Site characteristics and effect on elk and mule deer use of the Gardiner winter range, Montana
by Allen Francis McNeal

A thesis submitted in partial fulfillment of the requirements for the degree. Master of Science in Range Science y
Montana State University

Abstract:
A two year study was initiated in the spring of 1980 to evaluate elk and mule deer use of the Gardiner winter range, an integral portion of the northern Yellowstone winter range. The study was designed to determine the association of elk and mule deer with habitat parameters. Twenty-eight vegetation and landform variables were characterized into six habitat types; five were sagebrush-grassland and the sixth was a forest habitat type. Sagebrush-grassland habitat types were modified to include three subspecies of big sagebrush (Artemisia tridentata) and black sagebrush (Artemisia nova). All habitat types were considered to be near climax condition. Sagebrush taxa were important forage sources, as indicated by animal use observations and sagebrush form class designations. Animal use of the area was dependent on winter severity although there was apparent elk and mule deer preference for certain habitat types. Elk and mule deer use was specifically associated with environmental characteristics within habitat types. Elk use, as measured by elk pellet-counts, was most highly correlated with grass cover ($r = .66$). Five site variables entering a stepwise regression analysis accounted for 71 percent (R^2) of the variation in elk pellet-counts by site.. Mule deer use was most highly correlated With elevation ($r = -.52$), reflecting their physical inability to negotiate deep snow. Eight site variables accounted for 82 percent (R^2) of the variation in mule deer pellet-counts. Data analyses indicate elk selected feeding sites on the winter range where the relationship of food intake to energy expenditure was optimized. Deer selected activity areas where energy expenditure was minimized and security was optimized on this exposed winter range.

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A thesis submitted in partial fulfillment
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APPROVAL

of a thesis submitted by

Allen Francis McNeal

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

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Signature Allen F. McNeal

Date June 12, 1984

To my parents, Harry and Ora, for their help, perception, and faith through the long months of anticipation.

VITA

Allen Francis McNeal was born (1952) and raised in the Gallatin Valley where he grew to appreciate the intricacy and delicate nature of the surrounding environment. He spent many fine hours with his parents, F. H. (Harry) and Ora Helen (Veenker) McNeal, and sister Linda Rae (McNeal) Svensrud, enjoying a variety of outdoor activities. He didn't realize there was specific terminology applied to events he observed occurring in nature until after he entered Montana State University, from which he graduated in 1975 with a Bachelor of Science degree in Zoology. His graduate career was initiated in 1979.

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TABLE OF CONTENTS

TABLE OF CONTENTS - (Continued)

LIST OF TABLES

LIST OF TABLES - (Continued)

LIST OF FIGURES

ABSTRACT

A two year study was initiated in the spring of 1980 to evaluate elk and mule deer use of the Gardiner winter range, an integral portion of the northern Yellowstone winter range. The study was designed to determine the association of elk and mule deer with habitat parameters. Twenty-eight vegetation and landform variables were characterized into six habitat types; five were sagebrush-grassland and the sixth was a forest habitat type. Sagebrush-grassland habitat types were modified to include three subspecies of big sagebrush (<u>Artemisia tridentata</u>) and black sagebrush (<u>Artemisia nova</u>). All habitat types were considered to be near climax condition. Sagebrush taxa were important forage sources, as indicated by animal use observations and sagebrush form class designations. Animal use of the area was dependent on winter severity although there was apparent elk and mule deer preference for certain habitat types. Elk and mule deer use was specifically associated with environmental characteristics within habitat types. Elk use, as measured by elk pellet-counts, was most highly correlated with grass cover ($r = .66$). Five site variables entering a stepwise regression analysis accounted for 71 percent (R^2) of the variation in elk pellet-counts by site. Mule deer use was most highly correlated with elevation ($r = -.52$), reflecting their physical inability to negotiate deep snow. Eight site variables accounted for 82 percent (R^2) of the variation in mule deer pellet-counts. Data analyses indicate elk selected feeding sites on the winter range where the relationship of food intake to energy expenditure was optimized. Deer selected activity areas where energy expenditure was minimized and security was optimized on this exposed winter range.

INTRODUCTION

Judicious management of range ecosystems often incorporates the evaluation of wildlife requirements and impacts. Many factors influence wildlife activities in the dynamic environments they inhabit. Certain of these environmental factors influence an animal's selection of appropriate sites for its diurnal activities. The relative impact of environmental factors on animal behavior depends on the unique qualities of an area in combination with the season of the year.

Winter often provides environmental stresses that prove to be a rigorous test of endurance for animals, especially in the Rocky Mountains. The stresses of winter are particularly serious for herbivorous animals such as ungulates. Rocky Mountain elk (Cervus elaphus nelsoni) and Rocky Mountain mule deer (Odocoileus hemionus hemionas) are often affected by deep snow and the restriction it imposes on activity levels during winter months. These animals must sometimes adapt to very severe conditions by altering use patterns, and understanding their resulting behavior is essential to any comprehensive management program.

This study was conducted on the Gardiner winter range in southwestern Montana, an area ideally suited for examining winter behavior of elk and mule deer. The study area encompasses a portion of the northern Yellowstone winter range. A variety of ungulates utilizes the Gardiner winter range, but elk are most abundant during most winters. These elk comprise a portion of the largest remaining herds found in North America, those in and around Yellowstone National Park.

This study was designed to explain why these elk, and the abundant mule deer, select the specific habitat types they utilize on the wintering area. Definite winter use patterns helped in conceiving the hypothesis that specific vegetation and landform parameters can explain elk and mule deer use patterns.

The purpose of the study was to evaluate the association of elk and mule deer with habitat parameters on the Gardiner winter range. The primary objective was to determine preferential elk and mule deer use of specific habitat types by characterizing the vegetation and landform available. A secondary objective was to evaluate the current condition and potential of the winter range for elk and mule deer use.

LITERATURE REVIEW

Preface

When reviewing Rocky Mountain elk (*Cervus elaphus nelsoni*) and Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) literature, one is struck not only by the mass of information concerning these popular big game animals, but also by their wide distribution among diverse environments. Wecker (1964) emphasizes that each organism tends to be restricted in distribution by its behavioral and physiological responses to the environment. Clearly, these species are quite flexible in their habitat requirements with an ability to adapt to a variety of environmental dissimilarities. With current game management protecting viable populations, the disturbance or removal of suitable habitat appears to be the only significant environmental factor that the exceptional resilience of these species cannot tolerate.

Use of an area is determined by animal behavior patterns. Behavior is the first and most common way individual organisms adjust to their environments (Geist 1981). Because almost any environmental flux can influence animal behavior at a point in time, determining what has caused a behavioral adjustment to the multi-faceted environments elk and mule deer inhabit can be rather an indefinite undertaking. However, literature provides the basis for understanding general animal use characteristics under varying environmental conditions.

A thorough understanding of animal-habitat interactions within a particular area requires an evaluation of wildlife habitat on a site-specific basis, the importance of which cannot be over-emphasized. Drawing from previous studies conducted in similar environments is useful to the extent of understanding general principles, but applying management strategies developed in one geographic area to another area must be done with caution. Regional differences and yearly variation in complex environmental conditions may cause the dynamics and even genetics of different animal populations to vary. In view of this variability, animal use will not be consistent in all locations and habitats. Assuming animal use in one area will parallel that from another area may be a mistake, even if that area is the adjacent drainage.

Winter Environment - Habitat

Geist (1981) observes that mule deer move seasonally between areas of favorable microclimates and forage resources so as to maximize gain (e.g. on summer ranges) or minimize maintenance costs (e.g. on winter ranges). Cole (1969) states that northern Yellowstone winter elk distribution occurs along an elevational gradient in relation to suitable foraging areas, developed habits, the presence of other elk, conditioned responses to human disturbance, and variable weather influences on the availability of food. Winter in the northern Rocky Mountains is the time of year when resources are most limited for ungulates. This season is characterized by deep snow covering forage, with cold, often windy temperatures. Gilbert et al. (1970) list two factors making winter a critical period: 1) forage nutritional quality and abundance are at their lowest, and 2) snow limits the amount of range accessible for use.

DeNio (1938) concludes that most game animals are restricted in winter to less than 20 percent of the area available on summer range in the northern Rocky Mountain region. Approximately 1.2 million ha are available as summer range in the Yellowstone ecosystem, but Houston (1978) describes the winter range as only 100,000 ha in size. Discussing the same winter range, Greer et al. (1970) note that for short periods during severe winters animals are limited to a 20-30,000 ha area.

Animals are generally forced to lower elevations to escape the deepest snow. In the South Fork of the Flathead area of Montana, Gaffney (1941) recognizes the winter range as being confined to areas below 1981 m in elevation on south and west exposures, and below 1676 m on north and east exposures. Houston (1974) considers the northern Yellowstone winter range limited to areas below 2591 m in elevation.

Winter Environment - Weather

Moen (1973) emphasizes that the effect of weather on an organism involves the exchange of thermal energy between the organism and its environment. The four modes of this energy exchange are radiation, conduction, convection, and evaporation. To compensate for this exchange, an animal can increase or decrease body heat production by adjusting its physical activity and its metabolic rate.

Mule deer reduce food consumption during winter and remain in a maintenance state rather than a production state (Short 1981). Even in a maintenance state, the stress of sustaining thermal homeostasis during winter is energetically costly. Based on observations, Mautz et al. (1976) assume a white-tailed deer fawn may undergo a 20 percent weight loss over a 100-day winter period. DeCalesto et al. (1977) report that once energy-rich fat reserves are depleted, muscle catabolism provides an inadequate source of energy for a starving deer to sustain itself.

As Beall notes in 1974, little work has been done to evaluate interactions of big game with their natural energy environment. Most studies of this energy exchange have been achieved utilizing deer. Empirically thinking, deer and elk winter metabolism should be somewhat similar, although there are notable differences due to activity levels, nutrition, and size. Theoretically, it should be less expensive from the energetic point of view for a large homeotherm to live in a low temperature than it would for a small one (Beall 1974).

Where deer feed and rest is very much a function of weather (Geist 1981). Loveless (1964) has observed mule deer feeding up-slope in sunlight when air temperature is below -17.8°C (0°F), but seeking shelter during periods with wind above 40.2 km/hr (25 mph) and temperatures below -9.3°C (15°F). Beall (1974) notes that elk had little reaction to wind velocities below 16.1 km/hr (10 mph), but did seek shelter at higher wind velocities, depending on ambient air temperature. When the wind chill factor approaches -28.9° to -31.7°C (-20° to -25°F), elk seek shelter in timber or steep-sided draws. He further states that both thermal and solar radiation are important components of the elk's winter environment.

To illustrate the effect of diet and wind, Moen (1968) generates heat loss curves for a 50 kg white-tailed deer (Odocoileus virginiana) standing in an open field under clear nocturnal skies, with an air temperature of -20°C. He observes that a full-fed deer can withstand wind velocities over twice as great as a deer on a maintenance diet. A deer on a starvation diet would be in a negative energy balance at a wind velocity of 2 mph. Clearly, homeotherms must eat to stay warm (Gordon 1968).

Winter Environment - Snow

Snow not only initiates movement toward winter range (Anderson 1954, Gilbert et al. 1970) and influences dispersal from wintering areas (Stevens 1966, Ward et al. 1975), but its depth and condition can be a dominant influence controlling both elk and mule deer use of an area. Kelsall (1969) suggests that larger animals such as moose are physically capable of negotiating deeper snow than mule deer. He found that movements of deer and moose were seriously impeded when snow depths were approximately 70 percent of their respective chest heights. The larger elk would therefore be less severely hampered by snow condition than the relatively short-legged mule deer.

Ward et al. (1975) state that the depth and physical characteristics of snow determine the distribution, movements, and feeding habits of elk on their range. Gaffney (1941) reports several factors determining the amount of snow in which elk can winter successfully: 1) the composition, height, and volume of the palatable vegetation; 2) condition of the snow - - packed, crusted, or loose; 3) age and condition of the animals; 4) topography. He goes on to say the influence of topography is not great until snow reaches a depth of 77 cm, but he also points out that elk can negotiate 30 to 46 cm more snow on the flats than on a hillside.

Beall (1974) notes that elk move from areas when snow depths reach 46 cm, while Anderson (1954) reports that 15 to 25 cm of snow can cause elk to begin migrating out of Yellowstone Park. After reaching a winter range in the Lolo National Forest, Bohne (1974) observes that elk move freely over much of the area until snow is belly-deep or crusted. Although physically capable of negotiating deep snow, elk apparently avoid these situations if possible.

In western Canada, Edwards (1956) determines that deep snow appears to be a major factor controlling the abundance of mule deer. Severinghaus (1947) considers snow depth to be the critical weather factor affecting winter mortality among white-tailed deer in the Adirondacks. He points out the effect is especially severe if deep snow remains for prolonged periods late into the winter season, because a deer's vitality declines as winter progresses. Adverse weather in March or April will have a more severe effect on deer than if those conditions occur earlier in the season.

Snow depths from 45.7 to 50.8 cm essentially preclude deer use (Gilbert et al. 1970, Hayden-Wing 1979, Severinghaus 1947). Strickland and Diem (1975) suggest that as little as 30 cm of crusted snow may cause mule deer to avoid an area. In Idaho, Hayden-Wing (1979) theorizes that deer use is restricted to poorer quality browse sites where reduced snow depths allow them to balance their energy budgets, even though better quality browse is nearby on deep snow sites.

Forage and Nutrition

One of the main conclusions emerging from the study of animal behavior is that most activities ultimately can be related to the way an animal acquires sustenance (Geist 1981). Protein and energy are generally the nutritional components of forage critically limiting to wild ruminants (Wallmo et al. 1977). Bell (1971) explains the ruminant digestive strategy as maximizing the efficiency of protein use at the expense of the superabundant supply of energy found in plant carbohydrates. However, usable plant energy may also be limiting to ruminants on poor quality winter range or early spring range of lush, watery feeds having low dry matter content (Dietz 1965).

The three classes of forage are categorized by Cook (1972) according to ability to fulfill animal nutritional needs. Generally speaking, shrubs on winter ranges furnish animal protein requirements but are decidedly low in energy for animal metabolism, while grasses are a good source of energy but are deficient in other nutritional requirements. Forbs are generally intermediate between shrubs and grasses in meeting animal winter protein and energy requirements.

Describing elk diets, Hobbs et al. (1979) present the nutritional predicament of foraging animals in the winter. Explaining an observed increase in browse consumption as winter progressed, the authors note that because the difference between protein content of browse and grass increased, the relative benefit of consuming browse leaves and stems was greater in March than November. A consequence of increased lignin intake is declining dry matter digestibility.

The implication of Leach's (1956) and Cook's (1972) work suggests that deer and grazing animals in general require a diverse diet to meet their nutritional requirements through the winter. Wallmo et al. (1977) and Mautz et al. (1976) suggest the nutritive value of forage is a realistic means of determining deer winter range carrying capacity.

Food Habits

Food habit studies point out that diets of elk and mule deer are as varied as the environments they inhabit. Kufeld (1973) provides a compilation of 48 elk food habit studies. Kufeld et al. (1973) have compiled available information on food habits of Rocky Mountain mule deer.

Elk are generally browsers west of the Continental Divide in the heavily forested wintering areas having dense seral-shrub understory communities (Lyon and Jensen 1980, McNeill 1972). Browse may form as much as 90 percent of the winter diet (Gaffney 1941). A majority of the elk winter diet is comprised of grasses on the eastern slopes of the Rocky Mountains where winter ranges are more open-grassland (Greer et al. 1970, Knight 1970, Constan 1972). As demonstrated by Morris and Schwartz (1957), grass may constitute 100 percent of the elk diet on these eastern winter ranges.

The mule deer is by preference a browsing animal during the winter (Cowan 1947), although Geist (1981) suggests that stereotyping them as strictly browsers is a gross mistake, because deer may browse in some areas but not in others. Actual browse consumed is determined largely by what is available (Wilkins 1957). Studies show winter diets of mule deer contain from 62 to 78 percent browse on forested winter range (Lovaas 1958, Wilkins 1957, Constan 1972). On a grassland dominated winter range, Morris and Schwartz (1957) show only 2.5 percent browse in the deer diet, but a follow-up study by Nellis and Ross (1969) on the same winter range indicates a shift towards higher browse consumption by deer. Nellis and Ross conclude that this increase in browse consumption is the result of a better balance between deer numbers and the amount of preferred forage following a herd reduction.

Foraging Strategies

Mule deer increase the energy potentially available to them by selecting foods carefully (Short 1981). Bell (1971) observes that the small ruminant feeds very selectively on the more easily digested plant parts high in protein, such as leaves, fruits, and shoots which maximizes nutrition from a relatively sparse intake of food. This observation is not necessarily valid for larger ruminants which can afford to be somewhat less selective in consuming greater quantities of stems and other less easily digested food parts.

Deer prefer to feed where there is no snow, but they may remove snow with their muzzles or by pawing with a front hoof (Geist 1981). Elk are capable of pawing through 91 to 122 cm of snow to feed (Gaffney 1941, Smith 1930), but they generally feed in less restrictive conditions. Of 19,067 elk feeding observations by Houston (1976), 94 percent of the elk were feeding in 30.5 cm of snow or less. Both deer and elk utilize wind-exposed sites and exposed hillsides as accessible feeding areas (Grimm 1939, Gilbert et al. 1970).

The most active daily feeding periods are early morning and late evening (Beall 1974, Morgantini and Hudson 1979), but animals may also feed through the daytime when severe conditions cause a shortage of feed (Gaffney 1941). Elk and deer foraging activity will often occur in the productive bottomlands and sagebrush-grasslands in December-January but will shift under forest cover to escape snow crusts and severe conditions that may develop in February-March (Houston 1976, Knight 1970, Constan 1972).

Cover

Cover of some form is essential to elk and mule deer for thermal, escape, and security reasons. Cover for elk is generally considered to be coniferous forest (Black et al. 1976, Reynolds 1966). Mule deer will use coniferous trees as well as shrubs for cover in the winter (Loveless 1964). Geist (1981) explains the value of long, steep hillsides as escape terrain for mule deer.

Elk apparently have a higher security requirement for cover than deer (Lyon and Jensen 1980). Elk fled into areas with an average of 85 percent tree canopy coverage as escape cover in Coop's (1971) study. Black et al. (1976) describe hiding cover as vegetation capable of concealing 90 percent of an elk from human view at a distance equal to or less than 61 m. If hiding cover requirements are satisfactory for elk, the same cover should be more than adequate for deer (Black et al. 1976).

Beall (1974) determines that elk purposefully select bedding sites according to the thermal comfort range needed. During colder periods elk tend to bed on more open southerly exposures during the day and in small clumps of dense forest near the largest trees at night to maximize the benefits of solar and thermal radiation. When ambient temperatures increase this diurnal bedding pattern is reversed. Black et al. (1976) describe deer winter thermal cover as a forest stand of at least sapling size with 60 percent crown closure. Wallmo and Schoen (1981) maintain that although thermal cover is an important aspect of forested habitat, current knowledge dictates management must be based on broad principles rather than precise prescriptions.

Many elk calve on the upper portions of the winter range or adjacent transitional range (Johnson 1951, Coop 1971). Calving cover as described by Johnson (1951) consists of security cover for the cow and calf in close proximity to succulent forage and water. Fawning cover is vaguely described by Einarsen (1956) as shrub or tree cover with succulent vegetation and water nearby.

Human Influence - Direct Contact

Elk and mule deer are never far from human influence even in the "natural" environments set aside, in part, for their use. Impacts of human influence range from the temporary disturbance caused by backpackers to complete habitat elimination caused by subdivisions. An animal's threshold of tolerance for any disturbance can be especially low in the winter. Reed (1981) advises that mule deer suffer a pronounced energy deficit in severe winters and can tolerate little additional energy cost from disturbance if they are to survive.

The most obvious and easily recognized human impact is direct individual contact upon an animal's sphere of security. Ward (1976) and Lemke (1975) both report that elk prefer to stay at least 800 m from human activity, whether recreational or otherwise. Daneke (1980) points out that heavy cover minimizes a disturbing influence, indicating elk usually move no further than necessary to avoid people. Animals can also become habituated to certain activities, such as fishermen or sightseeing tourists, yet bolt from an unfamiliar human activity (Altman 1958, Beall 1974).

Sensitivity to the distance a human can approach a wild animal, without causing it to flee, will vary with the type of habitat, specific experience of the individual or group, and its reproductive and nutritional status (Altman 1958). Hayden-Wing (1979) describes a contraction of elk distribution due to human activity on a winter range which consequently expanded as soon as the human activity ceased. Animals soon return to normal activity areas once a temporary disturbance, such as hunters, has passed (Lemke 1975, Ward 1976, Morgantini and Hudson 1979).

