



Browse condition and trend on Montana ungulate ranges
by Scott Karl Thompson

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

Ungulate impacts on woody vegetation have been a concern in Montana for a half-century. Exclosures were built on many areas of concern to determine if ungulates were affecting browse species. Most exclosures were built many decades ago, thus allowing impacts of long-term browsing to be realized. My objective was to determine the condition and trend of a variety of browse species. This was achieved by comparing browse species growing inside exclosures to browse species on environmentally similar areas outside. Thirty-two exclosures restricting the access of all ungulates were evaluated across many different environmental types. Methods that evaluated short shrub species (< 2 m), tall shrub species (> 2 m) and trees, primarily aspen (*Populus tremuloides* Michx.), were used. Dominant browse species impacted included bearberry (*Arctostaphylos uva-ursi* [L] Spreng.), big sagebrush (*Artemisia tridentata* Nutt.), bitterbrush (*Purshia tridentata* (Pursh) DC.), curlleaf mountain mahogany (*Cercocarpus ledifolius* Nutt, ex Torr. & Gray), horizontal juniper (*Juniperus horizontalis* Moench), chokecherry (*Prunus virginiana* L.), serviceberry (*Amelanchier alnifolia* (Nutt.) Nutt.), willow (*Salix* L.), and aspen. Browsing was found to have had an impact on browse species at 22 sites. In addition, 5 sites were considered areas of caution because not all methods of evaluating browsing impacts agreed. These sites were likely coming out of a period of intense browsing or entering a period of intense browsing. No browsing impacts were found at 2 sites. At the remaining 3 sites, differences in browse species inside and outside exclosures were attributed to factors other than browsing such as natural successional changes. Sites with no browsing effects were not related geographically within Montana. Impacts were found at both the oldest exclosure (57 yrs) and most recent exclosure (10 yrs). My findings imply browsing levels have been and remain a deterrent to development of shrub and aspen communities throughout Montana.



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APPROVAL

of a thesis submitted by

Scott Karl Thompson

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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ABSTRACT

Ungulate impacts on woody vegetation have been a concern in Montana for a half-century. Exclosures were built on many areas of concern to determine if ungulates were affecting browse species. Most exclosures were built many decades ago, thus allowing impacts of long-term browsing to be realized. My objective was to determine the condition and trend of a variety of browse species. This was achieved by comparing browse species growing inside exclosures to browse species on environmentally similar areas outside. Thirty-two exclosures restricting the access of all ungulates were evaluated across many different environmental types. Methods that evaluated short shrub species (< 2 m), tall shrub species (> 2 m) and trees, primarily aspen (*Populus tremuloides* Michx.), were used. Dominant browse species impacted included bearberry (*Arctostaphylos uva-ursi* [L.] Spreng.), big sagebrush (*Artemisia tridentata* Nutt.), bitterbrush (*Purshia tridentata* (Pursh) DC.), curlleaf mountain mahogany (*Cercocarpus ledifolius* Nutt. ex Torr. & Gray), horizontal juniper (*Juniperus horizontalis* Moench), chokecherry (*Prunus virginiana* L.), serviceberry (*Amelanchier alnifolia* (Nutt.) Nutt.), willow (*Salix* L.), and aspen. Browsing was found to have had an impact on browse species at 22 sites. In addition, 5 sites were considered areas of caution because not all methods of evaluating browsing impacts agreed. These sites were likely coming out of a period of intense browsing or entering a period of intense browsing. No browsing impacts were found at 2 sites. At the remaining 3 sites, differences in browse species inside and outside exclosures were attributed to factors other than browsing such as natural successional changes. Sites with no browsing effects were not related geographically within Montana. Impacts were found at both the oldest exclosure (57 yrs) and most recent exclosure (10 yrs). My findings imply browsing levels have been and remain a deterrent to development of shrub and aspen communities throughout Montana.

