Big sagebrush maintains 57% digestibility (Striby et al. 1987) during winter while bluebunch wheatgrass ranged from 21% to 23% in southwestern Montana (Wambolt et al. 1997).

Elk use big sagebrush dominated vegetative types during late fall and winter (McNeal 1984). However, elk depend more on grasses throughout the year (Morris and Schwartz 1957, Greer 1970). Winter severity and grass availability affect elk use of big sagebrush. Greer et al. (1970) found big sagebrush among the most frequent forage items in winter elk diets. Browse, including big sagebrush, averaged 17% of elk diets and increased in volume during severe winters across the NYWR (Houston 1982). Use of NYWR sagebrush habitats near Gardiner increased with number of elk in the area (Wambolt 1996). Big sagebrush comprised as much as 9% of elk diets on range areas depleted of sagebrush by past use (Rush 1932, Wright and Thompson 1935, Cahalane 1943, Kittams 1950). Harvest numbers from the special late elk hunt near Gardiner (mid-December through February) are a good indicator of winter severity when forage limitations force elk from the security of YNP into the Gardiner Basin. Wambolt (1996) found this elk harvest was positively related to utilization of sagebrush leaders. Deer also use big sagebrush at lower elevations of the NYWR. On part of the NYWR near

Gardiner, Wambolt (1996) found mule deer winter diets averaged 52% sagebrush over 10 years. The same study found percent dead crown on mountain big sagebrush was significantly correlated to plant browsing, indicating extremely high levels of use on sagebrush habitats in the Gardiner area of the NYWR. With adult elk and deer daily intakes of approximately 2% of body weight per day (Nelson and Leege 1982), a 200 kg elk and 54 kg mule deer will consume 4.0 kg and 1.1 kg of forage per day respectively. An elk consuming a minimal 9% sagebrush will consume approximately 0.36 kg of sagebrush per day and a mule deer consuming 52% sagebrush will consume approximately 0.57 kg of sagebrush per day. Given the current (1999) elk population of approximately 13,000, 4680 kg (5.2 tons) of sagebrush per day would be removed by elk, and the approximately 2000 mule deer would consume another 1140 kg (1.3 tons) of sagebrush per day on the NYWR.

Big Sagebrush Response to Ungulate Browsing on Yellowstone's Northern Range

Sagebrush responses to ungulate browsing are well studied. Several growth characteristics of big sagebrush make it less tolerant to browsing than other browse species (Bilbrough and Richards 1991). Because mountain big sagebrush is wind pollinated, seed heads are elevated above the canopy making them susceptible to browsing. Also, the productive buds on the distal ends of stems are vulnerable to browsing. Terminal leaders contribute most to biomass production, and production generally decreases toward the base of the plant. Shoots older than one year are unable to initiate new growth (Bilbrough and Richards 1993). Compensatory response by big

sagebrush is significantly reduced if the current year's growth is removed (Cook and Stoddard 1960). Clipping shoots or removal of previous or current year's growth induced significant crown death, root death, and even plant mortality in mountain big sagebrush (Bilbrough and Richards 1993, Cook and Child 1971, Cook and Stoddard 1960, Wandera et al. 1992). Cook and Stoddard (1960) found that when half of plant crown was clipped, the intact portion of the crown grew back more vigorously while the clipped portion of the crown died. However, Painter and Belsky (1993) warn against the concept of compensatory growth in a natural setting. Patten (1993) applied this compensatory growth viewpoint to browsing by elk in YNP and concluded herbivory did not benefit grass or woody species including big sagebrush.