Human Influence - Livestock Grazing

Alterations of animal habitat by man's activities can be subtle or devastating, but any change is potentially harmful if wildlife requirements in an area are misunderstood. Winter range, because of its scarcity and intensity of animal use, is sensitive to land management decisions (Black et al. 1976).

Livestock grazing is a land management practice that can have significant impacts on wildlife use of winter ranges. A major aspect of the conflict between domestic livestock grazing and wild ungulates is competition for forage (Holechek 1980). Even though big game and livestock may not occupy a winter range concurrently, they may be in direct competition for the same forage plants (Jensen et al. 1972). Southern Colorado data in Cooperrider (1982) show a 52 percent dietary overlap with summer cattle diets and elk winter-spring diets. The same study reports a 25 percent overlap between summer cattle diets and deer winter-spring diets. Smith and Julander (1953) report that the similarity of deer and sheep diets is sure to cause conflict wherever the supply of preferred forage is inadequate to satisfy the requirements of both animal species.

Jensen et al. (1972) conclude that sheep grazing is compatible with big game winter use of similar forage mix provided sheep spring grazing is restricted to the early growing season. Anderson and Scherzinger (1975) also attribute their success with cattle spring grazing on elk winter range to removing cattle at the correct stage of plant phenological development. However, in a forage competitive situation, an intense livestock management system should be employed if wildlife are to benefit; grazing vegetation at critical growth stages causes not only insufficient regrowth during the growing season, but also causes a decrease in plant growth the following year (Wilson et al. 1966, Blaisdell and Pechanec 1949). Certain environments may not be conducive to a spring-winter grazing schedule. Cook and Stoddart (1963) indicate that arid salt-desert shrub ranges are best adapted to winter grazing and if used only in the winter would have about twice the grazing capacity of spring use.

Competition for space can also be an important factor in livestock - wildlife interaction (Lonner and Mackie 1983). Elk have been seen grazing in proximity to cattle (Ward et al. 1973, Delguidice and Rodiek 1982), but in portions of Montana, Mackie (1970) and Lonner (1975) maintain that elk preferentially avoid areas being concurrently grazed by cattle and areas where cattle grazing recently occurred. Mule deer do not seem to exhibit the avoidance behavior to livestock that elk do (Compton 1975).

The substantial increase in elk use of an Oregon winter range through use of a cattle grazing system reported by Anderson and Scherzinger (1975) warrants closer inspection. Associated mule deer use did not respond, but elk numbers increased in a 10-year period from 320 to 1190 animals, with a concurrent 2.6 times increase in cattle animal unit months grazed. These remarkable increases accompanied by reported ecological improvements are attributed to improvement of winter forage quality for elk. Three details mentioned in their report are interesting to bear in mind: 1) the study area is a natural grassland with sparsely occurring shrubs, 2) the area receives 45.7 cm (18 inches) annual precipitation with 1/3 occurring during the plant growing season, and 3) the wintering area was closed to all vehicle traffic during elk occupancy.

Houston (1971) speculates that turn-of-the century high sagebrush densities in the Gardiner area of the northern Yellowstone winter range were the result of domestic livestock grazing. He considers the decline in sagebrush density after livestock removal as a return to more "natural" conditions. The Gardiner area is an arid shrub-steppe, with certain portions of the winter range receiving less than 30.5 cm (12 inches) annual precipitation (Houston 1974). Smith (1949) reports mule deer grazing alone caused a reduction in shrubs on a northern Utah sagebrush-grassland range, but livestock grazing plus deer reduced herbs and increased shrubs.

Human Influence - Logging

Logging practices significantly alter wildlife habitat. Animals habituate to the activity of logging (Beall 1974, Hershey and Leege 1976), but potential changes in habitat use occur after the logging operation is completed. Various silvicultural techniques influence animal post-logging use. Juxtaposition, size, shape, and cleanliness of a timber cut help determine a logged areas usefulness to animals (Beall 1974, Reynolds 1969, Marcum 1976, Lyon 1976).

Reported benefits of logging to deer and elk focus on an increased, better quality, forage supply (Resler 1972, Pengelly 1963). However, animal use of created openings is tempered by the security level provided (Lyon and Jensen 1980)

Detrimental impacts of logging can be many. Removal of tree canopy by logging increases snow depths noticeably (Pengelly 1972). Elk avoidance reaction to post-logging conditions are attributed by Beall (1974) to removal of choice bedding sites and poor slash clean-up. A distinct negative correlation is noted by Leege (1976) between the percentage of summer range logged and elk counts on an adjoining winter range. Even-aged regrowth, when mature for timber yield, and intermediate stages of timber regrowth are both impoverished deer habitat (Wallmo and Schoen 1981).

Permanent establishment of logging roads and the decreased hiding cover quality of even-aged timber rotations has reduced elk habitat security and forced more restrictive hunting regulations in Montana (Lonner and Cada 1982). However, elk do not necessarily avoid roads unless there is human activity on them (Gruell and Roby 1976, Daneke 1980). Perry and Overly (1976) estimate construction of roads in elk habitat can negatively impact more than 259 ha (640 acres) of habitat per 1.6 km (1 mile) of road, unless protective guidelines are considered. Marcum (1976) reports areas where roads are closed to vehicular traffic receive greater elk use than areas where roads remain open, especially during hunting seasons.

Black et al. (1976) suggest careful study of elk and deer use before a decision is taken to alter the cover - particularly thermal cover. A well used elk winter range is a limited, critically important area and should be protected from timber harvest (Beall 1974, Zahn 1974, Bohne 1974, Lemke 1975).

Wildlife Range Impacts

Grazing animals exert an influence upon the productive rangeland system by their defoliation of plants through eating and physical damage, by their digestive processes, and by their movements (Heady 1975). A review by Ellison (1960) indicates that any damage caused by grazing animals depends on intensity, frequency, and time of utilization and also upon individual plant species response to forage removal. Plants are least susceptible to heavy concentrations of big game animals during the dormant winter period because grazing or clipping plants after the food-storage cycle has been completed has the least effect on subsequent production (Stoddart et al. 1975).

Blaisdell and Pechanec (1949) report late fall clipping (October 30) had a negligible effect on bluebunch wheatgrass (Agropyron spicatum) and arrowleaf balsamroot (Balsamorhiza sagittata). Certain shrubs can withstand repeated heavy utilization during the winter (Stoddart et al. 1975, Wright 1970) which may even promote subsequent increased forage production (Garrison 1953, Willard and McKell 1973).

In general, defoliation early in the growing season, when big game may still be on a winter range, is less detrimental than later use (Stoddart et al. 1975). Removal of vegetative parts has the least effect during the first 2-3 weeks of the growing season, but clipping after these growth stages can be quite detrimental to a plant (Blaisdell and Pechanec 1949, McIlvanie 1942, Wilson et al. 1966). Cook and Stoddart (1960) found spring defoliation especially severe on big sagebrush (Artemisia tridentata). A late spring dispersal by large numbers of elk and deer could thus be potentially damaging to a winter range.

Gaffney (1941) considers about 8094 ha of the South Fork of the Flathead elk winter range to be in a badly depleted condition. He reports that not only are preferred browse plants being killed by overuse but bunchgrasses are being damaged from early spring grazing. Robinette et al. (1952) attribute the loss of 40 percent of one mule deer herd to overbrowsed range, which they compare to a 10 percent loss of deer following a severe winter on good condition browse range.

Many of the early authors discussing the northern Yellowstone winter range describe its deteriorated condition (Rush 1932, Grimm

1939, Kittams 1953), which prompted large elk herd reductions continuing through 1968. After examining over 200 sites, Houston (1971) concluded that very little of the northern Yellowstone winter range was in a depleted condition. Instead, he considered ridgetops and other harsh topoedaphic sites previously considered abused, as zootic or topoedaphic climax conditions (Houston 1974). Yellowstone Park now maintains a policy of natural regulation for its ungulates, after concluding that herbivores are not causing retrogressive changes of vegetation on some Park winter ranges (Cole 1978).

Grazing animals can increase compaction of soils to surprising depths, especially during spring or other moist seasons (Stoddart et al. 1975). Soil compaction restricts soil moisture, root development, and seedling emergence and vigor (Stoddart et al. 1975, Barton et al. 1966, McNeal and Weaver 1982). Possible soil compaction caused by "yarded" elk or mule deer in early spring is an interesting, unexplored topic.

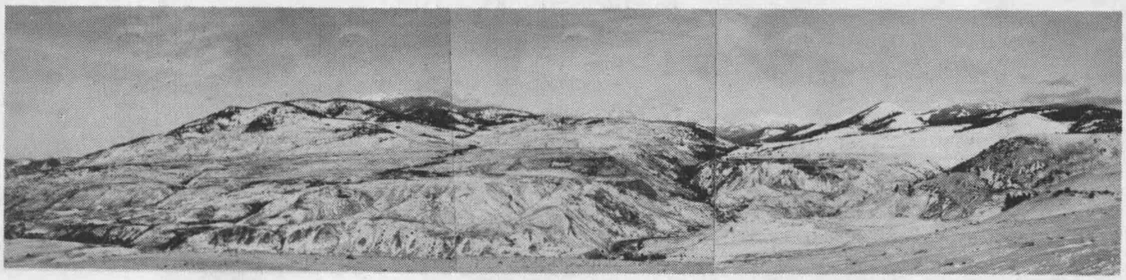
An estimated 47 percent of the earth's land surface is rangeland (Williams et al. 1968). The knowledge to preserve land resources partly involves early detection of changes in plants, soil, and animals, and the skill to return a measure of stability to the ecosystem (Stoddart et al. 1975). Although elk and mule deer winter ranges are only a small fraction of our rangeland, the benefits of preserving such a small land resource are returned in many ways (Swift 1941, Robinette et al. 1952, Reed 1981).

STUDY AREA DESCRIPTION

Location

The study area is located in the Gallatin National Forest near the town of Gardiner in southwestern Montana (Figure 1). The study area is bounded by Little Trail Creek on the north, Yellowstone National Park on the south, and U. S. Highway 89 which follows the Yellowstone River on the west. Deep winter snow in the Absaroka Mountains forms the less well-defined eastern boundary. The area encompassed contains about 5830 ha (14,000 acres) of National Forest with approximately 1416 ha (3500 acres) of private land intermixed.

Figure 1. Panorama of the Gardiner study area.



The panorama in Figure 1 was taken from within Yellowstone National Park looking towards the study area. View is to the north on the left side of the panorama and to the east on the right side. Gardiner is located just out of the picture on the lower left. The Park boundary line follows the Yellowstone River in the immediate foreground to the forested ridge on the far right. Bear Creek is the forested channel in the middle-right of the panorama.

Gardiner is situated in the Yellowstone River valley at 1615 m (5300 feet) elevation surrounded by peaks reaching 3353 m (11,000 feet). A rain shadow created by these mountain peaks makes the benches and adjacent slopes of the Gardiner valley a preferred winter range for animals forced out of higher elevations by deepening snow. Migratory herds summering in Yellowstone Park and the adjacent Absaroka-Beartooth Wilderness Area comprise the majority of animals utilizing the study area.

Animals approaching the Gardiner valley arrive along deeply entrenched stream channels or adjacent steep-sloped mountains into a relatively wide (4-6 km) valley of open slopes and benches grading into the Yellowstone River. Upon entering this relatively snow-free valley they are confronted with sagebrush-grass covered slopes and terraces with a scattering of conifers. The protective cover of continous forest is about 762 m (2500 feet) above the valley floor on the upper limit of the wintering area, where snow cover may be over 1 m deep. A large part of the animals' foraging time is consequently spent on the relatively exposed sagebrush dominated range during the winter. Therefore, animals become especially susceptible to environmental stresses.

Geology

Transformations which occurred during geologic times are responsible for making the Gardiner area a winter range. Geologic forces which formed the volcanic Yellowstone plateau to the south and the spectacular Beartooth Mountains to the east had a significant role in shaping the Gardiner area. The study area adjoins these two distinct geologic units.

The Beartooth Mountains which shape the study area's northeastern boundary result from an uplifted granitic block. This northwest trending uplift (Foose et al. 1961) forms a ridge approximately 64.4 km (40 miles) long with more continuous area above 3048 m (10,000 feet) in elevation than anywhere else in the United States (Koch 1972). In addition to pre-Cambrian rocks, paleozoic limestones and dolomites constitute the prominent backbone of these impressive mountains (Ritter 1967).

Nearly the entire Beartooth range is outlined by faults, one of which runs east and west through the lower portion of Little Trail Creek (Fraser et al. 1969). This fault action in late Cretaceous or early Tertiary times (Wilson 1934), raised the area north of the fault, and dropped and folded the area to the south. The Yellowstone River flowed over the dropped area carving out the broad valley of the Gardiner winter range.

Lava flowing northwest from the volcanic Absaroka Mountains or from farther south in the Park "during the Pliocene (?) epoch ponded in the Gardiner valley" (Fraser et al. 1969). At least five different episodes surged into the valley and formed its broad basalt benches. On these same benches Pleistocene-aged travertine was formed from hot carboniferous spring water. Mining for this decorative rock began in the 1930's (Whithorn 1968) and still continues on the winter range today.

Three Pleistocene glacial advances first described by Blackwelder (1915) affected the Yellowstone area. The second and third of these, the Wisconson Bull Lake and Pinedale, applied finishing touches to topography of the Gardiner winter range. During Pinedale time, major ice streams from four sources converged near Gardiner (Pierce 1979). Pierce's (1979) work suggests ice was at least 1100 m thick and covered the entire area.

Choice foraging sites for wintering wildlife were created as glacial scouring and till deposition smoothed the surface of Deckard and Travertine Flats. Eroded outwash channels now provide relatively level feeding and resting areas on the otherwise steep mountainsides. Morainal deposits dissected by melt-water channels contribute topographic relief in the exposed Bear Creek and Eagle Creek areas.

Climate

The Gardiner area is humid with a summer water deficiency following Thornthwaite's (1948) classification. Although Gardiner summers can be dry, convectional showers often provide some growing season moisture. During winter months when storms are more widespread and severe, snow may be 1-2 m deep in nearby mountains yet absent in Gardiner.

Farnes' (1975) annual precipitation map of the area illustrates the rain shadow created in the Gardiner valley with isohyets closely following land contours and greatly increasing with elevation. Annual precipitation along the Yellowstone River gorge averages 30.5 cm (12 inches), while the basalt benches get about 40.6 cm (16 inches).

and surrounding mountains receive up to 76.1 cm (30 inches). About half of this moisture generally falls as snow.

The U. S. Weather Bureau station at Mammoth, located about 300 m higher and 8 km upstream from Gardiner, affords a good approximation of conditions on the Gardiner winter range. Weather data representing 94 years accumulation show annual average precipitation of 41.2 cm (16.25 inches) with February the driest month, averaging 2.7 cm (1.05 inches) and June the wettest, averaging 4.9 cm (1.92 inches). Temperature data reveal a mean annual temperature of 4.1°C (39.9°F) with January the coldest month averaging -7.4°C (18.7°F) and July the warmest averaging 17.3°C (63.1°F).

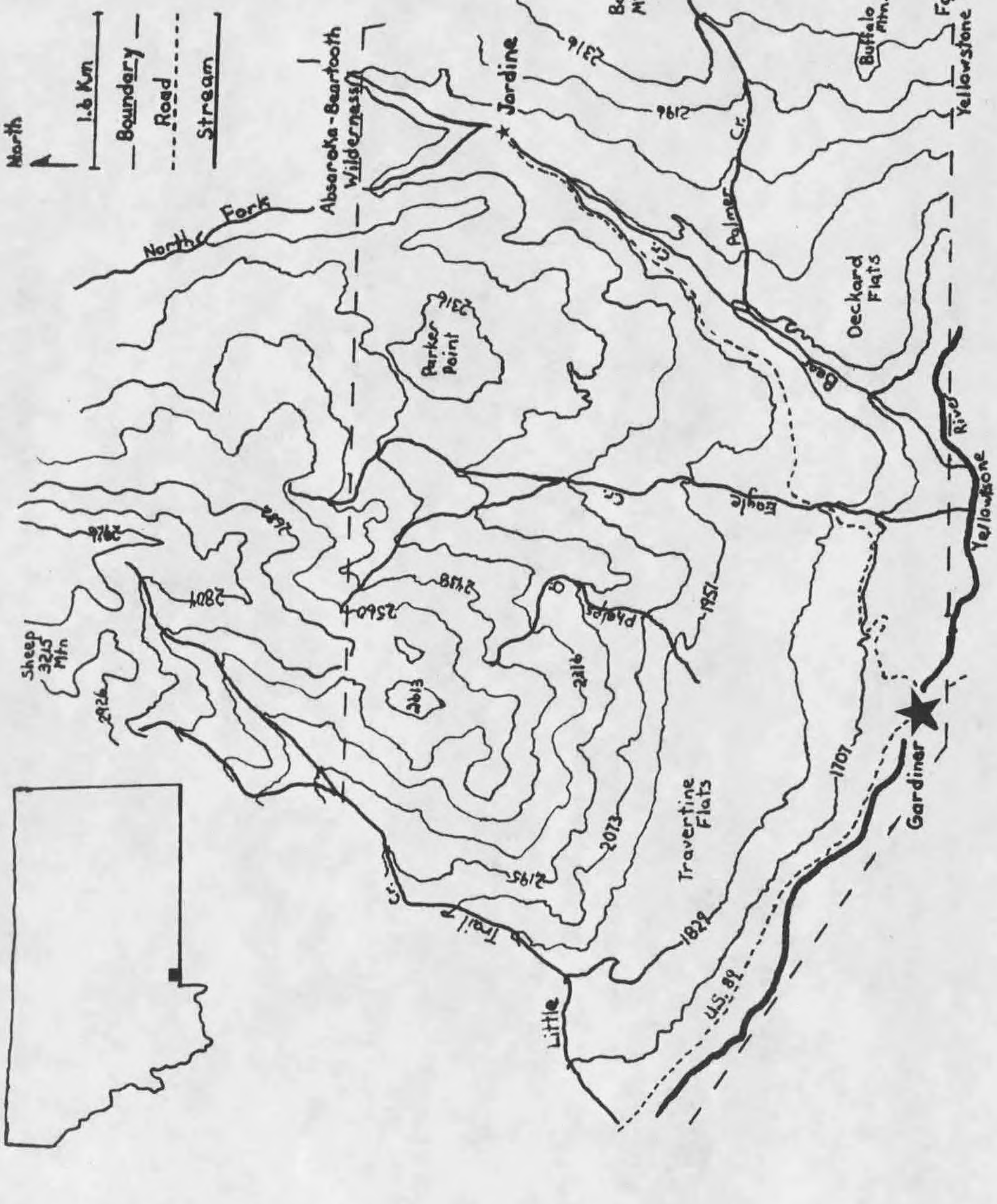
The growing season is from about mid-April to mid-September although a killing frost can occur during any month. Fall regrowth can be substantial during a favorable "Indian summer". Overall, climate combined with other environmental features of the study area creates a diverse, yet often limiting plant environment.

Topography and Soils

Topography of the area is characterized by high steep-sloped mountains with nearby relatively flat or rolling benchlands dissected by deeply entrenched streams (Figure 2). Elevations within 5 km of the Yellowstone River rise 1100 m above the river floor. Steep, weakly dissected slopes are prevalent.

Slopes of 50-60 percent rise from the Yellowstone River and Bear Creek to the 1-2 km wide basalt bench which extends from the Park line northwest to Little Trail Creek. From Deckard and Travertine Flats, slopes again rise abruptly into the Absaroka Mountains. Morainal

Figure 2. Map of the Gardiner study area showing topographic features with elevation expressed in meters.



topography in the Eagle Creek area provides a more gradual ascent into the mountains.

Most of the study area has a south and west facing aspect. North and east facing slopes are mainly along stream channels and in mountainous elevations. Both convex and concave shaped slopes of 2-70 percent rise are existent.

Soils[1] in the area have been strongly influenced by glacial scouring, morainal deposition and outwash sediments. Parent lithologic materials are a mixture of granites and limestones from glacial action in areas to the south and east. Cold winters and dry summers characterize the soil climate.

Soil regolith depth ranges from a few centimeters in glacially scoured areas to several meters in depositional areas. Glacial till has a sandy loam texture and a high course fragment content ranging in size from gravels to boulders 3-4 m in diameter. The surface is covered with granite erratics which probably came from the Black Canyon of the Yellowstone (Pierce 1979).