CHAPTER 1

INTRODUCTION

Consideration of browse species is an integral part of natural resource management. Tree and shrub species providing forage from leaves, twigs, and young shoots are considered browse species (Webster 1996). Plant communities often include a number of browse species and their ecological processes may depend on browse species. Specifically, shrubs and trees are vital components of wildlife habitats by providing animals with necessary forage and cover (Urness 1989, Welch 1989). The sustainability of many wildlife species is dependent on the browse in their habitat.

During the twentieth century, primarily the mid decades, resource managers determined the need to study the impacts and extent of ungulate use of plant communities. Browse use was, and still is, of great concern on winter ranges where wild ungulates congregate. To evaluate the influence of ungulates on browse and other plants, ungulate proof exclosures were constructed on many winter ranges and other areas of concern across Montana. In some cases, 2 exclosure designs were built in the same area to distinguish the impact of wild ungulates versus domestic ungulates on plant communities. These exclosures offer insight to changes and differences in plant communities in the absence or presence of all ungulates or the presence of only wild ungulates.

Many of these exclosures remain functional, but are deteriorating and nearing the end of their useful life. Many have not been rigorously measured in 20 years or more and

maintenance of fences is lacking (Moynahan et al. 1999). The remaining functioning exclosures provided a unique opportunity to evaluate the long-term effect of ungulate use on browse species. Comparisons were possible across a variety of environmental types and management practices throughout Montana.

My objective was to determine the impact of long-term browsing by wild and domestic ungulates on tree and shrub species growing under a variety of environmental conditions and management scenarios. This objective was achieved by quantitatively and qualitatively comparing browse species inside exclosures to the same species outside exclosures. The goal of this research was to provide information to resource managers about the long-term impact and level of ungulate use on a variety of browse species throughout Montana. The data collected provide continuation of long-term studies started by construction of these exclosures.

CHAPTER 2

LITERATURE REVIEW

Browse Species on the Landscape

Ecosystem Function. Browse species play an integral role in ecosystem function. Shrubs cycle nutrients and provide protected and fertile sites for other plant species (Garcia-Moya and McKell 1970, West 1989). Riparian function is dependent on willows (*Salix* L.) to trap sediments and stabilize streambanks (Clary 1999, Shields et al. 1995). Upland shrubs reduce overland water flow and reduce soil erosion (West 1989). Infiltration and storage of soil moisture has been shown to be greater on shrub-dominated ranges (West 1989). Browse species increase plant diversity of communities that in turn increased community stability (McKell 1989).

Historical Management. Individual or agency objectives of an area dictate management of browse species. Herbivory, fire, herbicides and use of machinery are tools by which managers manipulate rangelands (Vallentine 1989). Fire is the most commonly used tool and has been extensively used in sagebrush (*Artemisia* L.) dominated ranges to improve livestock forage (McKell 1989, Vallentine 1989). Following a burn, livestock forages are not always improved and wildlife habitat can be destroyed (Fraas et al. 1992, Wambolt et al. 2001). Herbicide application and use of machinery are more intensive management practices used on smaller acreages and can be used to control unwanted shrubs (McKell 1989, Vallentine 1989).

Value of Browse to Wild Ungulates

Forage. Shrubs and trees, due to their growth habits and nutritive properties, provide valuable forage to wildlife. Browse is especially important to wild ungulates in the non-growing season (typically winter). Nutrient needs of wild ungulates drop to maintenance or gestation levels during winter (Welch 1989). Most range plants do not meet nutrient requirements at that time with the exception of browse species (Cook 1972). Shrubs, as a vegetative class, have higher values for crude protein, phosphorus, and carotene than most grasses or forbs during fall and winter and typically remain more digestible (Cook 1972). Browse species also typically grow taller and remain above or closer to the surface of the snow.