Mortality of sagebrush on the NYWR was attributed to heavy browsing by elk as early as the 1930's (Wright and Thompson 1935). More recently, nearly 80% of the ungulates in YNP forage on the NYWR during winter (Singer 1991), and Houston (1982) estimated elk represent 89% of the winter biomass of ungulates on the NYWR. High elk numbers have dictated high levels of browsing. Wambolt (1996) found 35% of mountain big sagebrush across the NYWR were killed by excessive browsing. Among surviving plants, crown die-back attributed to browsing averaged 44.7% among 3 big sagebrush subspecies. Sagebrush densities, canopy coverages and production of winter forage were all significantly greater on 19 protected sites compared with unprotected sites across the NYWR (Wambolt and Sherwood 1999). Ungulate use is depressing sagebrush community productivity on the NYWR. This is additive to the effects of wildfire on sagebrush loss discussed in the following section.

Big Sagebrush Response to Fire on Yellowstone's Northern Range

Fire has long been used to control or alter big sagebrush stands. Burning sagebrush has been a source of controversy between those who believe burning harms big sagebrush rangelands and those who believe fire benefits such rangelands. Peterson (1995) claims sagebrush removal does not automatically benefit wildlife while improving forage for livestock. He maintains that, in most cases, sagebrush removal is not necessary to properly maintain, manage, and improve rangelands.

Managers have attempted to mimic natural burning cycles of big sagebrush communities. However, the length of these cycles is debated, and also greatly altered by other man-induced actions such as other methods of sagebrush removal, livestock grazing, and proliferation of exotic species. Natural fire frequencies may range from 60 to 110 years (Whisenant 1990). On cheatgrass (*Bromus tectorum* L.) infested sagebrush areas along the Snake River in Idaho, stands may burn every 2 to 4 years, completely eliminating sagebrush and other native species (Whisenant 1990). Following a 30 year study in the Gravelly Mountains in southwestern Montana, Lomasson (1948) claimed sagebrush on sites favorable for growth will continue to reproduce indefinitely without disturbances such as fire. However, in more recent years with heavier browsing pressure, Petroni (1991) recommended burning stands in the same area every 20 years. In different areas, Wyoming big sagebrush recovered little 12 years after fire (Blaisdell 1953) or 18 years after fire (Wambolt and Payne 1986). Sagebrush stands require at least 30 years to recover significantly from burning (Harniss and Murray 1973, Watts and Wambolt 1996), while recovery from spraying, plowing, or rotocutting may take nearly 20 years (Watts

and Wambolt 1996). Wambolt et al. (2001) compared burned and unburned portions of 13 sites in southwestern Montana 2 to 32 years post fire. Thirty-four of 38 comparisons showed significantly ($P \leq 0.05$) greater sagebrush canopy coverages, densities, and production of winter forage while native perennial bunchgrasses were not affected (Wambolt et al. 2001). Wambolt et al. (1999) found minimal recovery of mountain big sagebrush on the NYWR 19 years after fire. Canopy coverages were 12 times greater on unburned sites compared to burned sites, and established shrub densities on unburned sites were 15 times those of burned sites (Wambolt et al. 1999).