Most of the soils in the area are Mollisols. Soil families range from loamy-skeletal Aridic Haploborolls to fine-loamy Pachic Argiborolls. There are some Inceptisols near bedrock outcrops and Alfisols in forested areas.

Vegetation

There is a great deal of plant diversity in the area, from the semi-arid valley floor to the subalpine meadows. A list of plants

[1]Soils data collected by Gallatin N. F., U. S. Forest Service soils crew, July 1980.

identified on the study area is presented in Appendix A. A characterization of vegetation is presented in this section with a quantitative description of vegetative composition presented in Results and Discussion.

Study area vegetation is predominantly sagebrush-grassland. Over 54 percent of the area is open sagebrush-grass range with another 14 percent having sagebrush dominanted understory and a scattered tree overstory. About 27 percent of the study area provides protective overstory cover of continuous forest which begins at about 2300 m elevation on the upper periphery of the wintering area. The remaining 5 percent of the area has been clearcut.

Due to microsite variation, vegetational mosaics are created mainly by orographic precipitation, varied topography and differing soil properties. This mosaic provides a high degree of vegetational choice to animals wintering in the area. Vegetational asymmetry is best described in terms of dominant shrubs and grasses.

A water limited environment occurs along the Yellowstone River, especially from Gardiner upstream to the mouth of Bear Creek. Saline seep on the steep hillsides has created a vegetative complex usually described as a salt desert shrub type dominated by greasewood (*Sarcobatus vermiculatus*), spiny hopsage (*Grayia spinosa*), Gardner saltbush (*Atriplex gardneri*) and inland saltgrass (*Distichlis stricta*). This site is relatively small but it reflects the most restrictive relationship of precipitation to evapotranspiration on the area.

Three subspecies of big sagebrush (Artemisia tridentata) and black sagebrush (Artemisia nova) occur sympatrically but with varying frequency. These deep rooted shrub taxa each have an optimum niche but all are important components of the Gardiner winter range. Rubber rabbitbrush (Chrysothamnus nauseosus), green rabbitbrush (C. viscidiflorus) and gray horsebrush (Tetradymia canescens) also occur throughout the sagebrush dominated portions of the area.

Black sagebrush appears to be closely associated with clacareous soils over buried travertine. This low shrub dominates the overstory on sandy till covering travertine and it is also found downslope from these areas. Wyoming big sagebrush (A.t. wyomingensis) is found on deep sandy loam soils resulting from glacial outwash and more recently placed alluvial silts.

Basin big sagebrush (A.t. tridentata) grows mainly downslope of basalt outcrops, on lower portions of steep slopes or in other areas where water flow is enhanced. Mountain big sagebrush (A.t. vaseyana) is the most frequent and dominant shrub in the area. It grows throughout the study area and is the only sagebrush taxon found above 2100 m.

Bluebunch wheatgrass (Agropyron spicatum) and Idaho fescue (Festuca idahoensis) are the two principal grass species on the study area. Dominance by either species appears to be related to a greater tolerance for aridity by bluebunch wheatgrass. Bluebunch dominates lower elevation sites with steep south facing exposures, sandy soil or other moisture limiting factors.

Idaho fescue is the principal grass on north facing slopes and deep silty soil sites. Idaho fescue is a prominent grass species at higher elevations where moisture availability is not limiting. Other prominent grasses in local areas are prairie junegrass (Koeleria pyramidata), needleandthread (Stipa comata) and Indian ricegrass (Oryzopsis hymenoides).

Scattered trees at lower elevations are mainly Rocky Mountain juniper (Juniperus scopulorum) and limber pine (Pinus flexilis). Near streams and at higher elevations Douglas fir (Pseudotsuga menziesii) is the dominant overstory species. Above 2300 m multiple-species mixtures of Douglas fir, whitebark pine (Pinus albicaulus), lodgepole pine (Pinus contorta), and subalpine fir (Abies lasiocarpa) occur.

Dominant overstory and understory vegetation was used to differentiate habitat types in the area. Pfister et al. (1977) was used as a reference for the forest habitat types. Mueggler and Stewart's (1980) shrubland habitat types were modified to include the subspecies of big sagebrush for the non-forested portion of the study area.

Animals

The study area is part of the northern Yellowstone winter range which is best known for the large number of migrating elk utilizing it. Most of these elk summer in the broad expanse of Yellowstone Park while a smaller number summer in the mountainous Absaroka-Beartooth Wilderness. Small summer herds forced to lower elevation by fall snow begin to congregate on benches and exposed hillsides along the Yellowstone River and its tributaries. These congregating herds are collectively known as the northern Yellowstone elk herd, which is currently estimated at 16,000 animals[2].

Elk may begin arriving in the Gardiner area as early as mid-November. Many more elk continue their migration in search of less severe conditions as winter snows deepen. Some may travel as far as 113 km to reach the Gardiner area (Craighead et al. 1972). Deep mountainous snow may persist well into the spring, however, by May, most of the elk have left the study area, moving back toward their respective summering area.

Elk migration in large numbers beyond the Park boundary may occur one year in two or two years in three (Houston 1978). Thus, there may be only a few hundred elk, or up to four to five thousand, utilizing the study area in a given winter. Winter range north of the Park is essential in more severe winters to compensate for unavailable winter range inside the Park. The value of the study area and the rest of the winter range north of the Park to elk is thus evident. However, the area's ability to furnish much needed winter habitat is also important to other large animal species.

Four hundred or more mule deer are conspicuous residents utilizing the Gardiner winter range. Elk may be more numerous most winters on the study area, but deer migrate to the winter range each year, although their distribution is dependent on winter severity.

Dominance of the area by elk has detracted from the attention that might otherwise have focused on this significant deer population.

[2]DeSpain, Don. Research Biologist, National Park Service, personal communication, October 1982.

Most of the deer appear to spend summers in the nearby mountains of the Wilderness, the Park or the study area itself. They usually begin to arrive on the study area around the first of October and may remain through June.

Other big game animals occasionally frequent the Gardiner winter range as part-time residents. Small bands of bighorn sheep (Ovis canadensis) can be found wintering along the bluffs of the Yellowstone River and Bear Creek around Deckard Flats (Figure 1). These sheep are part of the northern Park sheep herd which currently numbers around 100 animals but can number twice that many. An occasional moose (Alces alces) may wander across the area, although it seldom stays long. During deep snow winters, a few bison (Bison bison) migrating down the Yellowstone River valley may cross the Park boundary onto the Deckard Flats area and remain for short periods of time.

Additional large animal species present on the area can have an indirect influence on the range resource. Grizzly bear (Ursus arctos) and black bear (U. americanus) are present in the fall and spring when the large herbivores are also on the winter range. Coyote (Canus latrans), bobcat (Lynx rufus) and mountain lion (Felis concolor) complete the diverse list of large animal species present on this winter range.

Human Influences

Man's activities have historically infringed on traditional winter range in the Gardiner area (Appendix B). Man's impact on the winter range is exemplified by the town of Gardiner itself and the Park it serves. Gardiner, a town of about 350 people, and the nearby mining community of Jardine with a population of about 30, lie directly in the path of animals migrating out of the Park and nearby mountains. Animals must not only migrate around these two towns, but they are also confronted with thousands of people attracted each year to this scenic area to view wild animals.

Gardiner had been an integral extension of Yellowstone Park for three decades when Theodore Roosevelt dedicated the Park's north entrance there in 1903. As the Park's north entrance, it has accommodated millions of people travelling through the world's oldest national park. This close association with the Park not only influences Gardiner's economy, but it also helps dictate management of migratory animals on adjacent public lands.

Management

A. L. Haines (1963) describes the first decade of Yellowstone Park as one beset with official indecision. Nevertheless, during the Park's infancy there were great expectations of preserving animal populations reminiscent of the once large Great Plains herds. It was soon evident that elk was the most prominent species in the Yellowstone ecosystem. Management was directed at increasing elk and other ungulate numbers with little attention given to the consequences.

Around the turn of the century, administrators began to recognize that sensitive mountain habitat could not withstand the range deteriorating impacts of livestock grazing, in addition to grazing by large numbers of wildlife. A Park superintendent's report from 1905 (Rush 1932) mentions the completion of a fence along the Gardiner-Park line excluding free-ranging livestock from adjacent Park winter range. Thereafter, people were amazed to see wildlife appearing on winter range which in previous years had been denuded by livestock.

Winter range north of the Park was perceived as critical to wildlife and efforts began in 1917 to secure this land for public management. In 1926, all public lands in the area were withdrawn from homesteading and mining and were proclaimed National Forest. Efforts were made to purchase or trade for private landholdings to consolidate public lands on the crucial wintering area, a practice which continues today. Removal of most grazing permits on winter rangelands further assured forage availability. Today, livestock grazing is not allowed on National Forest lands in the study area.

Management of the area has occasionally relied on concepts borrowed from the livestock industry. Contract hunters were hired by the National Park Service to exterminate predators "threatening" the existence of other wildlife both in and outside the Park (Wonderland 1905). Consequently, there were very few, if any, mountain lion and wolves in the area by the early 1920's. Salting to influence better distribution and winter hay feeding were continued into the 1930's for the intended advantage of all ungulates. The only real benefit of these management efforts was the realization that wild ungulates do not always respond to management or manipulation as domestic stock do.

Management of the winter range has mainly been directed at restoring depleted range by controlling elk numbers. The National Park Service, U. S. Forest Service, and Montana Department of Fish, Wildlife and Parks are all involved with some aspect of the animals' lives. Study area land management is controlled by the U. S. Forest Service, while animals on those lands are the responsibility of the Montana Department of Fish, Wildlife and Parks.

Sport hunting has always been the accepted method for controlling numbers of elk migrating outside the Park. For many years large groups of elk were occasionally caught on the open sagebrush flats of the winter range by unrestricted numbers of hunters. These disagreeable episodes gave rise to the notorious Gardiner "firing line" stories surrounding the hunt.

Since 1963, a late season providing 2-4 day weekend elk hunts has often been authorized in the Gardiner area for special permit holders[3]. A limited number of hunters is allowed on the hunting district, which includes the study area, making the hunt more aesthetic and less disruptive for wintering animals. Hunter success for the last eight years (1975-1983) ranges from 11 to 87 percent, and during this period 7199 hunters have averaged 67 percent success.

In addition to monitoring range trends, land management on the study area has included logging on the periphery of the winter range at the head of Eagle Creek and in Bear Creek. Also, more than 809 ha (2000 acres) of sagebrush range has been burned during the last four years by the U. S. Forest Service with the objective of improving range conditions for wildlife by increasing winter range forage (Tyers 1981). The validity of this hypothesis will be considered with the

[3]Foss, Arnold. Wildlife Biologist, Montana Department of Fish, Wildlife and Parks, personal communication, April 1983.

results of this study. By increasing available forage through burning, it is hoped more animals will remain on public lands longer thereby decreasing the impact on privately owned segments.

METHODS AND MATERIALS

Data Collection

This study was initiated in June, 1980, as a survey of elk and mule deer winter range, but shortly evolved into an analysis of animal use. Field work was completed in June, 1982, with approximately eleven months spent on the study area during this two year period. Almost nine months of field work were conducted during the summer and fall periods with the remaining two months spent during the winter and spring periods.

Definite elk and mule deer use patterns were discernible upon initial inspection of the study area. These findings gave rise to the hypothesis that an animals' preference of one area over another might be measured indirectly by investigation of associated environmental parameters. Realizing a multitude of environmental factors can influence animal use, the study methods were designed to measure animal association with vegetation and landform parameters.

The study area was delineated by habitat type after extensive survey of aerial photographs and ground reconnaissance. Habitat types recognized are continuous over at least 160 ha although ecotones and microsite inclusions exist within the different habitat types. Shrubland habitat types described by Mueggler and Stewart (1980) were modified to include the three subspecies of big sagebrush present, in order to consider differences in animal use within and among the sagebrush taxon. Mueggler and Stewart's (1980) research classifies grasslands and shrublands of the western third of Montana based on potential natural vegetation.

Twenty-eight permanent transects to sample vegetation and animal use were established during the summer of 1980. A stratified random sampling procedure was employed to locate transect sites. Transects were transversely placed every 400 m along north-south lines throughout the area. These north-south lines were approximately 800 to 1600 m apart, moving from east to west.

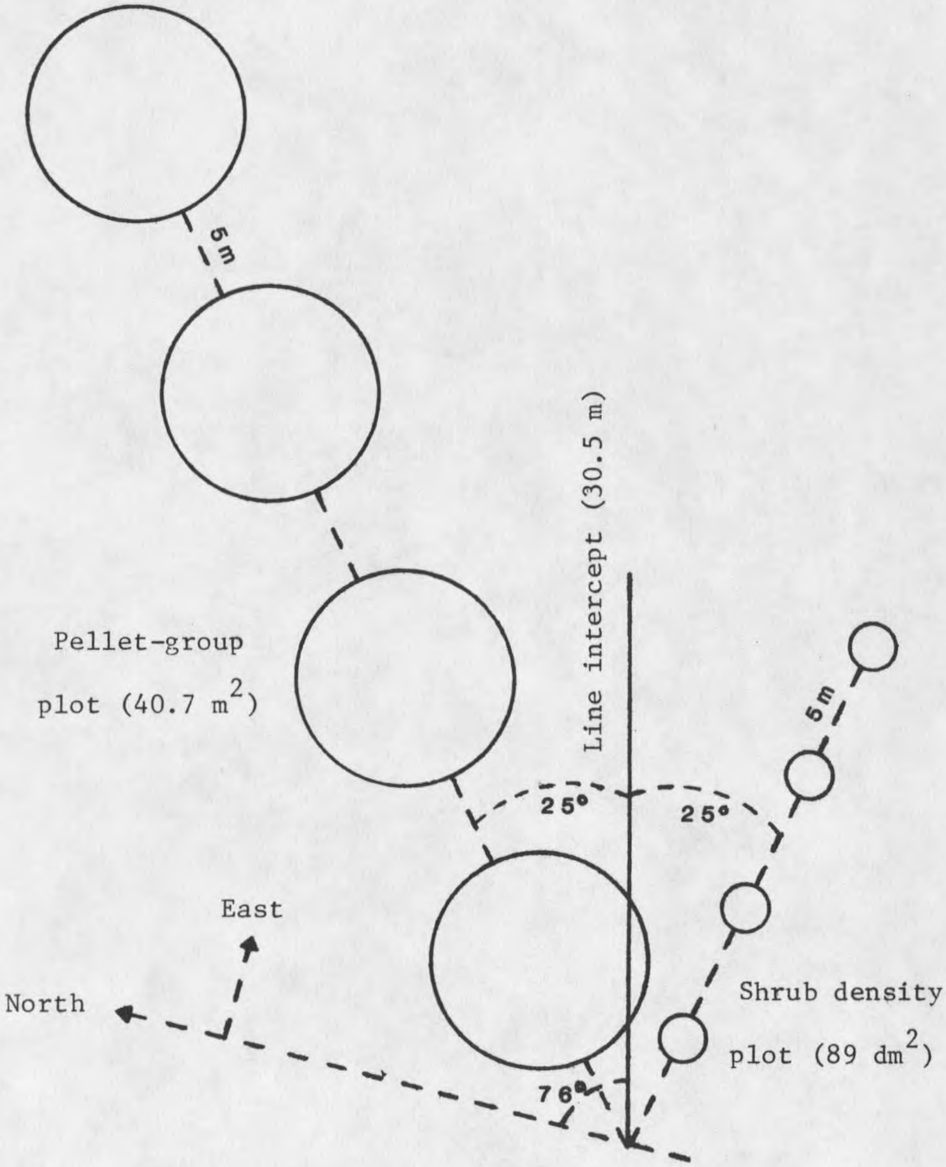
The 30.5 m line intercept employed (Figure 3) was a modification of Canfield's (1941) method. Shrub density plots were 89 dm^2(9.6 ft^2) circular hoops. Pellet-group plots were 3.6 m in radius (1/100 acre).

After baseline vegetation information was collected in 1980, the focus of field work attempted to distinguish associated animal use. Animal use was observed during the winters of 1980-81 and 1981-82. Selected permanent transects were re-examined during the summer of 1981 to determine year-to-year variation in grass and forb production. Thirty-six belt transects modified from a description by Groh and Dore (1945) were utilized during the summer of 1981 to provide additional browse and pellet-group information.

Vegetation Measurements

To determine vegetation potentially available to wintering animals, vegetation information was gathered after the first of July and continued until snow became limiting. Grasses had set seed and most forbs had flowered by the first of July. Consequently, many early flowering forbs were senescent and sampling did not provide a reliable estimate of their earlier status. Sagebrush plants were

Figure 3. Transect for vegetation and pellet-group analysis.



essentially in winter foliage having lost most ephemeral leaves except those on flower stalks (Depuit and Caldwell 1973).

Plant cover was recorded by species line intercept to the nearest 2 mm. Grass and forb cover was obtained from basal line intercept. Shrub canopy cover interception was measured and considered continuous if canopy openings were less than or equal to 15 cm. A measure of leaf interception was noted for decumbent, mat forming species, such as dense clubmoss (Selaginella densa). A plumb bob was used to accurately assess intercepts on steep slopes or when the line was elevated due to shrubs.

Litter, rock, gravel and bare ground intercepts were also recorded. Dead vegetative or animal material forming a protective cover on the soil surface was considered litter. Rock was denoted as any mass greater than 5 cm in width while gravel was defined as stony material from 2 mm to 5 cm in width.

Annual production of grass and forb species was determined by clipping 10 rectangular plots of 18.6 dm^2 (2 ft^2) at 3.05 m intervals along the line used for collection of plant interception data. Clipped plant material was oven-dried at 59° C and weighed to the nearest .01 gm.

Shrub density was determined by counting only those plants rooted within the shrub density plot (Figure 3). Annual shrub production was intially calculated by clipping current annual growth and weighing the green clippings. Leaders of deciduous shrubs encountered were clipped and stripped of leaves to estimate winter forage production.

A proficiency in estimating green weight of shrubs was developed after clipping several plants from each shrub taxon. Ocular estimates of production were then made by grouping leaves of evergreen shrubs and all current year leaders into 5 gm increments. Periodic clipping of entire shrubs showed the estimates to be within 10 percent of the actual weight. Clipped shrub production was oven dried for conversion of green weight estimates to dry weight.

Three-dimensional crown measurements as used by Rittenhouse and Sneva (1977) for Wyoming big sagebrush were recorded for all shrubs encountered within the shrub density plots. These shrubs were also assigned to one of three browse form classes determined by past animal use. The form classes were none to light, moderate, and heavy, depending on second year or older growth exhibiting about 0-20 percent past use, 21-60 percent past use, and greater than 60 percent past use, respectively.

The 1981 belt transects employed a 30.5 m line. Shrub plants rooted within 1.5 m on either side of the line were recorded to obtain density. Crown measurements were also recorded for these plants.

Permanent transects from 1980, representing a cross section of production values in each habitat type, were reclipped in 1981 to estimate annual variation in grass and forb production. Vegetation cover and browse densities were assumed to be similar to those of the previous year and were not re-measured.

Transects were not established in the forest habitat type until 1981. Vegetation measurements taken on all previous transects were recorded for the forest habitat type. Additionally, tree canopy coverage was measured using a spherical densiometer described by Lemmon (1956).

Animal Use Measurements

Animal use in this study was considered a function of time spent by elk and mule deer on various habitat types in the course of their diurnal activities. Consequently, knowing what those activities were became a necessary component of the study. Due to the nature of this investigation, determining animal winter use patterns involved summer surveys when few animals were present on the winter range and periodic winter observations when animals were generally abundant.

During the summer and fall surveys, pellet-group counts were relied on for quantitative analysis of use. Four 40.25 m^2 pellet-group plots incorporated in the permanent transects (Figure 3) were used at sampling sites during the 1980 summer-fall period. In 1981, pellet-group counts were conducted within the 92.9 m^2 belt transects adapted for browse density counts. During both years, at least one-half of a pellet-group had to be within a plot to be counted.

Elk and deer pellet-groups were counted and assessed an approximate age on the basis of firmness, color and weathering. Pellet-groups were aged as either new or old. New would have been deposited within the last 3-4 months or classified post-winter, and old was deposited during the previous winter or pre-winter. Pellet-groups were permanently located throughout the study area in 1980 to support these age assessments and also to establish pellet deterioration rates on the area.