Kufeld et al. (1973) reported browse species averaged 74% of mule deer (*Odocoileus hemionus*) diets in winter. Fecal analyses show that mule deer consume the greatest quantities of browse during winter months (Kasworm et al. 1984), but also rely on browse during summer months (Hansen and Clark 1977, Ngugi et al. 1992). Mule deer and whitetailed deer (*Odocoileus virginianus*) rumen analyses have also shown dominant use of browse in winter (Lovass 1958, Martinka 1968, Wilkins, 1957). Pac et al. (1991) reported green herbaceous vegetation dominated mule deer diets during spring, summer and fall, but browse was dominant in winter.

Kufeld (1973) summarized elk (*Cervus elaphus nelsoni*) food habit studies and reported varying results relative to the forage value of plants in an area. Browse dominated elk diets during winter in Montana, northern Idaho, northeastern Washington, New Mexico, Manitoba and Colorado (Blood 1966, Boyd 1970, DeNio 1938, Lang

1958, Trout and Leege 1971). Young and Robinette (1939) in Idaho and Blood (1966) in Manitoba found browse dominated elk diets in summer and fall. Other studies included in Kufeld (1973) found shrubs and trees in elk diets at lesser amounts, but browse still made up significant proportions of elk diets.

Antelope (*Antilocapra americana*) rely on browse species as a year round food source (Bayless 1969, Cole and Wilkins 1958). In Montana, browse made up 34% of rumen samples collected in summer, 80% in fall, and 70% in winter (Cole and Wilkins 1958). They reported silver sagebrush (*Artemisia cana* Pursh) and big sagebrush (*Artemisia tridentata* Nutt.) as the most important species. Mountain big sagebrush (*A. t. ssp. vaseyana* [Rydb.] Beetle) made up 76% of spring antelope diets and Wyoming big sagebrush (*A. t. Nutt. ssp. wyomingensis* Beetle & Young) made up 91% of spring antelope diets in south-central Wyoming (Ngugi et al. 1992). Ngugi et al. (1992) reported antelope bitterbrush (*Purshia tridentata* (Pursh) DC.) made up 90% of antelope diets in fall. Antelope in northeastern Montana heavily rely on big sagebrush communities in winter (Martinka 1967).

Bighorn sheep have been reported to use browse species for 25% of their summer diet and up to 43% of their winter diet (Erickson 1972, Schallenberger 1966). Kasworm et al. (1984) in northcentral Montana reported grasses were the most important part of sheep diets throughout the winter, but use of browse was 23% in early winter and 42% in late winter. Horizontal juniper (*Juniperus horizontalis* Moench), Douglas fir, big sagebrush and fringed sagewort were the browse species of greatest use.

Browse was reported as the most important forage class for moose (*Alces alces*) in Montana during all seasons (Schladweiler 1974). In southwest Montana, Dorn (1970) reported browse accounted for 98.3% and 99.8% of all forage used by moose in summer and winter, respectively. Moose were observed using willow dominated areas 84% of the time in summer and 93% of the time in winter (Dorn 1970). Rumen samples of moose in the Gallatin Mountains of Montana consisted of 88% browse in the fall, 99% in the winter, and 94% in the spring (Stevens 1970). Various shrubs were found in moose diets, but Douglas fir and aspen (*Populus tremuloides* Michx.) communities were considered key winter ranges. Reviews of several moose studies reported moose primarily rely on browse as forage year long and especially noted the importance of willow species (Hosley 1949, Peek 1974).

Cover. Browse species provide necessary thermal and security cover for wildlife according to growth habit and height of the tree or shrub (Urness 1989). Security (hiding) cover was defined as “vegetation capable of hiding 90% of a standing adult deer or elk from the view of a human at a distance equal to or less than 61 m (200 feet)” (Thomas et al. 1979). Topography may add to security cover when the angle of observation is elevated, but has not been demonstrated as an adequate substitute for vegetation (Thomas et al. 1979). Mule deer rely on big sagebrush communities for security cover year round (Carson and Peek 1987, Main and Coblentz 1996). Conversely, Van Dyke et al. (1983) found bighorn sheep (*Ovis canadensis*) avoided habitats with dense vegetation on gentle slopes. Bighorn sheep prefer habitats with greater sight distances.