CHAPTER 3

METHODS

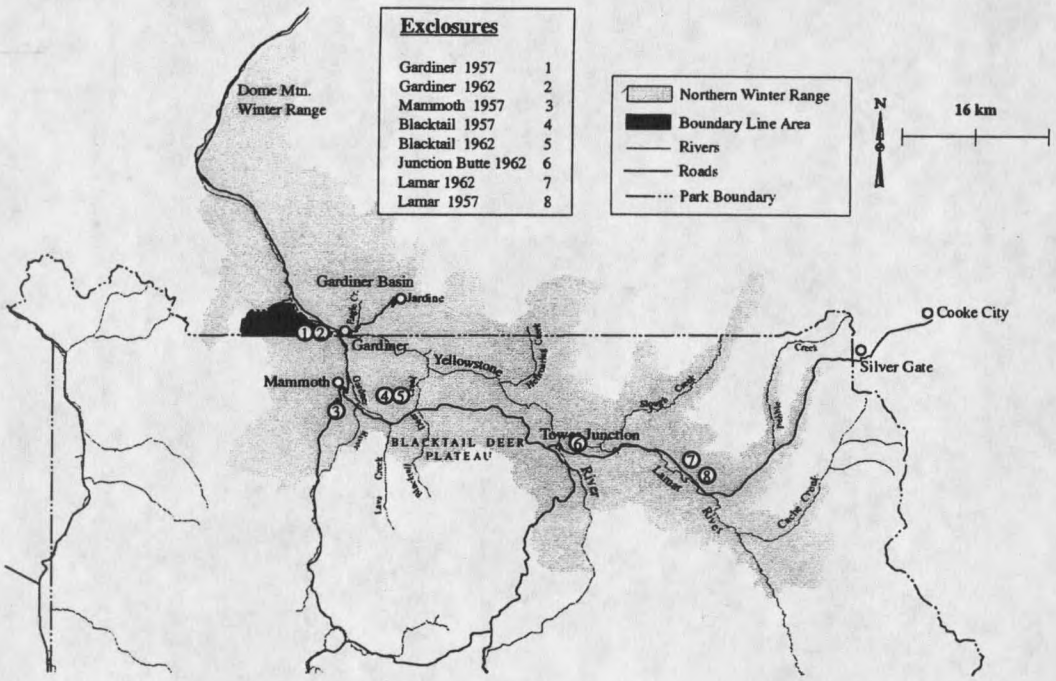
Study Area

Location

This study was conducted on the Black-tailed Deer Plateau of the Northern Yellowstone Winter Range (NYWR) in north central Yellowstone National Park (YNP). The NYWR occupies 100,000 ha over an 80 km stretch along the lower elevations in northern YNP and extends northward into Montana along the Yellowstone River drainage (Houston 1992) (Figure 1). The Lamar and Gardner Rivers also drain portions of the lowlands in YNP that are relatively free of snow. These conditions provide a reliable location for ungulate foraging (Houston 1982).

The 97.7 km^2 Black-tailed Deer Plateau of the NYWR (Coughenour 1991) covers a portion of the northern boundary of YNP approximately midway between Mammoth and Tower Junction. The 2 ungulate exclosures on the Black-tailed Deer Plateau used for this study are located on a ridge top and generally southeasterly facing slope in the approximate center of the NYWR. The NPS erected 1 exclosure near Black-tailed Deer Creek in 1958 and the other nearby in 1962 to evaluate the effects of ungulate grazing (Barmore 1980, Houston 1982, Singer and Harter 1996).

Figure 1. The Northern Yellowstone Winter Range. The Black-tailed Deer Plateau exclosures 4 and 5 were used because they were the only 2 completely burned in 1988.



Landscape

The NYWR contains portions of the Yellowstone, Lamar, and Gardner river drainages in the lowlands of YNP. The Yellowstone River drains the areas of the NYWR extending out of YNP, while the Gardner River drains lower and mid elevations in YNP, and the Lamar River drains mid and higher elevations of the NYWR. Foothills and

mountains rise away from floodplains, and valleys are trough-like with foothills rising steeply from floodplains to rolling benchlands often at 50° to 60° slopes (McNeal 1984). These slopes are windswept and provide the majority of snow-free foraging areas for wild ungulates (McNeal 1984). North and east facing slopes provide timbered thermal cover for wintering ungulates (McNeal 1984).

The Black-tailed Deer Plateau is approximately one-third of the NYWR, and lies between the highest elevations drained by the Lamar River in YNP and the lower elevations in the Gardiner Basin outside YNP. The elevation on the Black-tailed Deer Plateau is approximately 2040 m above sea level, midway between the lower (1600 m elev.) and higher (2600 m elev.) elevations of the NYWR (Houston 1982, Coughenour 1991).