During the summer field season, general observation of distinct signs also indicated animal use patterns. When compared to the entire area, certain sections of intense browse use, obvious trails, and a few small areas of range deterioration all pointed to areas of high use. This evidence of heavy past use was quite discernible the following summer.

Seventeen sagebrush plants had been selected near permanent transects by the second year of the study as a check on shrub utilization estimates. Leaders of a few plants were tagged and measured during the fall to gauge actual utilization and to also provide a basis for accurate estimates. These plants also monitored the validity of the previously discussed browse form classes for sagebrush plants.

Six branches were tagged on each selected sagebrush plant following Aldous's (1945) method. Leaf material, seedhead, current year's leader and secondary growth were each measured above the tag to the nearest millimeter. These same branches were then re-measured the following spring to obtain a direct enumeration of utilization.

Field observations were conducted both winters to observe animal behavior. Animals were tracked throughout the area with special emphasis on relative amounts of time spent and type of activities in the various habitat types. Actual observation of animals was also used to substantiate these perceptions whenever possible.

Grass and forb utilization estimates during the winter employed a form of ocular estimate by plot described by Pechanec and Pickford

(1937). An 89 dm^2 circular microplot was used to estimate the air dry weight of grass and forb utilization at twenty-two feeding sites encountered. Three 1.85 m^2 utilization exclosures were placed on the area in the fall of 1981. One 18.6 dm^2 plot clipped within and adjacent to these cages served as checks for 1981-82 winter utilization estimates.

Landform Description

At each transect site, both permanent and belt, certain landform characteristics were quantified. Transect elevation was accurately derived from U.S.G.S. topographic maps. Due to microsite variation, the dimensions of other landform parameters were determined by the most prevalent condition at each transect site. As an example, the most prevalent slope at a site was determined using a Kleinometer.

Aspect was determined from grid North using a compass and following grid divisions, as detailed by Bohne (1974). Soil-groups were classified after a description by Zacek et al. (1976). These soil-groups combine soil sub-surface texture with topographic features.

Two descriptive classifications were employed to define differences among landforms. Slope configuration at each site was characterized as: 1) flat, 2) concave, 3) convex, or 4) changing aspect (rolling). Topographic position of a site included five categories: 1) bench, 2) midslope, 3) upper slope, 4) ridge, and 5) swale.

Data Compilation

All data for continuous variables were scaled to comparable dimensions for each transect. Measurements on an area basis such as browse density, pellet-group density and vegetation production were converted to units per hectare to equate values from the various plot sizes. Cover data were calculated as a percent of the total.

Browse geometry was deduced as an ellipsoid and calculated in increments of decimeters. Canopy area was determined with the formula, $A = (\frac{L_1}{2})(\frac{L_1}{2})\pi$, where L_1 and L_2 are the longest canopy width and a perpendicular measurement, respectively, as described by Rittenhouse and Sneva (1977). Shrub volume was computed using the formula, $V = 4/6(\frac{H}{2})\ A$, where H is the average height of photosynthetic material.

General trends in the data were discovered from averaging measurements for each transect and comparing the range of values among habitat types. For statistical comparisons, data from each transect were considered an individual set of data or case, and were compared with all other transects for significant differences. Vegetation data were divided into grass, forb or shrub categories for statistical analysis.

Statistical Analysis

Statistical comparison of data from this study is more abstract than first imagined due to microsite variation and varying habitat size generating unequal sample sizes. The intended purpose of many statistical procedures does not always lend itself to data from a natural environment where sample size of a specific variable can not be predetermined or controlled by a form of random sampling. The need for caution in choosing appropriate statistical procedures and also in interpreting results of these tests is therefore essential. Cautionary interpretations of certain statistics from this study is discussed where appropriate with the results.

Scatter diagrams were plotted comparing elk and deer use with the environmental parameters sampled. Analysis of variance and simple correlations among the continuous variables were computed to test for significant differences. All variables were subjected to a multiple regression procedure (step-wise forward selection) suggested by Nie et al. (1975) to select the environmental parameters sampled that were most influential on elk and deer use.

RESULTS AND DISCUSSION

Preface

This chapter is divided into three major parts. The first section details the vegetation and landform available, while the second describes how elk and mule deer use that environment. A third section statistically combines the environmental parameters measured with associated animal use as a means of interpreting the influence of these parameters on animal behavior.

The Gardiner winter range is a unique area to study wildlife-environment interaction due to the number and variety of animals involved. Determining animal "preference" for various sites actually becomes an attempt to segregate intensely utilized areas from areas less intensely used.

Environmental factors evaluated in this study are mainly vegetation and landform parameters. Vegetation succession in the area developed with the existing climate, physiography, and edaphic characteristics unique to the Gardiner area. However, present day vegetation also developed in conjunction with historical wildlife use, in addition to concentrated human influence within the last century. Judgment of the natural vegetation potential of the area must consequently be tempered with awareness of past use and the intended present use.

Vegetation - Visual Observations

Edaphic and physiographic features appear to be the primary influences determining plant species distribution and dominance within the relatively arid Gardiner valley. Both categories greatly impact the effective moisture available to plants, especially at lower elevations where annual precipitation is 31 to 38 cm. Increased precipitation with rising elevation affects vegetation composition also.

Initial inspections of the Gardiner winter range revealed the unique feature of three subspecies of big sagebrush (*Artemisia tridentata*) together with black sagebrush (*Artemisia nova*) growing in close proximity on the study area. Subspecies of big sagebrush include mountain (A.t. subsp. *vaseyana*), Wyoming (A.t. subsp. *wyomingensis*), and basin (A.t. subsp. *tridentata*). All sagebrush taxon are found growing in an elevational belt from the valley floor at 1615 m to approximately 1950 m.

These sagebrush taxon were initially identified taxonomically following the classification of Beetle (1960) in association with use of an ultraviolet light (Winward and Tisdale 1969). Further taxon verification was later made with thin-layer chromotography from specimens in the area (Kelsey et al. 1976).

Mountain big sagebrush is the most common dominant and widely dispersed overstory shrub in the area. It is most productive at elevations from the Yellowstone River gorge at 1600 m to 1950 m on glacial till. Its highest densities in this elevational belt are on slopes of less than 20 percent or in swales where water stress is less severe. Mountain big sagebrush is the only sagebrush taxon growing above 1950 m where it is found interspersed with forest habitats to 2700 m.

Wyoming big sagebrush and black sagebrush are found growing on the most arid sites on the winter range. Winward (1980) points out that Wyoming big sagebrush is the most xeric taxon of the big sagebrush complex. Both taxa grow in the 30.5 to 38.1 cm (12-15 inch) annual precipitation zone.

Wyoming big sagebrush is generally found growing on gentle slopes of south or west facing aspect that receive maximum solar radiation. It is dominant on sandy loams which are typical of glaciated crystalline till from pre-Cambrian rock in the area. These are evidently areas of alluvial deposits due to the large subsurface layers of well sorted sand. These soils are relatively free of coarse fragments, but there is a definite compaction of the sandy C horizons. Calcium carbonate layering detected in these areas is generally 30 to 45 cm below the soil surface which probably indicates very shallow moisture penetration.

Black sagebrush appears to have an affinity for strongly calcareous soils (Winward 1980). Black sagebrush in the Gardiner area thrives on sandy loam soils high in calcium. These soils either cover or are downslope from travertine deposits. Travertine is a calcium carbonate deposit resulting from hot spring water emanations in the area. An Aridic Calciboroll developed on glacial alluvial deposits over travertine has high calcium carbonate concentrations from the surface down through the horizons.

Basin big sagebrush's tolerance for high soil moisture (Morris et al. 1976) is demonstrated in the Gardiner area. Areas dominated by basin big sagebrush receive considerable amounts of spring runoff.

Evidence of runoff is the weak dissection of steep (50 to 60 percent) slopes with moderate channel entrenchment in localized areas. Basin big sagebrush is also found in small stands downslope of basalt outcrops or around outcrops and erratics on more level ground.

Idaho fescue (Festuca idahoensis) and bluebunch wheatgrass (Agropyron spicatum) are the two dominant grasses on the study area. Dominance of either in the understory vegetation appears related to moisture availability. Bluebunch wheatgrass is prominent in more xeric situations while Idaho fescue is the predominant grass in more mesophytic circumstances with approximately 38 cm or more annual precipitation. Ecotones where both species are codominant occur throughout the area.

Bluebunch wheatgrass is the principal graminoid in the 30.5 to 35.6 cm precipitation zone, which is found from 1615 to 1830 m elevation. Above this zone, bluebunch wheatgrass is conspicuous on drier south and west facing aspects, steep slopes, and sandy loam soil sites. Idaho fescue is the predominant grass on north and east facing slopes and silty loam soils. Wright and Wright (1948) noted in the Bridger Mountains that bluebunch wheatgrass communities occupied south facing slopes while Idaho fescue communities occupied north facing slopes. Idaho fescue is the dominant grass in sagebrush-grassland and open forest areas above approximately 2300 m elevation.

Vegetation - Habitat Types

Six major habitat types were vegetatively analyzed on the study area (Tables 1 and 2). Five of the six habitat types studied were shrub habitat types as a consequence of sagebrush-grassland prominence and apparent importance to animals on the study area. Mueggler and Stewart's (1980) work was further differentiated to include subspecies of big sagebrush, in addition to black sagebrush, because these taxa occupy substantial acreages and appear to be stable populations. One forest habitat type investigated in 1981 follows Pfister et al. (1977).

Table 1 illustrates the relative abundance of the major plant species and forage classes in each habitat type. Sagebrush is a prominant component of total cover in all of the sagebrush-grassland

Table 1. Percentage of total mean cover[1] for three forage classes and six dominant taxa evaluated in 1980.

Habitat[2]	Dominant taxon[2] cover						Forage class cover			
type	A.t.va	A.t.wy	A.t.tr	Arno	Feid	Agsp	Grass	Forb	Shrub	Total
A.t.va/Feid	6.7	0.2	0.1	-	6.8	1.5	11.2	2.6	7.2	21.0
Arno/Agsp	0.8	0.7	-	17.0	0.3	1.0	3.8	1.8	18.8	24.4
A.t.va/Agsp	13.1	-	-	0.2	1.1	1.6	5.0	1.2	14.4	20.6
A.t.wy/Agsp	4.6	14.6	-	-	0.4	2.4	6.1	2.3	19.5	27.9
A.t.tr/Agsp	2.8	-	20.1	-	-	1.8	2.0	0.1	22.8	24.9
Psme/Feid[3]	1.5	-	-	-	3.6	0.8	7.0	6.1	1.8	14.9

[1] A.t.va/Feid and A.t.va/Agsp include data from burned areas: cover is basal for grass and forb, canopy for shrub.

[2] Common names of scientific name abbreviations are: A.t.va - mountain big sagebrush; Feid - Idaho fescue; Arno - black sagebrush; Agsp - bluebunch wheatgrass; A.t.wy - Wyoming big sagebrush; A.t.tr - basin big sagebrush; Psme - Douglas fir.

[3] Data from 1981.

habitat types. Low forb cover values are a reflection of forb dessication and disintegration by the time of sampling in the relatively arid shrub habitat types. Forb ground cover is relatively insignificant by the dates migrating animals reach the study area.

Mean shrub canopy cover for mountain big sagebrush habitat types is somewhat less in Table 1 compared to Mueggler and Stewart's (1980) study of pristine Montana shrub habitat types. Mountain big sagebrush/Idaho fescue shrub canopy cover is 66 percent less on the study area, while mountain big sagebrush/bluebunch wheatgrass has a 20 percent reduction from shrub cover reported by Mueggler and Stewart (1980). Grass and forb cover measurements in Table 1 are greatly reduced in comparison to their work, because basal cover was measured in this study as opposed to canopy cover in theirs.

The largest habitat type delineated is mountain big sagebrush/Idaho fescue. The majority of this habitat type lies between 1830 and 2290 m elevation on rolling topography primarily in the Eagle Creek and Deckard Flats areas (Figure 2). This habitat type encompasses approximately 1980 ha of the study area. Soils may or may not have coarse fragments, but they are generally silt loams.

Mountain big sagebrush/Idaho fescue is the only shrub habitat type encountered where sagebrush cover is less than grass cover. Other shrubs occasionally encountered are rubber rabbitbrush (_Chrysothamnus nauseosus_), green rabbitbrush (_C. viscidiflorus_) and gray horsebrush (_Tetradymia canescens_). Prominent graminoids are bluebunch wheatgrass, prairie junegrass (_Koeleria pyramidata_), and Sandberg bluegrass (_Poa sandbergii_). Forbs are generally scarce at the lower, more arid elevations. In higher elevations, arrowleaf balsamroot (Balsamorhiza sagittata) and silky lupine (Lupinus sericeus) are common.

Black sagebrush/bluebunch wheatgrass is the second largest habitat type in the area. It is located mainly in the Travertine Flats area between Phelps Creek and Little Trail Creek and west to U. S. Highway 89. This habitat type covers an area approximately 1130 ha in size. Rocky Mountain juniper (Juniperus scopulorum) is sporadically scattered throughout the area. Occasional patches of limber pine (Pinus flexilis), with an average of 16 percent canopy coverage, provides the only tree cover on the habitat type.

Islands of all three subspecies of big sagebrush are found growing in alluvial outwash channels of Travertine Flats. Occasional shrubs are rubber rabbitbrush and green rabbitbrush. Grass cover is spotty with prairie junegrass prominent in localized sandy areas. Needleandthread (Stipa comata) and Indian ricegrass (Oryzopsis hymenoides) are other contributing graminoids. Although not abundant, stemless goldenweed (Haplopappus acaulis) and Hood phlox (Phlox hoodii) are the most prominent forbs in this relatively dry habitat type.

Mountain big sagebrush/bluebunch wheatgrass is a habitat type primarily located on steep (>20 percent) slopes of south and west facing aspects. This habitat type is situated primarily in the elevational belt from 1950 to 2130 m elevation where the Absaroka Mountains begin to rise from the basalt flats below. It stretches almost the entire width of the study area from the Park boundary line to Little Trail Creek. It is approximately 650 ha in size.

Mountain big sagebrush is the predominant shrub with rubber rabbitbrush and green rabbitbrush the only other shrubs of consequence on this relatively dry habitat type. Needleandthread is abundant in areas with sandy textured surface soil. Prairie junegrass is common throughout the habitat type. Hairy goldenaster (Heterotheca villosa) is abundant on drier sites while arrowleaf balsamroot and silky lupine are common forbs on wetter sites. Most of the habitat type soils have an abundance of surface rock and soil course fragments.

Wyoming big sagebrush/bluebunch wheatgrass is located on the northwest end of Travertine Flats and also near the mouth of Bear Creek. Although only approximately 280 ha in size, these two areas occupy an important ecological niche on the Gardiner winter range. This habitat type supports relatively productive vegetation on sandy loam soils in spite of occupying some of the most xeric sites on the study area.

All three subspecies of big sagebrush are found growing in this habitat type and constitute the majority of the shrubs present. Judging from morphological characteristics there appears to be some hybridization among the three subspecies. Beetle (1960) noted cases of hybridization.

Bluebunch wheatgrass makes up over one-third of total grass cover with prairie junegrass and needleandthread the only additional grasses of consequence. Occassional Idaho fescue plants indicate this habitat marks the limit of Idaho fescue's tolerance to aridity. As with other dry sites, this habitat exhibits a paucity of forbs. Most of the area occupied by this habitat type is on relatively gentle slopes.

Basin big sagebrush/bluebunch wheatgrass is found exclusively along the steep, south facing slope of Bear Creek. It is approximately 180 ha in size. This portion of the winter range is characterized by slopes of 50-60 percent with areas of exposed bedrock and scree rock. It receives a large portion of the spring runoff from drainages between Eagle and Bear Creeks. Consequently, this area is subirrigated during May and June. Steep slopes, southerly exposure, and paucity of developed soil combine to make the rest of the summer season very dry.

Perennial herb cover is sparse due to the relative scarcity of developed soils and extremes in growing conditions. Tall (up to 2.5 m) basin big sagebrush plants are regularly distributed with large individual bunches of bluebunch wheatgrass scattered on the ground surface. Indian ricegrass and prairie junegrass are the only other grasses of significance. Forbs are rare in the area.

Douglas fir (Pseudotsuga menziesii)/Idaho fescue vegetation transects were only conducted during the 1981 summer. This habitat type extends from approximately 2000 m to over 2400 m elevation in some areas. It occurs on all slopes and aspects on mid- to upper slopes. Overall it occupies around 400 ha.

Canopy cover of Douglas fir is relatively open with canopy coverage measurements ranging from 23 to 86 percent, with a mean of 60 percent coverage. Limber pine is associated with this habitat type at lower elevations with whitebark pine (Pinus albicaulis) and subalpine fir (Abies lasiocarpa) found scattered in the upper elevations. Bluebunch wheatgrass and mountain big sagebrush are prominent understory species, especially at lower elevations and on south facing aspects.

Vegetation on other land in the study area was not evaluated, including approximately 360 ha unavailable to animal use due to the two town sites, additional private residences, and active mine sites. Approximately 180 ha are occupied by riparian habitat. The remaining 1460 ha of the study area are subalpine and alpine habitat.

Vegetation - Composition

A compilation of vegetative composition by habitat type from all transects is provided in Appendix C. Table 2 summarizes vegetative production in the area for 1980 and 1981. These numbers exhibit the relative dominance of the principal plant species in each habitat type. Collectively, the two dominant species comprise a major portion of total production in each habitat type.

Mountain big sagebrush/Idaho fescue and basin big sagebrush/ bluebunch wheatgrass are the only shrub habitat types exhibiting much discrepancy between shrub and grass production. Abundance of grass in mountain big sagebrush/Idaho fescue is explained by relatively mesic conditions accompanied with reduced shrub production in localized areas of concentrated animal use. Basin big sagebrush/bluebunch wheatgrass shrub and grass production values reflect the dominance of large basin big sagebrush plants with robust solitary bluebunch wheatgrass plants scattered beneath them.

Table 2. Mean annual production[1] in kg/ha of three forage classes and six dominant taxa evaluated in 1980 and 1981.

Habitat[2] type	Dominant taxon[2] production						Forage class production			
	A.t.va	A.t.wy	A.t.tr	Arno	Feid	Agsp	Grass	Forb	Shrub	Total
A.t.va/Feid	220	1	22	-	335	116	586	257	265	1108
Arno/Agsp	9	2	T	258	21	86	215	88	282	585
A.t.va/Agsp	300	-	1	-	64	164	397	235	340	972
A.t.wy/Agsp	44	338	10	-	11	211	361	48	395	804
A.t.tr/Agsp	26	-	637	-	-	216	223	11	698	932
Psme/Feid[3]	135	-	-	-	142	71	270	198	139	607

[1]A.t.va/Feid and A.t.va/Agsp include data from burned areas.

[2]A.t.va - mountain big sagebrush; Feid - Idaho fescue; Arno - black sagebrush; Agsp - bluebunch wheatgrass; A.t.wy - Wyoming big sagebrush; A.t.tr - basin big sagebrush; Psme - Douglas fir.

[3]Data from 1981 only.

T = Trace (<0.5 kg/ha).

Higher forb values for mountain big sagebrush/Idaho fescue and mountain big sagebrush/bluebunch wheatgrass generally represent prevalence of arrowleaf balsamroot and silky lupine. Forb values in Douglas fir/Idaho fescue are accounted for by a variety of forb species and a slower forb dessication rate under forest canopy. Low forb values in other habitat types not only reflect a paucity of forbs, but also the rapid decomposition of forbs in the exposed sagebrush areas in the latter part of summer.

Wyoming big sagebrush/bluebunch wheatgrass is the only habitat type with appreciable amounts of all three subspecies of big sagebrush. Relatively low production values for black sagebrush in the black sagebrush/bluebunch wheatgrass habitat type, in comparison to its high cover values (Table 1), reflect its low stature and spreading growth form.

Comparison of basin big sagebrush/bluebunch wheatgrass production values with Daubenmire's (1970) classification of steppe vegetation communities shows the study area had only half the grass production but comparable total production. Daubenmire's (1970) study was conducted in eastern Washington. Although the two areas are not environmentally comparable, there is some value in making comparisons because habitat typing was also used in his research. Soils in his study were loams or stony loams and the study sites do not appear to have been as environmentally limiting as the south face of Bear Creek where basin big sagebrush/bluebunch wheatgrass was important on the study area.