Wild ungulates select certain topographic features and vegetation (thermal cover) that assist in maintaining a consistent body temperature. Deer and elk in the Blue Mountains of Oregon during winter benefit most from multistoried conifer stands with shrub understory for thermal cover (Thomas et al. 1979). Optimum thermal cover for mule deer in southeastern Oregon consists of evergreen or deciduous trees or shrubs at least 1.5 m tall and 75% crown closure (Leckenby et al. 1982).

Reproductive Success. The reproductive success of many wildlife species is dependent on the browse in their habitat (Urness 1989). Optimum mule deer and elk birthing habitat in the Blue Mountains of Oregon includes shrubs and trees 0.6 to 1.8 m tall and a tree overstory of 50% crown closure (Thomas et al. 1979). Elk prefer calving sites in open sagebrush or other shrub lands over adjacent conifer stands (Altman 1952, Johnson 1951, Thomas et al. 1979) and deer prefer even denser shrub cover for fawning (Fielder and McKay 1984).

Exclosures

Exclosures have been widely used in range and big game management to evaluate the impact of wild and domestic animals on vegetation and soils (Anderson and Holte 1981, Brand and Goetz 1986, Green and Kauffman 1995, Jones 1965, Kay and Bartos 2000, McArthur et al. 1988, Rice and Westoby 1978, Schultz and Leininger 1990, Wambolt and Sherwood 1999, Young 1958). Daubenmire (1940) defines an exclosure as, "any experimental area, which is protected from the activities of a particular class of animal by a barrier such as a fence or screen." A 3-phase exclosure system was designed

to differentiate impacts of wild ungulates and domestic ungulates (Austin and Urness 1986, Young 1958). The 3-phase system includes an area enclosed by a 1.8 to 3 m tall fence that prevents access of wild and domestic ungulates (big game exclosure). An area enclosed by a 4-strand barbed wire fence, 1 m tall, restricts the access of domestic ungulates, but allows wild ungulates to enter the area (livestock exclosure). The area outside both of these exclosures receives use by both wild and domestic ungulates. Gross and Knight (2000) caution results from livestock exclosures smaller than 4 ha that are intended to allow access of elk.

Microclimate in Exclosures. Exclosures can produce different microclimates due to factors such as increased shading and litter accumulation (McInnes et al. 1992). Soil moisture can be higher inside exclosures (Lodge 1954, Smoliak et al. 1972). Lower soil temperatures, less wind movement, and less evaporation may occur inside exclosures (Whitman 1974). Differing microclimate and lack of some predators can favor higher rodent populations inside exclosures (personal observation).

Succession in Exclosures. Exclosures attempt to control ungulate herbivory while maintaining other disturbances constant. Exclosures are said to recreate climatic climax communities (Beetle 1974). Under traditional range ecology, excluding browsers enables secondary succession to occur and vegetation inside the exclosure should represent the climax state of the plant community (Clements 1916). Clementsian (1916) succession is the invasion by different plant communities until a climax community is established.

Brand and Goetz (1986) compared dominant growth forms inside exclosures to vegetation outside exclosures to identify secondary succession.

Classical theories of range succession were not useful in explaining vegetation in exclosures in semiarid shrublands of northern Utah due to inconsistencies in the observed plant community and the expected climax community (Rice and Westoby 1978). Smeins et al. (1976) also noted that exclosures may not lead to climax conditions and concluded that vegetation changes inside were adjustments in species dominance rather than species replacement. Woody species established following a disturbance (herbivory) tended to increase to a point of stabilization inside exclosures. These studies suggest that previous disturbance and vegetation established immediately after disturbance may determine community composition.