Climate

The climate across the NYWR is variable, although generally favorable for ungulates (Wambolt 1998). Gardiner, Montana (1616 m elev.) receives approximately 280 mm of precipitation, while Mammoth (1899 m elev.) receives approximately 400 mm, and Tower Falls (1912 m elev.) receives approximately 410 mm (Farnes 1991). Half of the precipitation is received as snow, and most rainfall occurs in spring and early summer (Farnes 1991). June usually has the most precipitation with about 50 mm (U.S. Weather Bureau Station, Mammoth, WY). Localized thunderstorms may be the only moisture in July and August. Elevation and precipitation on the Black-tailed Deer Plateau are similar to Mammoth and Tower Falls.

The growing season on the plateau is generally from mid-April to mid-September. The warmest month is July, which averages 17.3° C, although a killing frost may occur any month. Winter snows begin limiting ungulate movement and foraging sometime in November and snows recede in approximately mid-March. This concentrates animals for approximately four months on the NYWR. Elk numbers and amount of time spent on the NYWR depend in part on snow depths and densities (Farnes 1999).

Soils

Glacial scouring and deposition have had the largest influence on the soils of the Black-tailed Deer Plateau. The geologic parent material for soils in these exclosures is Pinedale glacial till including material from Absaroka volcanics, limestone, precambrian crystalline rocks, and tuff (Lane 1990).

Soils are generally characterized as Mollisols with a cryic temperature regime. The mean annual soil temperature falls between 0° C and 8° C (NOAA 1994). Alfisols and Inceptisols are common under forest canopies and on rock outcrops, respectively (McNeal 1984). Most of the plateau is depositional and soil profile depths may be several meters in certain areas. Soils texture is typically loam, gravelly loam, gravelly sandy loam, or very gravelly loam (Lane 1990) with coarse fragments ranging from gravel to boulders, respectively (McNeal 1984).

Vegetation

Sagebrush-grassland dominates much of the Black-tailed Deer Plateau and is often interspersed with heavily forested areas. Above 1770 m, the mountain big sagebrush and bluebunch wheatgrass habitat type dominates, especially on south facing

slopes. Prairie junegrass (*Koelaria macrantha* Ledeb.), Columbia needlegrass (*Stipa columbiana* Macoun), arrowleaf balsamroot (*Balsamorhiza sagittata* [Pursh.] Nutt.), lupine (*Lupinus* spp. L.), and fringed sagewort (*Artemisia frigida* Wild.) were other herbaceous species associated with this vegetation type. Green rabbitbrush (*Chrysothamnus viscidiflorus* (Hook.) Nutt.), rubber rabbitbrush (*C. nauseosus* (Pallas) Britt.), and gray horsebrush (*Tetradymia canescens* D.C.) were the sprouting shrubs associated with this vegetation type. Sprouting shrubs are those that sprout from roots remaining in the soil after disturbances such as fire.

The mountain big sagebrush and Idaho fescue (*Festuca idahoensis* Elmer) habitat type is also found at elevations above 1770 m, most often on north and east facing slopes. Mountain brome (*Bromus carinatus* H. & A.), common timothy (*Phleum pratense* L.), sticky geranium (*Geranium viscosissimum* F. & M.), common snowberry (*Symphoricarpos albus* [L.] Blake), and Wood's rose (*Rosa woodsii* Lindl.) are other species associated with this habitat type.

Sites with higher available moisture and deeper soils in areas such as depressions, may contain the basin big sagebrush and bluebunch wheatgrass habitat type. This type is extremely rare on the Black-tailed Deer Plateau. Common understory species include basin wildrye (*Elymus cinereus* Scribn. & Merr.), Columbia needlegrass (*Stipa columbiana* Macoun), and the exotic species smooth brome (*Bromus inermis* Leys) and crested wheatgrass (*Agropyron cristatum* [L.] Gaertn.).