Comparison of Table 2 data with production data means reported by Mueggler and Stewart (1980) shows total production in the mountain big sagebrush habitat types are equally comparable, although there are differences between production of forage classes. Production in Table 2 for mountain big sagebrush/Idaho fescue is 29 percent more for grass, 59 percent less for forbs, and 68 percent more for shrubs than comparable numbers presented in Mueggler and Stewart (1980). Comparison of mountain big sagebrush/bluebunch wheatgrass numbers reveals grass production is essentially equal, forb production 15 percent more, and shrub production 14 percent more than their data.

The Ecological Site Method used by the Soil Conservation Service (SCS) for determining climax composition was not used as a guideline for assessing range condition on the study area. After discussions with SCS personnel[4], it was concluded that this method does not adequately account for the climate, topoedaphic conditions, or class of animal use in the Gardiner area. Consequently, a condition rating of any of these habitat types from the SCS technique (Zacek et al. 1976) would not reflect the actual ecological status of the study area.

Plant communities on the study area appear to be stable and near climax status as determined by the composition of dominant plant species present (Appendix C, Tables 1 and 2). Signs of deteriorating range condition (retrogression) in localized areas is probably attributable to human influence such as mine sites, road cuts, etc. Overall, wild ungulate use has not significantly altered vegetative composition on the study area.

Vegetation - Sagebrush Burns

Production and cover values in Tables 1 and 2 include data collected from sagebrush sites burned in past years. Since 1979, the U.S. Forest Service has implemented a program of controlled sagebrush burns to promote increased forage production for wintering ungulates.

[4]Phillipi, Dennis. State Range Conservationist, Soil Conservation Service, personal communication, August 1981.

Vegetation regrowth in two burned areas has been compared with vegetation of similar unburned sites (Table 3).

Data presented in Table 3 were collected in 1980 from transects located in the mountain big sagebrush/Idaho fescue habitat type. All of the sites were on glacial till in the Eagle Creek area. Unburned sites were near the burned areas. Transects on unburned sites were situated on approximately the same percent slope, position on the slope, and aspect, as transects within burned areas. The spring 1980 burn was a controlled fire while the summer 1974 burn resulted from a wildfire on July 29.

Data from Table 3 reveal a decrease in grass prominence on the 1980 spring burn. Idaho fescue and prairie junegrass composition was

Table 3. Comparison of vegetation production and cover from two burned sites with environmentally paired unburned sites.

Location	Production (kg/ha)				Cover (% of total)			
	Grass	Forb	Shrub	Total	Grass	Forb	Shrub	Total
Spring 1980 burn site	387	479	17	883	5.2	4.2	0.1	9.5
Unburned site	511	191*	227*	929	13.7	4.4	10.6	28.7
Summer 1974 burn site	851	175	38	1064	13.9	1.9	0.4	16.2
Unburned site	823	143	634*	1600**	11.9	1.8	14.3	28.0

*Production values significantly different from the paired site value, at the .01 probability level.

**Production values significantly different from the paired site value, at the .10 probability level.

noticeably less in the burned area compared to surrounding areas. Idaho fescue production and cover were 32 and 31 percent, respectively, of the unburned site. Prairie junegrass production and cover were 27 and 9 percent, respectively, of the unburned site. Damage to Idaho fescue by fire has been observed and explained in other studies (Conrad and Poultan 1966, Blaisdell 1953).

Mueggler and Blaisdell (1958) noted that burning sagebrush areas caused an increase in forbs lasting at least three years. Silky lupine, purpledaisy fleabane (Erigeron corymbosus), and western yarrow (Achillea millefolium) were among the forbs showing increased production on the 1980 burn. Increased forb production in shrub habitats on the Gardiner winter range has little potential benefit to elk and mule deer. As noted earlier, summer dessication and disintegration of most forb species leaves negligible amounts of standing herbage available to wintering animals.

Herbaceous species production and cover in the six year old burn was approximately equal to that of unburned areas. Idaho fescue production and cover was equal to 74 and 78 percent, respectively, of comparable data from the unburned site. Increased production and cover of bluebunch wheatgrass on the burned site accounted for the relatively equal grass production and cover between the two sites. Bluebunch wheatgrass is less affected by fire than Idaho fescue (Conrad and Poulton 1966). Evidently, decreased Idaho fescue presence in the vegetation niche was compensated for by increased bluebunch wheatgrass abundance.

Mountain big sagebrush has essentially been eliminated in the burned areas. Sagebrush density around the periphery of the six year old burn was .03 seedling plants per square meter. Seventy-six percent of shrub production in the rest of the burn was either rabbitbrush or gray horsebrush, species which are undamaged and often benefited by sprouting after fire (Vallentine 1977).

Total production in the 1974 burn, compared to the paired unburned site, is significantly different at the .10 probability level. However, the only real difference between the two sites is in shrub production. In the test for differences between two independent samples (Snedecor and Cochran 1980) the significance of t depends on the number of observations. Consequently, differences in grass and forb data between the paired sites would actually be weighted more heavily, because grass and forb production were estimated from ten plots while shrub production was estimated from only four plots.

From these data, it appears that there may be no potential benefit to animals from increased herbage production in burn sites on the study area. Total vegetal cover may be greatly reduced the first year with fire, as it was in the spring 1980 burn, and this reduction may persist. However, sagebrush composition appears to be the only component of the plant community significantly altered by fire on the winter range. Because size of the controlled burns range from spot burns to more than 20 ha, the potential effects of sagebrush removal on wildlife use will be discussed further in this chapter under Animal Use.

Vegetation - Annual Variation

Weather variation has a pronounced influence on plant production and vigor. Precipitation in southwestern Montana during the period of most active plant growth may contribute more to total production than that falling at other times (Mueggler 1967). May precipitation in the Gardiner area was 62 and 88 percent above the mean for 1980 and 1981, respectively. June precipitation was 30 percent below normal in 1980 and 31 percent above normal in 1981. Three years of below average growing season precipitation preceded these two years of increased moisture.

The percentage change in herbaceous production and grass vigor from 1980 to 1981 is presented in Table 4. Number of flowering grass culms is a sensitive indication of vigor (Mueggler 1970). Eleven representative transects were reclipped in 1981. Flowering culms were counted only on clipped grass plants.

Grass production increased in ten of the eleven transects reclipped. Forb production changes were less well defined. Forb production showed slight increases on five of eleven transects, but since production was relatively scanty, small changes translated to high percentages.

Table 4. Percentage change in production and flowering culms of dominant herbaceous species in four habitat types from 1980 to 1981.

Item	Habitat type[1] A.t.va/Feid	Arno/Agsp	A.t.va/Agsp	A.t.tr/Agsp
Herbaceous production				
Grass	+55	+71	+54	-42
Forb	-44	+44	+28	+135
Flowering culms				
Agsp[1]	+145	+28	+155	-32
Feid[1]	+11,219	+1800	+1371	-

[1] A.t.va - mountain big sagebrush, Feid - Idaho fescue; Arno - black sagebrush; Agsp - bluebunch wheatgrass; A.t.tr - basin big sagebrush.

Another factor contributing to increased grass production and vigor could have been the below average number of ungulates on the study area during the winter of 1980-81. However, early growing season moisture received in 1980 and 1981 is believed to be the primary explanation for the increased grass production and vigor noted throughout the study area. Annual variation in plant production and vigor has an important relationship with data analysis throughout the Results section.

Vegetation - Correlations

Plant relationships among the forage classes and with numerically continuous environmental parameters are shown in Table 5. These correlation coefficients help characterize the vegetation component of the Gardiner winter range. Many of the correlations show relationships that would be expected in any plant community. Other correlations demonstrate the vegetation's adaptation to the landform characteristics peculiar to the Gardiner area.

The positive relationship between grass cover and grass production (r = .65) is an example of an expected high correlation. Another would be the negative relationship between grass cover and shrub cover with r = -.63. This negative relationship reflects the aridity in the shrub habitats. An interesting note is that forb cover compared with forb production has an r value of .32. This relatively low correlation probably is due to the fact that basal cover was recorded for herbaceous vegetation. Basal cover of an arrowleaf balsamroot plant might be identical to that of an elk thistle (Cirsium foliosum) nearby, but production of each plant would be quite dissimilar.

Of the three forage classes, grass production is most highly correlated with total production. Similarly, forb cover is the most highly correlated with total cover. These correlations illustrate the role of prominent bunchgrasses in forage production and the importance of the ground covering forbs in the vegetation component of the area.

Grass and forb cover is negatively correlated with all shrub parameters. However, both grass and forb production are slightly

Table 5. Correlation matrix of site variables on the Gardiner winter range.

Site variable	Cover				Production				Shrub				Species		Ele-	Bare			
	Grass	Forb	Shrub	Total	Grass	Forb	Shrub	Total	Density	Volume	Height	Area	number	Slope	vation	ground	Litter	Gravel	Rock
Grass cover	1.00	.42**	-.63**	.20	.65**	.18	-.48**	-.35*	-.47**	-.04	-.06	-.16	.31*	-.32*	-.13	.21	.32*	-.36**	-.29*
Forb cover		1.00	-.26*	.42**	-.11	.32*	-.21	-.07	-.04	-.26*	-.08	-.32*	.37**	-.17	.11	-.04	.27*	-.16	-.46**
Shrub cover			1.00	.35*	-.57**	-.32*	.64**	-.25	.58**	.04	.07	.12	-.53**	.10	-.27*	.05	-.55**	.35*	.16
Total cover				1.00	-.23	.04	.15	-.08	.16	-.11	.04	-.11	-.12	-.22	-.23	-.03	-.20	-.09	-.14
Grass production					1.00	.01	-.40**	.64**	-.53**	.27*	.08	.15	.25*	-.15	-.03	.11	.22	-.22	-.01
Forb production						1.00	-.14	.48**	-.24	.08	.01	.01	.29*	.21	.37**	-.23	.33*	-.25	-.06
Shrub production							1.00	.24	.08	.69**	.60**	.74**	-.65**	.41**	.10	-.16	-.57**	.30*	.51**
Total production								1.00	-.46**	.66**	.47**	.56**	-.06	.24	.17	-.14	-.01	-.13	.31*
Shrub density									1.00	-.37**	-.45**	-.43**	-.38**	-.27**	-.27**	.06	-.36**	.52**	-.34*
Shrub volume										1.00	.75**	.85**	-.16	.41**	.09	-.19	-.26*	.09	.51**
Shrub height											1.00	.83**	-.12	.35**	.18	-.12	-.13	-.12	.52**
Shrub area												1.00	-.25	.48**	.16	-.23	-.35*	.06	.73**
Species number													1.00	.01	.35*	.13	.47**	-.23	-.38**
Slope														1.00	.42**	-.32*	-.15	.04	.55**
Elevation															1.00	-.26	.38**	-.26*	.14
Bare ground																1.00	.12	-.30*	-.30*
Litter																	1.00	-.75**	-.41**
Gravel																		1.00	-.06
Rock																			1.00

* Significant at the .05 probability level.
** Significant at the .01 probability level.

positively related to shrub size parameters, possibly indicating the tendency for herbaceous plants to cluster around the base of larger sagebrush plants. All shrub size parameters are highly correlated with one another. Conversely, shrub density is negatively associated with shrub size.

Other correlations help to explain some of the distinctive characteristics of the study area. Slope tends to increase with elevation, indicating the abrupt rise of the Absaroka Mountains. Number of plant species also significantly increases with elevation, which reflects more mesic conditions at higher elevations.

Total production and grass production significantly decline as shrub density increases. Black sagebrush/bluebunch wheatgrass has the highest density of shrubs on the study area. Yet, overall production is the lowest of any habitat type because of black sagebrush's growth form in addition to the low grass production on this arid site. Another factor accounting for these negative associations is that some of the highest grass producing sites in other habitat types are areas where animals congregate and deplete the shrub component.

Grass production is significantly associated with shrub volume increases which expresses the tendency for grass plants to grow underneath large robust sagebrush plants. Grass plants are not only protected from grazing under sagebrush plants, but are also shielded from the drying effects of the sun and wind. Shrub parameters are all negatively correlated with litter accumulation which possibly reflects sagebrush's slow cycling of nutrients back into the ecosystem.

Total production increases significantly with increased rock cover due primarily to shrub production. Big sagebrush plants increase around areas of exposed rock, of which there are considerable quantities on the study area. Rock outcrops, large erratics from glaciation, and even old mine sites contribute rock surface to gather additional runoff moisture which seems to benefit big sagebrush.

Most of the correlations discussed illustrate plant competition for moisture in the dry Gardiner environment. Yet, microsite variation has created a unique and diverse plant environment. Generally speaking, vegetation adapted to the area appears to be in relatively good range condition, probably closely approximating climax conditions. Vegetation condition is surprisingly good despite the large number of animals using the area. The explanation lies in the way animals use the study area.

Animal Use

Animal observations and indications of animal use were documented throughout the study period. An effort was made to observe animals without being detected, whenever they were encountered. A major part of the summer period was spent on the lower elevations of the winter range where animal summer use is infrequent. However, sufficient time was spent on the upper elevation periphery to identify animal activity patterns and areas.

Observation of animal winter use was conducted during periodic field trips to the study area. Because these field trips were believed insufficient to adequately sample animal use under all winter conditions, observations were not numerically analyzed in comparison with site variables. Rather, observations were used to substantiate or interpret these data.

Animal Use - Summer

Although the majority of animal use occurs during winter months on the study area, there is also substantial summer use of the winter range periphery. Both elk and mule deer are scattered throughout the Douglas fir and subalpine habitats during summer months. Some of the migrating animals appear to use the upper periphery as intermediate range while others remain in the area through the entire summer.

A majority of elk on the study area began a reverse migration back into the mountains as soon as snow and weather conditions moderated during both years of the study. This movement began slowly with a few animals but grew in numbers as weather continued to moderate. Some elk crossed the Yellowstone River on their route back into the Park. Others began drifting into the mountains towards Crevice Creek, often travelling through snowdrifts over 1 m deep.

Some elk remained on the study area taking advantage of the vegetation greenup in April and May. These elk slowly followed greenup as it progressed upward in elevation and scattered into the forest. In both June 1980 and 1981 there were over 300 elk in the North Fork of Bear Creek-Monitor Peak area which is on the periphery of the winter range. These elk dispersed toward the end of June, possibly indicating they summer in the high alpine areas of the Wilderness and were waiting for snowmelt.

The number of elk actually remaining on the study area for the entire summer appears related to winter numbers. There were over 2000 elk on the study area during the winter of 1979-80[5] while the following winter there were only about 500. Approximately 100 elk were using the Eagle-Phelps Creeks area during the summer of 1980 while during the summer of 1981 about 40 elk were in the same area, indicating "resident" summer herds may be augmented by migrating elk. In the summer of 1980, a group of 35 yearling elk with 15 spike bulls was observed in the Eagle Creek area. This excessive number of yearlings among the local elk suggests many of these yearlings probably remained on the study area when the cow herds migrated back to the Park or Wilderness. Martinka (1965) also observed a disproportionate number of yearling elk in resident herds during a study of the southern Park elk herd near Jackson Hole, Wyoming.

[5]Erickson, Glenn. Wildlife Biologist, Montana Department of Fish, Wildlife, and Parks, personal communication, July 1981.

Forested areas of Eagle, Davis, and Phelps Creeks also serve as calving grounds. Cows with newborn calves were often observed in these drainages, which are typical of elk calving areas as described by Johnson (1951). On June 11, 1980, seventy-plus cows and yearlings were observed moving off the study area into the North Fork of Bear Creek. At least eight newborn calves were in the group indicating this area also serves as calving grounds for some of the migratory elk. Proposed U.S. Forest Service timber sales in the Eagle Creek drainage would potentially remove vital calving security cover in the area, in addition to accompanying complications from logging critical winter range (See Human Influence in Literature Review).

Mule deer migration from the Gardiner winter range occurred only when the snowline receded in the spring during both years of the study. Deer followed spring greenup as it advanced upslope, but they only utilized areas that were relatively snow-free. Many deer also tended to remain on the low elevation sagebrush-grassland of the winter range into mid-May, foraging mainly on herbaceous vegetation.

Most of the deer had moved up into the forested areas by the first of June, after which time very few does with fawns were observed. These observations are not necessarily an indication that deer do not give birth on the study area. Rather, it is believed to be a reflection of deer scattering throughout the immense area available.

There were relatively few deer sightings on the study area in comparison to elk sightings during summer months. Deer observed were mostly solitary or occasionally in groups of two to five. Perhaps 20 to 30 deer used the study area during each summer.

Animal Use - Winter

Animal use during the two winters of the study was quite different because of variation in snow accumulation. Precipitation levels until the first of December were near normal in both 1980 and 1981. However, December through March precipitation during 1980-81 was only 29 percent of the 93 year mean with virtually no snow falling in January. December through March precipitation in 1981-82, on the other hand, was 121 percent of normal with above average snowfall in all months.

The contrast in weather allowed the observation of extremes from light to heavy animal use between the two years. Virtually no Park elk appeared on the Gardiner winter range in 1980-81 compared to approximately 3000 using the area during the 1981-82 winter. Mule deer numbers were approximately the same each winter although deer use of the winter range was much more restricted in 1981-82.

Animal Use - Migration

Migration patterns to the winter range play a key role in determining elk use of the study area. Elk migrating north on the east side of the Yellowstone River converge on the Gardiner Valley in the Deckard Flats area. Those arriving on the west side of the river congregate along the Park line, moving north as numbers build. Elk crossing into the study area from the west side may only spend a few hours traversing parts of it along migration routes, while others remain longer.

Elk migration to the Gardiner valley is described by Craighead et al. (1972). Basically, elk reach the Gardiner valley either on the east or west side of the Yellowstone River, depending on where they started in the Park. Elk movement corridors on the study area are illustrated in Johnson (1981), but an explanation of these corridors helps to describe elk use of the area. Elk migration patterns were largely assessed from observations during the second winter of the study.

Most elk reaching the Crevice Mountain area continued towards the Bear Creek drainage upstream from Jardine if snow depths were less than 2/3 m. If snows were deeper at these migratory elevations, elk tended to move down to the Deckard Flats area. Any elk movement farther north from Deckard Flats crossed Bear Creek downstream from Jardine and continued into Eagle Creek. Deckard Flats is thus a key staging area for elk movement north of the Park, especially during more severe winters.

Elk entering the west side of the Gardiner valley must cross the Yellowstone River to reach the study area. Some elk crossed the river near the mouth of Bear Creek and scattered onto Deckard Flats or into the Eagle Creek area. Most elk crossed the river and U.S. Highway 89 near the airstrip about 2 km north of Gardiner.

Few of the elk crossing near the airstrip appear to remain in the area long. Most elk moved up into Little Trail Creek and traversed over into Bassett Creek. Elk were also noted crossing the river at night to feed in the Little Trail Creek area and then returning to the

Park before daylight. Evidently the river and highway are not barriers to nocturnal movement.

Mule deer migration to the study area was much less well defined than elk movement, although deer numbers on the area were relatively constant through both winters. It appears most deer using the study area migrate from the nearby Wilderness or Park lands on the east side of the Yellowstone River. Deer began accumulating in the forested areas in mid-October both years of the study even before there was any appreciable snow accumulation. Movements after October were generally to lower elevations in accordance with snow depths. Deer were rarely observed in snow over 1/3 m deep.

Human impacts influencing winter animal distribution ranged from wildlife sightseers, vehicle traffic, mining activity, to people searching for shed antlers. However, late elk hunting activities were by far the most significant human influence. Deer were often dislodged from feeding areas by hunter activity, but the effect was generally short term.

Elk were displaced to higher elevation forested areas which in 1981-82 meant negotiating over 1 m of snow. Elk returned to feed in the sagebrush-grassland at night, but they also fed on upper elevation south facing exposures. Feeding sites in as much as 1.5 m of snow were observed in 1981-82 at over 2500 m elevation. Despite the evident hardship imposed on animals, the current method of conducting late hunts did not appear to significantly alter elk migration out of the Park during the more severe winter of 1981-82.

The practice of closing Deckard Flats to hunting during the late elk hunt, initiated in 1980-81, should probably be continued. This practice allows elk a needed feeding and resting buffer zone below the deep snows of higher elevations. However, vegetation trends on Deckard Flats should be closely monitored as elk may become concentrated in the area for prolonged periods and thus cause ecological regression.

Animal Use - Feeding Habits

Even with the displacement caused by late hunts, feeding activity was most concentrated below 2100 m in sagebrush-grass range in 1981-82. Elk appeared to spend more time feeding in areas with 1/3 m or less snow accumulation, although they are certainly capable of feeding in much deeper snow. The few scattered elk on the area in 1980-81 spent most of their time above 2100 m elevation, but many feeding sites were observed in mountain big sagebrush habitat types at lower elevations. Deer were scattered up to 2300 m elevation during the 1980-81 winter, and they were also often observed feeding in sagebrush areas.