Anderson and Holte (1981) concluded that vegetation development without grazing on sagebrush rangelands fit Egler's (1977) stability/initial floristic model. The stability/initial floristic model states that the relative abundance of a species largely depends on the disturbance history and the vegetation composition at the time of disturbance (Egler 1977). Under this theory, any stable community might be considered climax.

Species richness and species diversity were reduced due to declines in disturbance (ungulate herbivory) inside exclosures on a riparian community (Green and Kauffman 1995). This would agree with Grime (1979) who presented competition models implying that species that adapted to habitats with moderate disturbance (herbivory) are displaced

by competitive species when disturbance decreases. Erecting an exclosure provides the decrease of disturbance.

Ungulate Impacts on Browse Species

Browsing and trampling can alter vegetation and have long-term effects on plant communities (Naiman 1988). Wild ungulate impacts on browse species as shown by exclosures have been documented on the Northern Yellowstone Winter Range (NYWR). Big sagebrush canopy cover on browsed and protected (unbrowsed) areas averaged 6.5% and 19.7%, respectively (Wambolt and Sherwood 1999). Production of winter forage and density of big sagebrush were significantly greater ($P \leq 0.0027$) on protected areas (Wambolt and Sherwood 1999). Kay (1995), also working on the NYWR, found significantly greater ($P \leq 0.05$) canopy cover, height, and volume of serviceberry (*Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roemer), chokecherry (*Prunus virginiana* L.), buffaloberry (*Shepherdia canadensis* (L.) Nutt.) and bitterbrush inside big game exclosures than outside exclosures.

Aspen regeneration in Utah failed or was significantly lower ($P \leq 0.08$) where cattle (*Bos taurus*), elk, and mule deer browsed as compared to excluded areas (Kay and Bartos 2000). Maschinski (2001) reported significantly reduced ($P \leq 0.005$) plant height and total branch length of Arizona willow (*Salix arizonica* Dorn) outside exclosures as compared to protected plants. McArthur et al. (1988) reported mountain big sagebrush browsed and unbrowsed (protected) by mule deer had an average dead crown of 64% and 17%, respectively, and dead sagebrush plants were 11 times more common where mule

deer browsed. An exclosure in central Washington revealed excessive use of snowbrush ceanothus (*Ceanothus velutinus* Dougl. ex Hook.) and chokecherry by mule deer and elk (Tiedemann and Berndt 1972). Snowbrush ceanothus canopy cover inside and outside the exclosure was 14.1% and 0.1%, respectively, and chokecherry canopy cover was 4.6% and 0, respectively. Shrub species richness was significantly greater ($P \leq 0.04$) inside exclosures than outside exclosures in Oregon (Moser and Witmer 2000). Moose (*Alces alces*) browsing in Michigan opened the tree canopy outside exclosures, which increased the amount of shrubs and herbs in the understory (Brandner et al. 1990, McInnes et al. 1992). Excluded areas had significantly greater ($P \leq 0.05$) tree biomass and less shrub and herb biomass (McInnes et al. 1992).

Mackie (1973) evaluated browsing impacts on antelope bitterbrush, western serviceberry, curlleaf mountain mahogany (*Cercocarpus ledifolius* Nutt. ex Torr. & Gray), and skunkbush sumac (*Rhus trilobata* Nutt.) by comparing shrub parameters inside exclosures to parameters outside at 12 exclosures in western Montana. Percent canopy cover of browse species was greater inside exclosures at 10 of the 12 sites. Browsing did not suppress density of plants and twig production was typically greater on shrubs that were browsed. Mackie (1973) cautioned against any generalizations concerning influences of browsing due to variations in species, location, time, site or other environmental conditions affecting browse species productivity.