The Wyoming big sagebrush and bluebunch wheatgrass habitat type, usually found below 1980 m, is also found on the Black-tailed Deer Plateau, but is limited by the

relatively high elevation. Common graminoids found with this community type are prairie junegrass, Indian ricegrass (*Oryzopsis hymenoides* [R. & S.] Ricker), needleandthread (*Stipa comata* Trin. & Rupr.), and green needlegrass (*Stipa viridula* Trin.). Common forbs include hairy goldenaster (*Chrysopsis villosa* [Pursh.] Nutt.), milkvetch (*Astragalus* spp. L.), and locoweed (*Oxytropis* spp. D.C.). Fringed sagewort, green rabbitbrush, rubber rabbitbrush, and gray horsebrush are common shrubs in this community.

Timbered areas commonly occur at higher elevations and northern slopes throughout the study area. The dominant species at these areas are Douglas fir (*Pseudotsuga menzeiesii* [Mirbel] Franco), Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), whitebark pine (*Pinus albicaulus* Engelm.), lodgepole pine (*P. contorta* Dougl.), and subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.). Sedges (*Carex* spp.), rushes (*Juncus* spp.), willow (Salix spp. L.), quaking aspen (*Populus tremuloides* Michx.), and common snowberry often occur near creeks, springs, and other areas with higher moisture.

Native Ungulates

The Black-tailed Deer Plateau, as part of the NYWR, contributes to sustaining one of the largest wintering herds of Rocky Mountain elk known (Houston 1982). The NPS actively reduced herds by transplanting or intensive harvesting over a 35 year period until 1968, when the NPS adopted a philosophy of non-interference (natural regulation). Populations subsequently increased from less than 4,000 animals to more than 23,000 by 1988 (Coughenour and Singer 1996). The winter of 1988-1989 drastically reduced the

herd by approximately 40%, but the population was estimated at 25,000 animals again in 1993 (Lemke 1999). Many elk also died in the winter of 1996-1997, but the population has slowly rebounded (Lemke 1999). In 1999, 11,742 elk were counted on the NYWR, compared with 11,692 in 1998. The northern Yellowstone elk population has decreased since the mid-1990's counts of 18,000-19,000 to the current level of 11,000-12,000 elk (Lemke 1999).

The Black-tailed Deer Plateau serves as a staging area for elk. Elk tend to congregate on the plateau prior to exiting YNP near Gardiner. This tendency is greatly influenced by winter severity. With increasing severity, elk spend less time on the plateau before exiting the Park. Some elk that congregate on the plateau may not leave during a less severe winter. In the last five years, 5,296-8,626 elk have migrated and wintered out of the Park (Lemke 1999). Many migrating elk spend some time on the Black-tailed Deer Plateau.

In addition to elk, mule deer, bison (*Bison bison*), antelope (*Antilocapra americana*), bighorn sheep (*Ovis canadensis*), mountain goats (*Oreamnos americanus*), and moose (*Alces alces*) also winter on the NYWR. Mule deer populations fluctuate from year to year around 2,000 animals, and most are restricted to lower elevations around Gardiner. Most winters, bison also wander from YNP. In the winter of 1988-1989, 600 bison were harvested and nearly 1,100 were harvested in the winter of 1996-1997. Both winters were relatively severe causing more bison to migrate out of YNP. In the winter of 1993-1994, 3,529 bison were counted on the NYWR, almost twice the number in 1988-1989. The following winter, 1994-1995, numbers were up to nearly 4,000 (John Mack

pers. com. Oct. 2000). In 1998, the Montana Department of Fish, Wildlife, & Parks and the Animal and Plant Health Inspection Service actively reduced numbers to 2,200 (John Mack pers. com. Oct. 2000).