Deer feeding habits are difficult to discern (Geist 1981), but sagebrush appears to constitute a substantial part of their diet on the study area. Deer use of mountain big sagebrush was noted as early as mid-October on the winter range. Deer used black sagebrush and all three subspecies of big sagebrush, but Wyoming big sagebrush and mountain big sagebrush received the most use. Not only did deer feed on sagebrush, but they also used dense stands of big sagebrush as resting areas. Sagebrush provides the only vegetative cover on much of the elevational zone deer are restricted to in winters such as 1981-82.

Grass utilization was prevalent at elk feeding sites during both years of the study. Utilization estimates indicated a preference for Idaho fescue and bluebunch wheatgrass early in the winter. Elk seemed to select forage in proportion to its abundance when grass resources became depleted as winter progressed in 1982.

There was a surprising amount of sagebrush utilization at elk feeding sites. Elk were observed browsing on sagebrush during their feeding activities. Greer et al. (1970) found that big sagebrush comprised from a trace to five percent of Park elk diets, with the high percentage correlated with high population density. Elk were using sagebrush on the study area even during the winter of 1980-81 when there were less than .07 elk per hectare. Sagebrush use on the Gardiner winter range by elk perhaps reflects a special need after the long migration for nutrients not provided by grass. There is little other browse of consequence on the study area.

Available forage received very little use on the study area during the winter of 1980-81 due to the relatively small number of elk present. Yet, up to an estimated 50 percent of the grass was consumed in localized areas on Deckard Flats where approximately 300 elk were concentrated for two weeks in February. However, by initial greenup in 1981 only an estimated average five percent of herbaceous vegetation had been grazed in other utilization plots on the winter range. Of six tagged mountain big sagebrush plants scattered over the study area, six percent of the previous year's growth was browsed by spring. Although the sample size was small, these measurements appeared to correspond with sagebrush utilization on most of the study area by the spring of 1981.

The winter of 1981-82 provided a completely different picture of animal vegetation use. Animal preference for feeding sites was clearly indicated by heavy foraging in certain areas compared to others. The delineation between preferred feeding sites and others closely approximated habitat type boundaries.

Sixteen utilization plots combined with utilization cage clippings provided the basis for grass use estimates. Spring 1982 production data from in and outside one utilization cage located in the mountain big sagebrush/bluebunch wheatgrass habitat type indicated 81 percent utilization for bluebunch wheatgrass. A similar utilization cage in the Wyoming big sagebrush/bluebunch wheatgrass habitat type had 29 percent utilization of bluebunch wheatgrass near it. Bluebunch wheatgrass showed an estimated 32 percent utilization in the nearby black sagebrush/bluebunch wheatgrass habitat type.

Of course, utilization within a habitat type also varied. The most drastic example was in the mountain big sagebrush/Idaho fescue habitat type. An estimated 80 percent of Idaho fescue had been grazed on most of Deckard Flats by the spring of 1982. However, clippings near a utilization cage in the 1974 wildfire burned area indicated 38 percent utilization of Idaho fescue. Grass utilization throughout the wildfire burn appeared to be considerably less than that found in nearby sagebrush areas. This pattern of decreased utilization was also noted in other prescribed burn areas which reflects the lack of observed animal winter use of sagebrush burns.

Elk did feed in burned areas. However, elk did not generally spend concentrated feeding time in burns, as they would in adjacent sagebrush areas. As Table 3 illustrated, burned areas did have relatively high grass production as secondary succession progressed, suggesting other possible explanations for decreased elk winter utilization in burned areas.

Average snow depth in burns was less than depths found accumulated between big sagebrush plants. However, snow accumulation under big sagebrush canopies was less than the uniform snow depths found on burned sites. Sagebrush canopies created a variable snow crust whereas the crusting in burned areas was more consistent. Elk feeding sites were often located near the base of big sagebrush plants, which was also observed by Houston (1976) in the Park.

Mule deer actually appeared to avoid the burned areas during the winter. Deer were possibly restricted by snow crusting in the burns, but also by the lack of thermal and security cover provided by big sagebrush. Deer could be approached more closely when feeding or resting in big sagebrush than in areas without it, such as in relatively low growing black sagebrush areas.

An example of these observations is a group of 18 deer encountered in March 1980 feeding around the periphery or in fingers of untouched big sagebrush of a burn. Deer standing in the exposed fingers of big sagebrush spooked when approached within 100 m, bounding approximately 100 m across the burned area and stopping in sagebrush on the far edge of the burn. Other deer in the surrounding sagebrush moved off when approached within 75 m, by walking within the sagebrush around the periphery of the burn to rejoin the other deer. Big sagebrush canopy cover perhaps provides needed security for deer in the exposed Gardiner area, especially with all the human activity during the winter.

One to three year old sagebrush burns were used extensively by both deer and elk during spring greenup. Animals were attracted to these burns by a two to three week earlier greenup, which Daubenmire (1968) attributes to increased soil temperature caused by blackened and unshaded soil in burns. Also, release of plant nutrients through burning may make subsequent forage more palatable (Vallentine 1977), but this effect is only short-term.

Big sagebrush achieves a definite hedged appearance with repeated herbage removal (Cook and Stoddart 1960). Many big sagebrush plants in the Gardiner area definitely have a hedged appearance, especially below 2100 m elevation. Seventeen sagebrush plants had been tagged by the fall of 1981 as a check on form class designations assigned to sagebrush plants tallied in summer density plots. Results from remeasuring sagebrush leaders in the spring of 1982 are presented in Table 6. Percentage utilization was determined by dividing the length browsed by the total length tagged. Form class estimations are those assigned to plants when tagged.

Although the sample size was small, data in Table 6 seem to indicate form class designations assigned to tagged sagebrush are a fair representation of past animal use. Annual growth utilization of

Table 6. Percentage utilization of 17 tagged sagebrush taxon by browse form class, postwinter 1982.

Taxon[1]	Form class	Utilization (%) Current year's growth	Woody growth
A.t.va	light	36	0
Arno	light	10	0
A.t.va	moderate	47	14
A.t.wy	moderate	46	7
A.t.va	heavy	93	16
A.t.wy	heavy	100	54

[1] A.t.va - mountain big sagebrush; Arno - black sagebrush; A.t.wy - Wyoming big sagebrush.

heavy form class plants was twice as high as that of plants placed in the moderate form class. Consumption of woody growth also increased greatly as browsing increased on particular plants.

All of the tagged sagebrush plants showed amounts of use characteristic of the pre-assigned form classes, except that of the light mountain big sagebrush class. Most of the utilization measured on light form class plants was from removal of leaf material. Animal browsing of sagebrush twigs removes much of the plants reserve carbohydrates because a high percentage of the stored carbohydrates are near twig growth points in big sagebrush (Coyne and Cook 1970).

Theoretically then, a considerable amount of big sagebrush leaf material could be removed during the winter without seriously affecting growth form. Browsing of leader growth would cause the more hedged appearance distinguishing moderate and heavy form classes.

When animals are concentrated on the study area, lightly browsed big sagebrush plants may receive more use than initially indicated by form class.

Big sagebrush can occasionally withstand considerable use during the fall and winter (Wright 1970). Heavily used sagebrush plants in the Gardiner area probably receive some use every winter, but are heavily utilized only when deep snow concentrates deer, and large numbers of elk are present. Other plants evidently receive much use only when animals are concentrated on the area. Heavy form class plants are found interspersed with light form class plants.

Variability of utilization among and within the sagebrush taxon has been noted in other regions (Wright 1970, Cook et al. 1954) and various explanations have been proposed (Powell 1970, Welch and Pederson 1981, Nagy et al. 1964). Data in Table 7 reveals the variability observed between and within the sagebrush taxon on the

Table 7. Contingency table of sagebrush form class designations from 1980 and 1981 browse transects.

Taxon[1]	Form class values, observed/expected[2]		
	Light	Moderate	Heavy
A.t.va	654/617	292/298	46/77
A.t.wy	16/63	47/30	38/8
A.t.tr	15/12	3/6	1/2
Arno	120/113	47/55	15/14

[1]A.t.va - mountain big sagebrush; A.t.wy - Wyoming big sagebrush; A.t.tr - basin big sagebrush; Arno - black sagebrush.

[2]Chi square = 179.3 with 6 d.f., significant at the .01 probability level.

study area. Form class designations were assigned to sagebrush plants encountered in browse transects.

Observed values indicate the relative abundance of the various sagebrush taxa on the study area. Mountain big sagebrush comprises 77 percent of sagebrush plants classified to form class. Basin big sagebrush, Wyoming big sagebrush, and black sagebrush make up 2, 8, and 14 percent of classified plants, respectively.

It appears only Wyoming big sagebrush is utilized heavily in proportion to its abundance. However, the only areas where basin big sagebrush, Wyoming big sagebrush, and black sagebrush grow is below 1950 m elevation where concentrated feeding activity occurs. Mountain big sagebrush grows to over 2500 m. Thirty percent of the mountain big sagebrush browse transects were conducted above 2100 m elevation where winter snow depths greatly curtail feeding activity. Form class designations indicate mountain big sagebrush has approximately the same proportion of use as Wyoming big sagebrush below 1950 m elevation.

Sagebrush receives considerable use on the study area as indicated not only by actual use of tagged plants, but also form classes symbolizing past use. Relatively light use of sagebrush in 1980-81 with average numbers of deer on the area indicate sagebrush is also important to elk as a food source. Indications of past use are too extensive to attribute all use solely to mule deer.

Animal Use - Impacts

Animal impacts on the study area are greatly minimized due to the season of use, patterns of use dependent on winter severity, and human activity. Deer are generally scattered in small groups over as much of the area as snow depths allow. Large numbers of elk do not reach the Gardiner area yearly. Human activity keeps elk daytime feeding and resting activity restricted mainly to upper elevations, lessening the potential impact on lower elevation feeding areas. Damage to herbaceous vegetation is largely prevented by migration of most elk soon after greenup.

Sheer numbers of animals do cause damage in localized areas. Major travelways are trails sometimes 20 to 30 cm deep beaten into the ground by passing hooves through the years. A small percentage of the Rocky Mountain juniper are hedged or highlined.

Some areas on south and west facing slopes near forest cover exhibit less perennial grass cover than nearby areas. These are sites generally less than 10 ha in size that initiate spring growth sooner than other sites in migration areas, and are close to escape cover. Spring deer grazing probably contributes to a decline in grass abundance on the sites.

Big sagebrush on Deckard Flats is the only plant species that appears to have significantly decreased in abundance from wild ungulate use on the study area. Five transects on Deckard Flats showed mountain and Wyoming big sagebrush constitute 4.6 percent of total cover while the same taxa on the opposite side of Bear Creek make up 11.3 percent of total cover. Grass cover is comparable on both areas.

Animal Use Compared with Site Variables

Pellet-group counts were used to quantitatively assess animal use on the study area. Low (in Neff 1968) found 24.1 percent of marked pellet-groups were still recognizable after five years. On the Gardiner winter range, 77.8 and 71.4 percent of flagged elk and deer pellet-groups, respectively, were still recognizable after two years. Thus, pellet-counts on the study area represent several years of animal use and should depict an average of animal activity. Less than two percent of the pellet-groups counted were identified as being deposited during the summer, so most of the pellet-groups represent winter use.

Neff (1968) presents a review of the pellet-count technique for determining various big game trends. Neff (1968) and Collins and Urness (1979) have advised researchers to use caution when inferring animal habitat preference from fecal counts because defecation rates depend on animal activity and time of year (Collins and Urness 1979, Irby 1981). In this study, time of fecal deposition should not bias the data, since most pellets were winter deposited. Differences in animal activity levels between the habitat types would be the only reason pellet-counts might not accurately represent elk and deer use of the different habitat types.

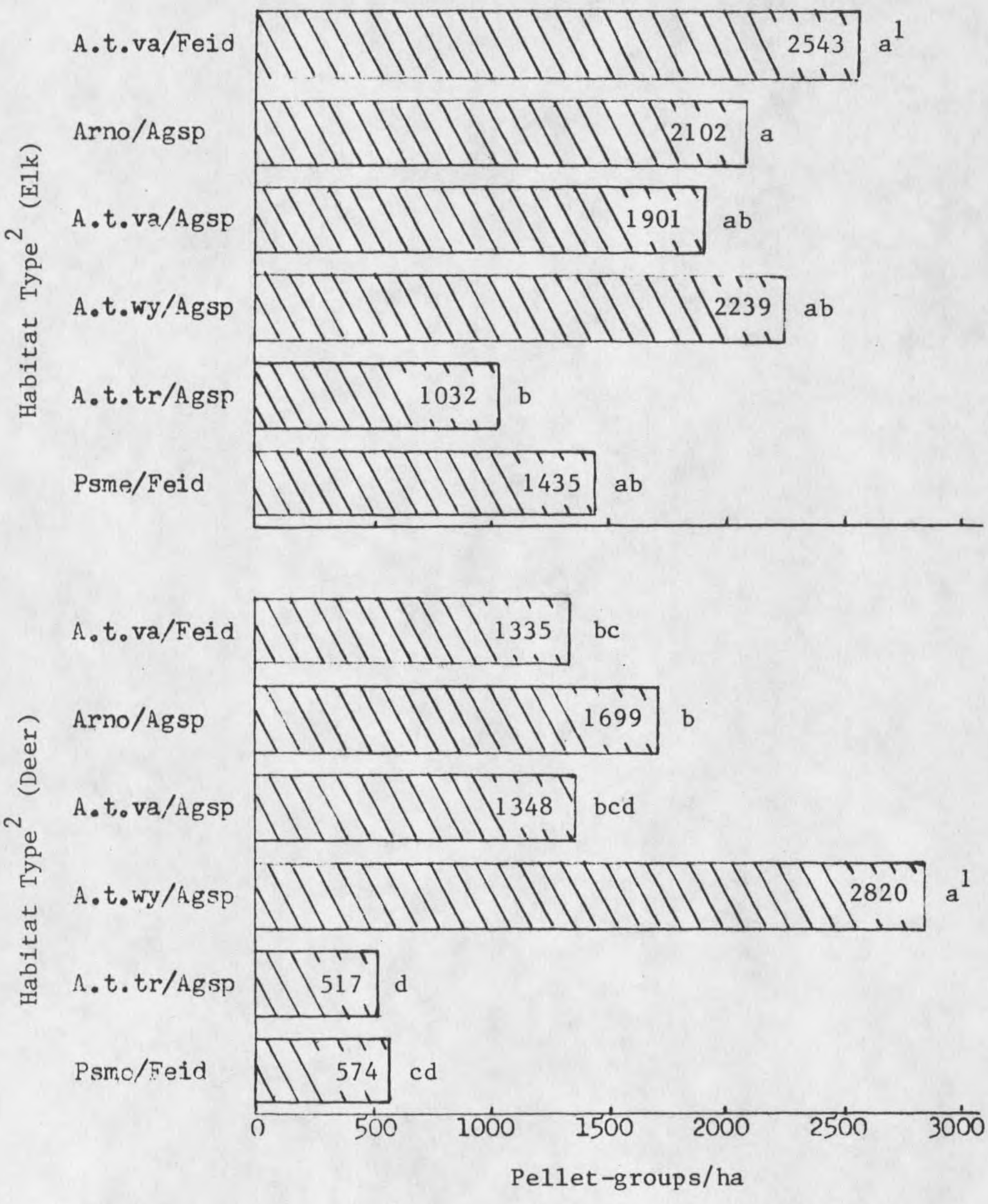
Observing pronghorn antelope, Irby (1981) concluded that pellet-counts could be an adequate index of time spent in an area if animals utilize the same areas for resting and activity. If animals feed in one area and rest in another, pellet-counts would presumably be biased towards the feeding areas. Following this reasoning, the Douglas fir/Idaho fescue habitat type would be the only area studied on the winter range where time spent might be under represented by elk pellet-counts. Elk appeared to spend more time resting than feeding in this habitat type. It is believed that pellet-counts accurately assess mule deer winter use of all habitat types studied.

Mean elk and mule deer pellet-group counts from all habitat types sampled during the two year study are illustrated in Figure 4. The mean counts correspond with observed animal use of the various habitat types. Since all shrub habitat types are equally accessible to animals during winter months, the differences in mean pellet-group counts are believed to represent animal preference for certain areas.

The significant differences between means may be somewhat confusing without explanation (Figure 4). Smaller mean differences being significantly different when larger mean differences are not can be explained by habitat size. Proportionately more transects were sampled on larger habitat types due to sampling technique. For example, 39 pellet-group transects were conducted in the mountain big sagebrush/Idaho fescue habitat type compared to only five transects in the relatively small basin big sagebrush/bluebunch wheatgrass habitat type.

The least significant difference (LSD) tests between means are influenced by sample size. Since the degrees of freedom are less in comparing two smaller habitat types, the difference between the means must be proportionately larger to be considered statistically significant. There are more degrees of freedom involved when a larger

Figure 4. Elk and deer use of six habitat types, as determined by mean pellet-group counts.



[1]Numbers among each animal species followed by a different letter are significantly different at the .05 probability level.

[2]Common names of these scientific name abbreviations are: A.t.va - mountain big sagebrush, Feid - Idaho fescue, Arno - black sagebrush, Agsp - bluebunch wheatgrass, A.t.wy - Wyoming big sagebrush, A.t.tr - basin big sagebrush, Psme - Douglas fir.

habitat type is compared with another mean, so that a smaller difference can be considered significant.

In the habitat type pellet-count means for deer, both mountain big sagebrush habitat types appear to be different from basin big sagebrush/bluebunch wheatgrass. Only mountain big sagebrush/Idaho fescue is significantly different because of sample size. However, the mountain big sagebrush/bluebunch wheatgrass mean compared with basin big sagebrush/bluebunch wheatgrass is close to the assigned significance level, with the mean difference only 61 pellet-groups/ha less than that required at the .05 probability level.

Elk and deer use of the basin big sagebrush area was the lowest of all habitat types. Both animal species did feed in the area, but generally just while travelling through the rough terrain of Bear Creek. Douglas fir/Idaho fescue had the second lowest fecal counts for both animal species. As previously mentioned, elk use of this habitat type may be underrepresented by pellet-counts. Deep snow kept deer out of most of this habitat type in 1981-82.

The black sagebrush/bluebunch wheatgrass habitat type straddles one of the major elk migration routes into Little Trail Creek partially explaining the relatively high pellet-counts. However, elk did frequent the area to feed and rest.

Elk use was also relatively high in both mountain big sagebrush habitat types and Wyoming big sagebrush/bluebunch wheatgrass. These were also the habitat types with the highest grass cover and production in the study area (Tables 1 and 2). Mountain big sagebrush/bluebunch wheatgrass had the highest grass cover and production along with the highest overall elk use. Pellet-counts in the Wyoming big sagebrush/Idaho fescue type may reflect elk searching out this relatively small habitat type for not only the grass, but also the sagebrush available.

Deer use of the Wyoming big sagebrush/bluebunch wheatgrass habitat type appears to show their preference for this area. Sagebrush utilization is heavy in the habitat type, but the area also provides some of the best cover in sagebrush habitats on the winter range. Relatively large sagebrush plants provide thermal and resting cover while nearby breaks and rolling topography offer escape terrain. Much of the habitat type is on south and west exposures generally without snow accumulation.

Some sites within the mountain big sagebrush and black sagebrush habitat types had high pellet-counts while others had less, reflecting fairly selective deer use within these types. Most deer use in these habitat types was on south or west exposures and areas near cover. Intensively used sites in the black sagebrush/bluebunch wheatgrass habitat type were near islands of big sagebrush or around Douglas fir stands.

Animal use appeared to be generally related to habitat type, but more specifically with certain characteristics within types. Information in Table 8 shows the correlation of all continuous numerical parameters measured with elk and deer pellet-group counts.

Elk use is highly correlated with a number of vegetation parameters. It is more closely associated with grass cover (r=.66) than any other parameter measured. Elk use is also positively

Table 8. Correlation coefficients of elk and deer pellet-group counts obtained in 1980 and 1981 and associated with vegetation and other site characteristics.

Site character	Elk	Deer	Site character	Elk	Deer
Grass cover	.66**	.21	Shrub height	-.15	-.15
Forb cover	.15	-.13	Shrub area	-.27**	-.16
Shrub cover	-.29*	.08	Plant species number	.14	-.11
Total cover	.24	.12	Slope	-.40**	-.24*
Grass production	.36**	.21	Elevation	-.34**	-.52**
Forb production	-.16	-.21	Bare ground	.26*	.31*
Shrub production	-.44**	-.16	Litter	.09	-.08
Total production	-.12	.06	Gravel	-.09	.07
Shrub density	-.03	.12	Rock	-.36**	-.22
Shrub volume	-.28**	-.18			

*Significant at the .05 probability level.
**Significant at the .01 probability level.

correlated with grass production, although not as strongly as with cover. Perhaps elk key more on grass cover because cover is a visual aspect of grass composition whereas production is a less visual component.

Elk use is negatively correlated with all shrub parameters, but most strongly with those related to shrub size. Sites with large robust sagebrush plants such as basin big sagebrush receive less elk use, and also, sagebrush plants in higher elk utilization areas are relatively smaller due to their hedged stature. Less elk use in areas with increased forb production probably reflects fewer elk at higher elevations where forb production is relatively high, rather than a direct relationship with forb production.

Elk were hampered by snow accumulation, as indicated by the negative correlation with elevation. Percentage slope increases with elevation which partially accounts for its negative association with elk use (r=-.40). Slopes are also steep along the Yellowstone River and Bear Creek gorges which elk generally use only while travelling through. The highest percentages of rock cover are also found on steep slopes (see discussion of Table 5). Greater elk use with an increasing percentage of bare ground probably reflects use on drier south and west exposures.

Deer use is most strongly correlated with elevation (r=-.52). The negative association demonstrates mule deer's physical inability to negotiate deeper snows at higher elevations. There is also a significant negative correlation with slope (r=-.24), but it is not as high as that determined for elk. The relatively lower r value partially reflects the tendency of deer to feed on the steep slopes of the Yellowstone River gorge and near the mouth of Bear Creek. The strong association with bare ground may likewise indicate utilization of drier south and west exposures.

Deer use is not highly correlated with any of the vegetation parameters. This non-association could indicate at least two possible explanations. One explanation may be that deer activities during the winter are not associated with the vegetation parameters that were quantified. A second explanation may be that vegetation measurements and/or the use of forage means were not specific enough to detect variations in the selective nature of deer activity.

The only other site parameters evaluated with pellet-counts were six categories of variables recorded to help describe the characteristics of transect sites (Table 9 and Appendix D). These categories and variables were not quantifiable, but they were included to possibly help explain animal use. For both deer and elk, the analysis of variance was used to statistically test for significant differences between pellet-count means of the variables for each of the six categories (Table 9).

Table 9. Significance levels of F-values obtained by analysis of variance of six categories evaluated for elk and deer use.

Category	Significance of F Elk	Significance of F Deer
Topographic position	.01	.08
Slope configuration	.00	.05
Soil-group	.01	.19
Prominent grass	.13	.34
Prominent shrub	.00	.00
Habitat type	.02	.00

These significant differences suggest that elk and deer select for particular site categories. Habitat type variables are shown in Figure 4 where differences between habitat types are illustrated. Elk and deer pellet-count means within the other five categories are shown in Appendix D.

The association of elk use with topographic position and slope configuration reflects the tendency of elk to congregate and spend the most concentrated feeding time on relatively level areas.

Concentrated deer activity in and around glacial morainal deposits and various lava flows is revealed in the association with topographic position and slope configuration. These areas provide some of the best thermal and security cover in the sagebrush habitat types. Sagebrush in swales provides thermal and resting cover while nearby slopes offer escape terrain to deer.

The non-significant relationship of elk with the prominent grass category coincides with the observation that grass was generally consumed in proportion to its abundance. Deer use was most highly associated with Wyoming big sagebrush of the prominent shrub variables, probably for reasons previously discussed. The significant relationship of elk with the prominent shrub category is due to little use of the basin big sagebrush habitat type and decreased sagebrush prominence from heavy past utilization in localized areas. Two transects were conducted where elk pellet-counts were high and rubber rabbitbrush was the most prominent shrub. These were areas where past utilization was believed to have caused a reduction in sagebrush prominence, instead of a positive association between elk use and rubber rabbitbrush.

Data presentation to this point indicates animal use is associated wih site parameters on the Gardiner winter range. Animal use is apparently dependent to a significant degree on the relative abundance of some of these site characteristics. Consequently, all data were subjected to regression analysis to further define the relative association of site variables with animal use.

Elk and mule deer pellet-counts were used as dependent variables. Using the SPSS program (Nie et al. 1975), a true step-wise analysis with forward selection, and backwards elimination, of both linear and quadratic functions was conducted. All categorical data (Table 9) were coded as dummy variables (a variable entered either as 1 or 0, depending on its presence or absence).

When using categorical variables, one less dummy variable from each type of category is usually entered into the regression analysis. However, categorical variables potentially important in explaining deviations of data points from the mean may be excluded from analysis using this standard procedure. Therefore, all categorical variables were entered into the regression analysis to prevent this type of data misinterpretation, as suggested by Dorsett and Webster (1983).

In many regression applications, the independent variables are correlated among themselves and with other variables not included in the model, but are related to the model (Neter and Wasserman 1974). Multicollinearity is the statistical terminology applied to two independent variables within the regression that are highly correlated. The effect of multicollinearity is that the significance of a variable (or variables) entering the equation is only partially explained by that variable. With stepwise entry, if two variables are highly correlated with each other, the first to enter takes with it both its unique variance and the variance they share so that the second variable rarely has enough influence remaining to enter the equation (Tabachnick and Fidell 1983).

Many of the variables quantified in this study are highly correlated with one another, as discussed with Table 5. Some of these same variables are associated with site variables not quantified, but which have an effect on animal use. Implications of these associations will be discussed with appropriate regression analyses.

Results from the regression analysis of elk pellet-counts are presented in Table 10. All variables listed entered the model within the .10 probability level, as indicated by the F-to-enter. The relative contribution of each variable to the equation at the end of the analysis is also included as the final significance of F.

Table 10. Regression analysis of elk pellet-counts with all variables studied, and the resulting equation[1].

Step	Variable	R^2	Significance of F-to-enter	Final Significance of F
1	X_1 Grass cover	.44	.00	.00
2	X_2 Total production	.58	.00	.00
3	X_3 Elevation	.65	.01	.01
4	X_4 Forb cover	.68	.06	.04
5	X_5 Thin-hilly soil-group	.71	.07	.07

[1] $Y = 5987.5 + 150.5X_1 - 1.1X_2 - 0.6X_3 - 86.5X_4 + 489.6X_5$

Grass cover and elevation are the only two variables which are highly correlated with elk pellet-counts (Table 8) suggesting the other variables entered the equation for additional reasons. Grass cover appears to be the single most important factor measured for influencing elk use on the study area. In all data analysis, an increase in grass cover was a possible explanation for increased elk use in various areas. Its importance is a reflection of habitats studied which encompass essential feeding sites for elk.

The significance of decreased elk use with elevation likely reflects elevation's positive relationship with snow accumulation. Although elk were capable of negotiating deep snow, they only retreated as high in elevation as necessary for security during daylight hours. As with all wintering wild ungulates, the need to conserve energy plays an important role in elk activities, even during the late hunts administered on the area.

Total production is highly correlated with shrub size parameters (Table 5). Shrub size parameters were all significant at or below the .05 probability level before total production entered the equation. All shrub size parameters became highly non-significant after total production entered the regression equation, indicating multicollinearity. As previously discussed, elk use is negatively associated with shrub size which indicates elk have habitually avoided areas with large shrubs. Also, areas of more intensive elk utilization have smaller and less dense sagebrush due to historical browsing reducing sagebrush prominence.

Reasons for entry of forb cover and the thin-hilly soil-group into the model are more difficult to discern. Neither variable by itself is highly associated with elk use, and neither strongly improves the model. Forb cover is slightly positively correlated with elk pellet-counts and is not highly correlated with any other variable associated with elk use. The negative association of forb cover with the model is believed to be nothing more than an adjustment of the model for the high positive value of grass cover. The addition of the thin-hilly soil-group supports the adjustment of forb cover, as indicated by forb cover's increased final significance. Inclusion of forb cover and thin-hilly soil-group are believed to be only refinements of the equation that better explain variation in the data.

The model presented in Table 10 explains 71 percent (R^2) of the variation in the data and is included to illustrate the relative relationship of each variable with changes in pellet-counts. The predictive value of the equation is questionable, since the last two variables are not associated with elk use in any way detected from observation or data analysis. Therefore, a better predictive model might include just the first three variables and is: $Y = 5738.3 + 129.0X_1 - .9X_2 - .6X_3$, ($R^2 = .65$). Neither equation was tested for predictive ability.

Deer pellet-count regression analysis is presented in Table 11. The inclusion of such a variety of variables into the model is believed to indicate mule deer's winter dependence on the area studied. Also, variables entering the equation are relatively more site specific than those included for elk. Most of the variables in the equation are only found in limited regions of the study area, which reveals the selection of specific sites by deer on the winter range.

Table 11. Regression analysis of deer pellet-counts with all variables studied, and the resulting equation[1].

Step	Variable	R^2	Significance of F-to-enter	Final Significance of F
1	X_1 Wyoming big sagebrush	.36	.00	.00
2	X_2 Sandy soil-group	.49	.00	.00
3	X_3 Bare ground	.58	.00	.00
4	X_4 Midslope topography	.64	.02	.00
5	East-west aspect	.70	.01	
6	X_5 North-south aspect	.73	.08	.00
7	X_6 Thin-hilly soil-group	.76	.04	.00
8	X_7 (Forb production)^2	.80	.01	.01
9	X_8 Rolling configuration	.83	.04	.01
10	Remove east-west aspect	.82		.18

[1] $Y = -756.6 + 1778.5X_1 + 1661.7X_2 + 89.9X_3 + 693.7X_4 - 544.0X_5 + 1239.1X_6 - .002X_7 + 538.6X_8$

The large regression coefficients in the model also reflect the great variation in deer pellet-counts from site to site. These large positive coefficients are partially due to the scaling of pellet-groups/ha, but they generally indicate that there will be many more pellet-groups at a site, if the site variable is present. The east-west aspect dropped out of the model because its variation was explained away by variables entering after it.

Entry point and significance of Wyoming big sagebrush indicates the importance of this shrub taxon to deer on the winter range. Areas where this taxon grow are relatively small in size but deer seem to congregate on them. Deer are apparently attracted to these areas not only for the shrub, but also for the security (previously discussed) and relatively slight snow accumulation on these drier sites.

Sandy soil-group and midslope topography both appear highly correlated with elevation. Sandy soil-group is generally only found on the lower elevation glaciated flats and moderate slopes. Areas of midslope topography examined were generally below 2200 m elevation. The significance level of elevation in the regression dropped from .01 to .73 with the addition to the model of these two variables. Therefore, these two variables probably represent mule deer's avoidance of deep snow accumulation on the area.

Bare ground is also somewhat negatively correlated with elevation (see Table 5), but its entry into the model is believed to be more representative of deer use on drier sites. Both aspect delineations indicate deer's preferential use of south and west exposures. Although a majority of the study area slopes face west or south, deer did spend a disproportionate amount of time on them, especially during sunny days.

The entry of thin-hilly soil-group probably shows the importance to deer use of the steep slopes along the Yellowstone River gorge. As with elk regression analysis, no plausible explanation exists for the entry of forb production into the model, except as a refinement of the regression line. Rolling configuration is positively associated with deer use, possibly indicating deer's need for escape cover in the exposed sagebrush sites.

The model explains 82 percent (R^2) of the variation in the data. Again, this equation is not presented as a predictor of deer use, but rather as an example of the relative importance of the variables to deer use. A simplified version of the model, the possibilities of which could be investigated as a predictor of deer use on the study area is: $Y = -196.0 + 2922.8X_1 + 1337.1X_2 + 73.2X_3 + 668.9X_4$. These four variables explain 64 percent (R^2) of the variation in the data, approximately the same as the model suggested for prediction of elk use. However, prediction of animal use with any of the models should probably be used with caution, since none of the models have been tested for predictive ability or with any additional field data from the Gardiner area.

Management application of the models in the Gardiner area would require duplication of field measurements conducted in this study. Limitations imposed by time, money, research expertise, etc. could possibly make duplication of field data impractical. Perhaps a check list of the relative presence of the important variables would be a more practical management technique for determining the potential of future animal use in a given area.

Data analysis indicates elk and deer use is dependent on site characteristics, although each animal specie keys on different site variables. Elk are physically capable of utilizing most regions of the study area. Yet, their most intensive feeding activity is in areas with 1/3 m of snow or less and usually in the sagebrush habitats where grass is relatively abundant. Therefore, elk apparently select preferred feeding habitats where the relationship of food intake to energy expenditure is optimized.

Mule deer are generally restricted in their use of the Gardiner winter range to the sagebrush habitats because of snow accumulation on forested elevations. Deer use is consequently dictated by cover requirements in the relatively exposed feeding and resting areas. Therefore, deer evidently select activity areas to maximize security and thermal cover on sites where a minimum of energy is required to do so. The most intensively used areas meeting cover requirements are preferred feeding sites.

SUMMARY AND CONCLUSIONS

This study was initiated in the spring of 1980 and was continued through the spring of 1982 to evaluate wild ungulate use and to assess the function of the Gardiner winter range in defining elk and mule deer utilization. The study area encompassed about 5800 ha of the northern Yellowstone winter range from the Yellowstone National Park boundary line north to Little Trail Creek.

The Gardiner winter range is especially important to wild ungulates during severe winters when it serves as an essential wintering area for animals migrating from Yellowstone National Park. Elk are the most abundant animal species, but there are also substantial numbers of mule deer wintering in the area.

Vegetation and landform characteristics of the study area were characterized and quantified during the summers of 1980 and 1981. Vegetation was delineated by habitat types to aid in assessing plant communities and animal use.

Animal winter use was evaluated from pellet-group counts and browse form classes. Periodic winter field trips during the 1980-81 and 1981-82 winters helped to substantiate and interpret elk and mule deer use of the study area. Animals appeared to favor certain habitat types.

A major portion of the Gardiner winter range is sagebrush-grassland. Vegetation of the study area was categorized into six habitat types, five of which were dominated by sagebrush and grass.

Three subspecies of big sagebrush (Artemisia tridentata subspp. vaseyana, wyomingensis, and tridentata) in addition to black sagebrush (Artemisia nova) grow on the study area. The two most prominent grasses are Idaho fescue (Festuca idahoensis) and bluebunch wheatgrass (Agropyron spicatum). Vegetation on the area appears to be in stable, climax condition. Animal use has caused little retrogressive plant succession. Most areas of disclimax vegetation can be attributed to human impacts.

Animal use of the area is dependent on winter severity. Few elk migrated to the area during the moderate winter of 1980-81 and mule deer use was scattered over most of the winter range. In the relatively severe winter of 1981-82 over 3000 elk utilized the study area to some extent while mule deer use was generally restricted to elevations below 2100 m.

Both elk and mule deer browsed on sagebrush in the area, even during the mild winter of 1980-81. Selective browsing of sagebrush plants, both within and among the taxon, is evident from form class designations. Wyoming big sagebrush and mountain big sagebrush are the most heavily browsed shrub taxa in the lower elevation feeding areas, as indicated by 1294 plants classified to browse form class. Sagebrush in the area obviously receives heavy utilization in winters when large numbers of elk are present.

Elk and deer both showed significant differences in use among the habitat types. Mean elk use was highest in the mountain big sagebrush/Idaho fescue habitat type. Deer appeared to preferentially select for the Wyoming big sagebrush/bluebunch wheatgrass habitat type. However, most of the differences in animal use were attributed to elk and deer preferential selection of certain characteristics within habitat types.

The importance of the area for elk feeding activity is emphasized by statistical analysis. Elk pellet-counts have a positive correlation with grass cover ($r = .66$). Elk use of the flats and benches is significantly greater than that of other topographic and landform configuration features. A majority of elk feeding activity occurred below 2100 m elevation.

Elk use of the study area is highly dependent on a number of variables. Five of the environmental variables characterized had an R^2 of .71 when subjected to a true step-wise regression analysis with elk pellet-counts. Grass cover was the first to enter the equation, by itself accounting for 44 percent (r^2) of elk pellet-count variations. The data indicate that elk select feeding sites on the study area where the relationship of food intake to energy expenditure is optimized.

Deer, on the other hand, are restricted in use of the area by the physical limitations imposed by snow. The significance of snow imposed hinderance is indicated by elevation having the highest simple correlation with deer use of $r = -.52$. Increased deer use also occurred with percentage bare ground increases, indicating use of drier south and west exposures. Deer use of landform characteristics for security reasons is reflected by high association with a rolling configuration.

The very selective nature of deer choice for areas within habitat types is indicated by regression analysis. Deer use is highly associated (R^2 = .82) with eight environmental variables. The most important association (r^2 = .36) is with Wyoming big sagebrush. Data analysis reflects the total dependence of deer on the sagebrush-grassland areas during the winter and also the specific selection of sites to minimize energy expenditure.

Some management objectives for the area have also been examined. Sagebrush burns evidently do not attract winter elk use, while deer appear to avoid burned areas. There appears to be a marked decrease in total forage production after sagebrush burns with potentially long lasting effects on plant species composition. Sagebrush is an important food source for both elk and mule deer on the study area, especially during severe winters. Therefore, controlled sagebrush burns can not be recommended in the concentrated feeding areas below 2100 m elevation, based on the results of previous burns. Small burns above 2100 m might possibly enhance animal spring use for a few years.

The scarcity of easily accessible forest cover during severe winters is a possible factor limiting attractiveness of the study area to elk. Forest cover within the Eagle Creek area provides some of the only relatively accessible escape and resting cover for elk on the north side of Bear Creek. Therefore, further logging activity in the Eagle Creek area could only be a detriment to elk use and should be avoided. This area also provides what appears to be the best calving grounds on the study area for both resident and migrating elk, and these calving grounds could also be potentially harmed by timber removal.

Historical animal use of the Gardiner winter range establishes its uniqueness and potential for wildlife. Vegetation on the winter range is adapted to the dry moisture regime and topoedaphic conditions of the Gardiner area, in addition to this historical animal use. Man's efforts to manipulate the natural vegetation have not resulted in increased attractiveness to wintering animals. Further habitat alterations from multiple use oriented management of the area could easily make the area less valuable to elk and mule deer and possibly tip the delicate balance of animal range use toward range degradation.

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APPENDICES

APPENDIX A

PLANT SPECIES ON THE STUDY AREA

Table 12. Plant species identified on the Gardiner study area[1].

Graminoids

Agropyron cristatum
A. smithii
A. spicatum
A. subsecundum
A. trachycaulum
Agrostis exarata
A. stolonifera
Bouteloua gracilis
Bromus anomalus
B. inermis
B. japonicus
B. marginatus
B. tectorum
Calamagrostis canadensis
C. rubescens
Carex festivella
C. filifolia
C. geryi
Danthonia intermedia
Distichlis stricta
Elymus cinereus
Festuca idahoensis
Hordeum jubatum
Juncus balticus
Koeleria pyramidata
Lolium perenne
Melica spectabilis
Oryzopsis hymenoides
Phleum pratense
Poa ampla
P. cusickii
P. fendleriana
P. juncifolia
P. pratensis
P. sandbergii
Sitanion hystrix
Stipa columbiana
S. comata
Trisetum spicatum

Forbs, Ferns, Mosses, Vines and Cactus

Achillea millefolium
Actaea rubra
Agoseris glauca
Allium brevistylum
A. textile
Antennaria dimorpha
A. rosea
A. umbrinella
Arabis holboellii
Arenaria congesta
Arnica cordifolia
Artemisia dracunculus
Aster canescens
A. conspicuus
A. scopulorum
Astragalus cibarius
A. gilviflorus
A. miser
A. purshii
Balsamorhiza sagittata
Campanula uniflora
Castilleja angustifolia
Cerastium arvense
Cirsium arvense
C. foliosum
Clematis columbiana
C. hirsutissima
Collinsia parviflora
Comandra pallida
Crepis acuminata
Delphinium bicolor
D. occidentale
Dodecatheon conjugans
Draba paysonii
Epilobium angustifolium
Equisetum arvense
Erigeron compositus
E. corymbosus
E. glabellus
E. gracilis
E. ochroleucus
E. pumilus

Table 12. (Continued).