Since 1993, the pronghorn antelope population on the NYWR has hovered just over 200 animals, approximately 50% of observed numbers in the late 1980's and early 1990's. In 1993 the population was estimated at 439 animals, and in 1999, 204 antelope were counted (Lemke 1999). During winter, antelope are restricted to the lowest elevations in the Gardiner Basin. Sagebrush is an important component of pronghorn diets, particularly during winter on the NYWR (Barmore 1980). Big sagebrush averaged 48.7% and total sagebrush averaged 67.2% in fecal samples of antelope over 3 winters (1985-1988) in the Gardiner area (Singer and Norland 1995). The decline in pronghorn numbers is attributed to declining sagebrush in their traditional wintering areas.

Bighorn sheep also inhabit distinct, isolated portions of the NYWR. The population is so small, 181 in 1999 (Lemke 1999), that impacts to winter forage for other ungulate species are negligible. Mountain goats, like bighorn sheep, occur in such small numbers, and inhabit such distinct, high elevation portions of the NYWR, that their impacts to winter foraging is also negligible. Moose, with a total NYWR population of 100 to 200 animals, are very sporadic occupants of portions of the NYWR (Tyers pers. com. Oct. 2000). They also have a minimal impact on the winter forage base for other ungulate species on the NYWR.

Burning History

There were 8 to 10 large fires on the portion of the northern winter range inside YNP in the last 300-400 years (Houston 1973). The extent of sagebrush-grass habitats burned by these fires is unknown. Humans have suppressed fires in YNP since 1886 with increasing sophistication. Nearly all fires were being suppressed on NYWR grasslands by the 1950's (McNeal 1984). In the 1970's, managers recognized fire as an integral part of natural systems and began to use it as a management tool. In 1972, 12,000 ha of winter range within YNP were designated as areas where wildfires would not be suppressed.

Minor fires occurred in YNP prior to 1988, but these were relatively insignificant. The fires of 1988 affected approximately 320,000 ha in YNP. Approximately 20,000 ha of this were non-forested and another 15,000 ha were undifferentiated (Despain et al. 1989). Non-forested burn was characterized as burned sagebrush shrublands, grasslands, meadows, wet meadows, and alpine meadows. Undifferentiated burn comprised burned areas that could not be reliably placed in canopy, mixed, non-forested, unburned, and undeliniated burn categories (Despain et al. 1989).

The predominant burn type on the Black-tailed Plateau of the NYWR was a non-forested burn type. Infrared and color aerial photographs taken in October of 1988 and July of 1991, respectively, indicate both exclosures used in this study were nearly completely burned in the 1988 wildfires. No fires have directly influenced the areas observed in this study since 1988. However, there have been minor burns in the area as in 1998 when a lightning started fire burned approximately 40 ha north of the exclosures.

Measurements and Analysis

Study Sites

Of the 8 exclosures presently remaining on the NYWR, I used the 2 burned during the 1988 Yellowstone wildfires for comparisons. These exclosures contained considerable environmental variation. The sagebrush habitat type within each exclosure was stratified to separate topographic, soil, and microclimatic variation to isolate differences in shrub parameters existing among various environmental conditions. Twelve sites were studied, (5 and 7 sites associated with the West and East exclosures, respectively). Each site contained browsed (outside exclosures) and protected (inside exclosures) areas that were environmentally paired. Pairing was accomplished by stratifying sagebrush habitats based on slope, and aspect (Coughenour 1991) (Table 1.). Sagebrush dominated 5 of the 12 sites. Sagebrush parameter comparisons were made for these 5 sites. Four of the 12 sites were dominated by sprouting shrubs and used for parameter comparisons of those taxa. All 12 sites were used in comparing canopies of herbaceous species. Only established shrubs were used in making density and forage production comparisons to avoid overestimation of these parameters. Inclusion of very young plants, which have high seedling mortality in the first few years after germination, would obscure differences between protected and browsed sites. (Mehus 1995). Established sagebrush plants were those with an average horizontal axis (canopy) $\geq$ 15 cm from 4 canopy measurements (Wambolt et al. 1994). Established sprouting shrubs were those having an average horizontal canopy axis $\geq$ 3 cm. Data were collected during the summers of 1998 and 1999.