Eriogonum heracleoides	Monotropa hypopithys
E. ovalifolium	Myosotis alpestris
E. umbellatum	Oenothera caespitosa
Erysimum asperum	Opuntia polycantha
Fragaria vesca	Orobanche fasciculata
F. virginiana	Oxytropis sericea
Frasera speciosa	Paronychia sessiliflora
Fritillaria atropurpurea	Penstemon cyaneus
F. pudica	Phacelia sericea
Geranium richardsonii	Phlox caespitosa
G. viscosissimum	P. hoodii
Geum triflorum	Plantago patagonica
Grindelia squarrosa	Polygonum bistortoides
Haplopappus acaulis	Potentilla glandulosa
Helanthella uniflora	P. gracilis
Heracleum lanatum	Peteridium aquilinum
Heterotheca villosa	Sedum stenopetalum
Hieracium cynoglossoides	Selaginella densa
Lathyrus bijugatus	Senecio canus
Lesquerella alpina	S. serra
Lewisia rediviva	Sisymbrium altissimum
Linaria dalmatica	Smilacina racemosa
Linum lewisii	S. stellata
Lithospermum incisum	Solidago canadensis
L. ruderale	Sphaeralcea coccinea
Lomatium macrocarpum	Taraxacum officinale
L. triternatum	Thalictrum occidentale
Lupinus sericeus	Townsendia parryi
Medicago sativa	Tragopogon dubius
Melilotus officinalis	Trifolium haydenii
Mentha arvensis	Viola adunca
Mentzelia laevicaulis	V. purpurea
Mertensia ciliata	Zigadenus paniculatus

Table 12. (Continued).

Shrubs, Half-Shrubs and Trees

Abies lasiocarpa	P. contorta
Acer glabrum	P. flexilis
Alnus tenuifolia	Populus angustifolia
Amelanchier alnifolia	P. tremuloides
Arctostaphylos uva-ursi	Prunus virginiana
Artemisia frigida	Pseudotsuga menziesii
A. nova	Rhus trilobata
A. tridentata subsp. tridentata	Ribes cereum
A. tridentata subsp. vaseyana	R. setosum
A. tridentata subsp. wyomingensis	R. viscossissimum
Berberis repens	Rosa woodsii
Betula occidentalis	Rubus idaeus
Ceanothus velutinus	R. parviflorus
Ceratoides lanata	Salix spp.
Chrysothamnus nauseosus	Sambucus melanocarpa
C. viscidiflorus	Sarcobatus vermiculatus
Cornus stolonifera	Shepherdia canadensis
Grayia spinosa	Symphoricarpos albus
Juniperus horizontalis	S. occidentalis
J. scopulorum	Tetradymia canescens
Leptodactylon pungens	Vaccinium membranaceum
Physocarpus malvaceus	V. scoparium
Picea engelmannii	Xanthocephalum sarothrae
Pinus albicaulis	

[1]Main references: Hitchcock, A. S. 1951. Manual of the grasses of the United States. USDA Misc. Publ. No. 200. 1039 pp.; and Booth, W. E. and J. C. Wright. 1959. Flora of Montana Part II. Montana State Univ., Bozeman. 305 pp.

APPENDIX B

HISTORY OF THE STUDY AREA

History of the Gardiner Study Area

Natural wonders of the Yellowstone National Park area have attracted people to the Gardiner vicinity for a variety of reasons, from the early Indian hunters to the present-day tourist. Much early settlement in the Rocky Mountains was due to questing early day miners who were among the first to establish residence after arriving along routes described by early explorers. The initial settlement of the Gardiner area was typical of that era.

Prospector Joe Brown following the Yellowstone River found encouraging placer gold deposits at the mouth of Bear Creek in 1866 (Wonderland 1902). News of the discovery spread to surrounding mining camps and the inevitable rush to the area was on. Vestiges from the ensuing flourish of activity are still quite evident today.

Moss covered tree stumps attest to the lumber needed for everything from saloons to sluice boxes. Prospect pits abound throughout the area with placer diggings and hydraulic scars along streams. Dilapidated mills and mine works in high mountain meadows are evidence of the energy and persistance of those seeking to strike it rich.

James Graham and Joe Brown discovered intrusive quartz veins fairly rich with gold in 1870 (Seager 1944) about 6 km northeast of Gardiner in Bear Gulch. The veins looked promising and the mining camp, which became Jardine, sprang into existence. Jardine has since experienced the boom and bust periods associated with the fortunes of its mines.

The expense of hard rock underground mining has taken its toll on mining companies, including those operating near Jardine. In 1900, Jardine was described as "the most wide awake mining camp in Montana" with 130 buildings (Livingston Enterprise Souvenir 1900). Fifty years later it was essentially a town of hangers-on.

Jardine quartz veins have produced not only gold, but also marketable quantities of arsenic and tungsten. Denuded arsenic tailings ponds just downstream from Jardine testify to mills which have not operated since the late 1940's. However, old mines and claims in the area are currently being rejuvenated by new owners. Migrating animals may once again be subjected to sounds of the miner's bit and dislocation caused by new mines.

Back in 1870, Gardiner was acquiring a look of permanence as a center for the surrounding mining activity. Formation of Yellowstone Park on March 1, 1872, with its northern boundary at the very edge of town ensured the future of Gardiner. Along with this stability came the ranching and farming necessary to support a growing community.

Although there were not many tourists to greet during the Park's first few decades, Gardiner became the most accessible stepping-off point for Park freighting and manpower. Good roads and a large number of stock animals were required for transportation. These additional encroachments on traditional wildlife winter range were essentially unnoticed for many years.

Park management policies have historically been embroiled in controversy, especially those concerning the great elk herds. The nature and extent of these controversies have been well documented in other papers (Tyers 1981, Houston 1974). The Park Service has been entrusted to conserve the Park's splendor in such a manner as to leave it "unimpaired for the enjoyment of future generations" (Sutton and Sutton 1972). Therein lies the enigma of preserving the wildness of the Park area, yet allowing so much human influence into its ecosystem.

The problem of preserving an area like Yellowstone National Park for wildlife use is exacerbated when Park animals leave its sanctuary and move to study area lands outside the Park boundary. These lands are currently under multiple use management where the animal and range resources are not the sole concern. Therefore, maintaining the study area's range resource at a sufficient level to meet animal needs each winter and still fulfill man's resource objectives has understandably created conflicts through the years.

APPENDIX C

PLANT COMPOSITION ON THE STUDY AREA

Table 13. Plant and miscellaneous composition of six habitat types[1] evaluated for production, percentage cover (basal for grass and forb, canopy for shrub), and either frequency or density on the Gardiner study area.

Species or Item	Habitat type[2/]					
	A.t.va/Feid	Arno/Agsp	A.t.va/Agsp	A.t.wy/Agsp	A.t.tr/Agsp	Psme/Feid
Graminoid Species						
Agropyron spicatum	116/ 1.5/0.90[3/]	86/ 1.0/0.82	164/ 1.6/0.95	211/ 2.4/0.90	156/ 1.8/0.70	71/ 0.7/0.45
A. subsecundum	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	8/ 0.2/0.05
A. trachycaulum	2/ T /0.01	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
Bromus anomalus	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	- / T / -
B. japonicus	T / T /0.02	- / - / -	T / - /0.08	- / - / -	- / - / -	- / - / -
B. marginatus	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	- / T / -
B. tectorum	1/ T /0.01	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
Calamagrostis canadensis	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	- / 0.1/ -
Carex geyeri	4/ 0.1/0.10	1/ T /0.01	9/ 0.2/0.10	2/ - /0.10	- / - / -	4/ 0.6/0.15
C. festivella	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	10/ - /0.25
Elymus cinereus	- / T / -	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
Festuca idahoensis	335/ 6.8/0.98	21/ 0.3/0.05	64/ 1.1/0.78	11/ 0.4/0.10	- / - / -	143/ 3.4/0.70
Hordeum jubatum	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	1/ - /0.05
Juncus balticus	- / T / -	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
Koeleria pyramidata	50/ 1.1/0.79	67/ 1.7/0.69	77/ 0.9/0.75	95/ 2.1/0.95	3/ T /0.20	8/ 0.1/0.15
Oryzopsis hymenoides	- / - / -	6/ 0.1/0.21	- / - / -	T / T /0.05	41/ 0.1/0.10	- / - / -
Poa ampla	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	14/ 0.6/0.30
P. cusickii	10/ 0.2/0.11	1/ - /0.01	2/ - /0.10	- / - / -	- / - / -	- / - / -
P. juncifolia	4/ 0.1/0.02	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
P. sandbergii	32/ 1.0/0.71	10/ 0.5/0.24	5/ 0.1/0.35	10/ 0.4/0.75	- / - / -	- / - / -
Stipa columbiana	1/ 0.1/0.03	- / - / -	- / - / -	- / - / -	- / - / -	2/ 0.1/0.15
S. comata	32/ 0.2/0.19	26/ 0.2/0.34	76/ 1.0/0.62	32/ 0.7/0.45	- / - / -	- / - / -
Trisetum spicatum	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	6/ - /0.15
Forb, Fern, Moss and Cactus Species						
Achillea millefolium	2/ T /0.05	- / - / -	- / - / -	- / - / -	- / - / -	17/ 0.4/0.35
Allium textile	T / T /0.02	- / - / -	T / T /0.08	3/ T /0.10	1/ - /0.10	- / - / -
Antennaria dimorpha	- / - / -	7/ T /0.15	- / - / -	- / - / -	- / - / -	- / - / -
A. rosea	18/ 0.5/0.35	3/ 0.1/0.18	6/ 0.2/0.25	6/ 0.2/0.05	- / - / -	- / 0.2/ -
A. umbrinella	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	T / - /0.05
Arabis holboellii	- / T / -	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
Arenaria congesta	1/ T /0.03	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
Arnica cordifolia	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	2/ - /0.05
Aster canescens	3/ T /0.04	1/ T /0.04	3/ T /0.08	2/ T /0.15	1/ - /0.10	- / - / -
A. conspicuus	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	26/ 1.2/0.40
Astragalus gilviflorus	- / - / -	- / T / -	- / - / -	- / - / -	- / - / -	- / - / -
A. miser	13/ 0.3/0.08	- / - / -	- / - / -	- / - / -	- / - / -	38/ 0.8/0.50
A. purshii	14/ 0.2/0.18	5/ 0.1/0.10	8/ 0.1/0.10	- / - / -	- / - / -	- / - / -

Table 13. (Continued).

Species or Item	Habitat type[2/]					
	A.t.va/Feid	Arno/Agsp	A.t.va/Agsp	A.t.wy/Agsp	A.t.tr/Agsp	Psme/Feid
Balsamorhiza sagittata	71/ 0.2/0.08	- / - / -	64/ T /0.10	- / - / -	- / - / -	- / T / -
Castilleja angustifolia	1/ T /0.01	9/ 0.1/0.20	1/ - /0.02	8/ 0.1/0.10	- / - / -	- / - / -
Cerastium arvense	- / T / -	- / - / -	- / - / -	- / - / -	- / - / -	18/ 0.1/0.15
Collinsia parviflora	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	10/ 1.3/0.35
Comandra pallida	14/ 0.1/0.18	T / - /0.01	1/ T /0.05	2/ T /0.10	- / - / -	- / - / -
Crepis acuminata	4/ T /0.10	T / T /0.04	- / - / -	1/ 0.1/0.15	- / - / -	6/ 0.2/0.15
Erigeron compositus	T / T /0.02	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
E. corymbosus	7/ 0.1/0.18	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
E. gracilis	T / T /0.01	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
E. ochroleucus	- / - / -	2/ T /0.05	2/ - /0.10	4/ 0.1/0.20	- / - / -	- / - / -
Eriogonum heracleoides	7/ 0.4/0.06	- / - / -	- / - / -	- / - / -	- / - / -	8/ 0.6/0.10
E. ovalifolium	- / - / -	1/ 0.1/0.06	- / - / -	2/ - /0.05	- / - / -	- / - / -
E. umbellatum	- / - / -	1/ T /0.01	- / - / -	- / - / -	10/ - /0.10	- / - / -
Erysimum asperum	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	5/ 0.1/0.10
Fragaria virginiana	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	12/ 0.2/0.20
Geum triflorum	T / T /0.04	- / T / -	- / - / -	1/ - /0.05	- / - / -	1/ 0.1/0.05
Haplopappus acaulis	2/ T /0.03	18/ T /0.10	- / - / -	- / 0.2/ -	- / - / -	4/ - /0.15
Helianthella uniflora	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	10/ 0.2/0.10
Heterotheca villosa	- / - / -	- / - / -	95/ 0.6/0.28	- / - / -	- / - / -	- / - / -
Lesquerella alpina	- / - / -	3/ 0.1/0.15	2/ T /0.22	1/ 0.1/0.10	- / - / -	- / - / -
Lithospermum incisum	T / - /0.01	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
L. ruderale	- / T / -	5/ - /0.01	1/ - /0.02	- / - / -	- / - / -	- / - / -
Lomatium macrocarpum	T / - /0.01	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
Lupinus sericeus	71/ 0.2/0.25	- / - / -	37/ T /0.15	- / - / -	- / - / -	38/ 0.4/0.30
Myosotis alpestris	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	2/ - /0.05
Opuntia polycantha	- / - / -	- / - / -	- / 0.1/ -	- / 0.6/ -	- / - / -	- / - / -
Oxytropis sericea	- / T / -	- / T / -	- / - / -	- / - / -	- / - / -	- / - / -
Paronychia sessiliflora	- / 2.8/ -	- / 0.3/ -	- / - / -	- / - / -	- / - / -	- / 3.8/ -
Penstemon cyaneus	1/ - /0.02	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
Phacelia sericea	- / T / -	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -
Phlox caespitosa	- / - / -	- / 0.3/ -	- / - / -	- / - / -	- / - / -	- / - / -
P. hoodii	1/ 0.2/0.05	19/ 0.9/0.42	- / - / -	- / - / -	- / - / -	- / - / -
Pteridium aquilinum	T / - /0.01	- / - / -	- / T / -	- / - / -	- / - / -	- / - / -
Sedum stenopetalum	T / T /0.02	- / - / -	- / - / -	5/ 0.6/0.10	- / - / -	1/ 0.2/0.10
Selaginella densa	- / - / -	- / - / -	- / 0.4/ -	- / - / -	- / - / -	- / - / -
Taraxacum officinale	T / T /0.02	T / - /0.01	T / - /0.02	2/ - /0.05	- / - / -	- / - / -
Townsendia parryi	- / - / -	T / 0.1/0.01	1/ T /0.02	- / - / -	- / - / -	- / - / -
Tragopogon dubius	2/ T /0.02	- / - / -	1/ - /0.02	- / - / -	- / - / -	- / T / -
Viola adunca	- / - / -	2/ - /0.04	- / - / -	- / - / -	- / - / -	- / - / -
Zigadenus paniculatus	1/ T /0.08	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -

Table 13. (Continued).

Species or Item	Habitat type 2/					
	A.t.va/Feid	Arno/Agsp	A.t.va/Agsp	A.t.wy/Agsp	A.t.tr/Agsp	Psme/Feid
Half Shrub Species						
Artemisia frigida	8/ T /0.06	2/ T /0.04	9/ 0.2/0.18	4/ 0.1/0.05	- / - / -	- / - / -
Ceratoides lanata	- / - / -	6/ 0.1/0.04	- / - / -	- / - / -	- / - / -	- / - / -
Leptodactylon pungens	2/ T /0.06	T / - /0.01	4/ 0.1/0.05	4/ 0.3/0.15	- / - / -	- / - / -
Shrub Species						
Amelanchier alnifolia	- / - / - 4/	- / - / -	- / - / -	- / - / -	- / - / -	- / 0.2/ T
Artemisia nova	- / - / -	258/17.0/1.91	- / 0.2/ -	- / - / -	- / - / -	- / - / -
A.t. subsp. tridentata	22/ 0.1/ T	T / - /0.01	1/ - /0.01	10/ - /0.04	637/20.1/0.22	- / - / -
A.t. subsp. vaseyana	220/ 6.7/0.72	9/ 0.8/0.06	300/13.1/0.78	44/ 4.6/0.09	26/ 2.8/0.04	135/ 1.6/0.26
A.t. subsp. wyomingensis	1/ 0.2/ T	2/ 0.7/ T	- / - / -	338/14.6/0.49	- / - / -	- / - / -
Chrysothamnus nauseosus	14/ 0.2/0.01	1/ - /0.03	19/ 0.1/0.04	1/ 0.2/0.01	- / - /0.01	- / - / -
C. viscidiflorus	3/ 0.1/ T	11/ 0.2/0.06	16/ 0.1/0.03	1/ - /0.01	- / - /0.01	- / - / -
Ribes cereum	- / - / -	- / T / -	- / - / -	- / - / -	- / - / T	- / - / -
Symphoricarpos albus	- / - / -	- / - / -	- / - / -	- / - / -	- / - / -	- / 0.1/ T
Tetradymia canescens	2/ T /0.02	- / - / T	3/ - /0.01	- / - / -	- / - / T	3/ - / T
Xanthocephalum sarothrae	2/ T / T	T / - / T	- / - / -	- / - / -	- / - / -	- / - / -
Miscellaneous						
Litter	- /41.7/ -	- /28.8/ -	- /26.7/ -	- /26.8/ -	- /10.4/ -	- /72.5/ -
Dead pedon	- / 1.7/ -	- / 1.1/ -	- / 0.7/ -	- / 0.6/ -	- / 0.1/ -	- / - / -
Bare ground	- /11.4/ -	- /10.8/ -	- / 7.6/ -	- /22.6/ -	- / - / -	- / 7.7/ -
Gravel	- /11.4/ -	- /30.9/ -	- /21.4/ -	- /23.1/ -	- /13.4/ -	- / - / -
Rock	- / 8.3/ -	- / 3.1/ -	- /22.7/ -	- / - / -	- /46.1/ -	- / 1.0/ -
Lichen	- / 0.5/ -	- / 0.2/ -	- / 0.1/ -	- / - / -	- / - / -	- / 0.5/ -

1/ Data from 1980, except for Psme/Feid which is from 1981. - Not recorded.

2/ A.t.va - mountain big sagebrush; Feid - Idaho fescue; Arno - black sagebrush; Agsp - bluebunch wheatgrass; A.t. wy - Wyoming big sagebrush; A.t.tr - basin big sagebrush; Psme - Douglas fir.

3/ Mean composition for Graminoid species; Forb, Fern, Moss and Cactus species; Half Shrub species; and Miscellaneous = production (kg/ha)/percent cover (% of total)/frequency (production plots in which species found ÷ total plots).

4/ Mean composition for Shrub species = production (kg/ha)/percent cover (% of total)/density (plants/m^2).

T = Trace. For Graminoid species; Forb, Fern, Moss and Cactus species; Half Shrub species; and Miscellaneous - (production <0.5 kg/ha, percent cover <0.05%). For Shrub species - (production <0.5 kg/ha, percent cover <0.05%, density <0.005 plants/m^2).

APPENDIX D

ELK AND DEER PELLET-COUNTS

Table 14. Elk and deer mean pellet-counts obtained in 1980 and 1981 within five main categories of environmental variables, with sample number for each variable.

Categorical variables	Pellet-counts[1] Elk	Pellet-counts[1] Deer	Sample number
Topographic position			
bench	2888a[2]	1828a	20
midslope	1874 b	1217 b	31
upper slope	1757 b	982 b	8
ridge	2173ab	1321ab	13
swale	2331ab	1732ab	6
Slope configuration			
flat	3237a	1518ab	14
concave	1866 b	1128 b	35
convex	1844 b	1388ab	9
rolling	2246 b	1823a	20
Soil-group			
sandy	2687a	1725a	36
thin hilly	1786 b	1271ab	18
stony	1966ab	919ab	3
silty	1557 b	1283ab	5
thin breaks	1147 b	574 b	3
shallow to clay	1473 b	1028ab	4
shallow to bedrock	2835ab	1086ab	2
thin hilly to stony	2083ab	1079ab	7
Prominent grass			
Idaho fescue	2472a	1336a	42
bluebunch wheatgrass	1930 b	1599a	30
prairie junegrass	1829ab	790a	4
elk sedge	1828ab	861a	2
Prominent shrub			
mountain big sagebrush	2241 b	1352 b	52
Wyoming big sagebrush	2368 bc	3122a	3
basin big sagebrush	1032 c	517 c	5
black sagebrush	2077 b	1601 b	14
green rabbitbrush	2029 bc	856 bc	2
rubber rabbitbrush	5113a	1668abc	2

[1]Overall mean of all categories for elk = 2207; for deer = 1406.

[2]Numbers among each category for each animal species followed by a different letter are significantly different at the .05 probability level.