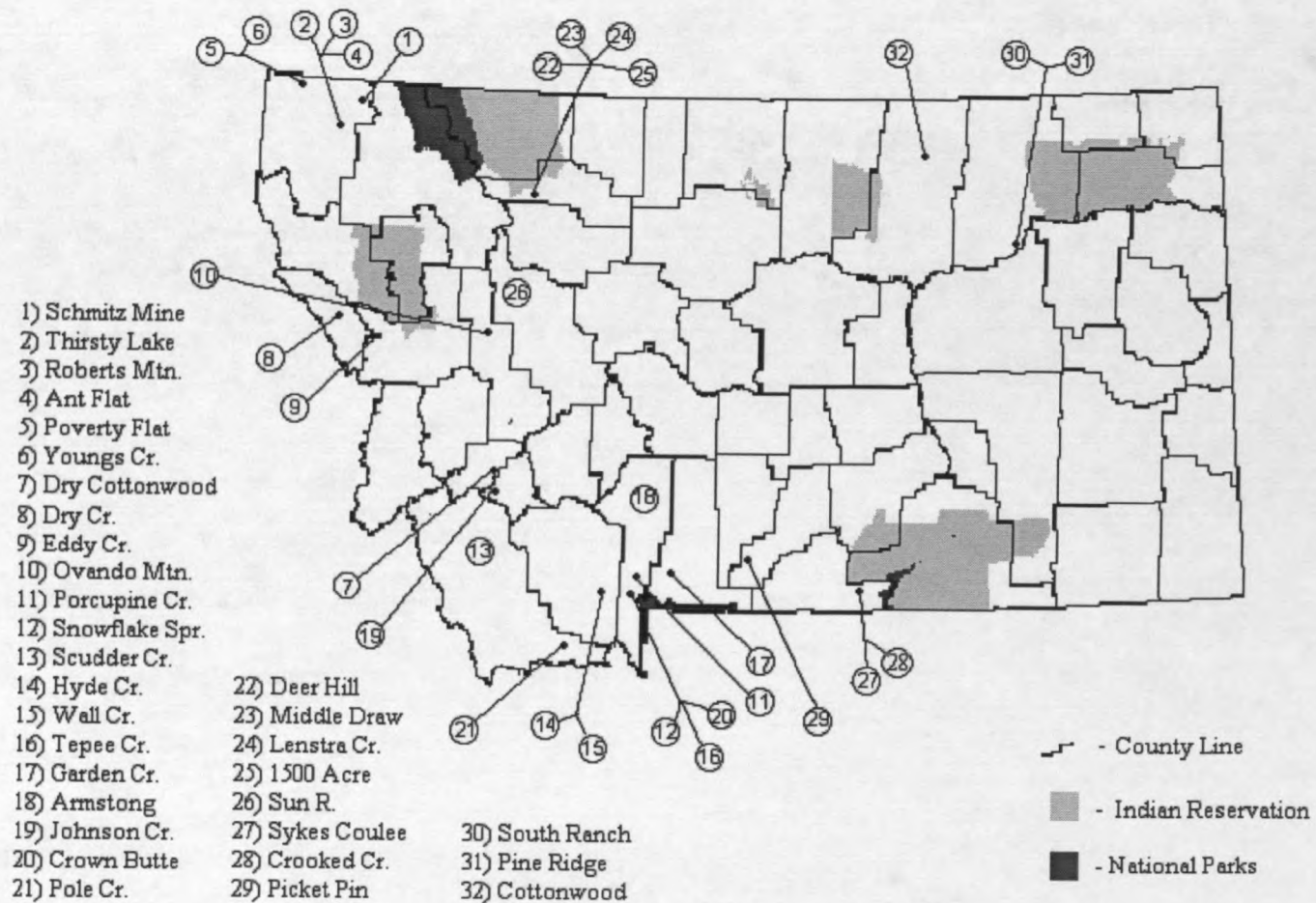


Figure 1. Location of study areas in Montana.

Table 1. Locations of the study areas.

No.	Name	Region	Legal Description			UTM Coordinates		
			Section	Township	Range	Zone	mE	MN
1	Schmitz Mine	1	7	35N	25W	11	0655965	5408356
2	Thirsty Lake	1	34	36N	27W	11	0641675	5412134
3	Roberts Mtn.	1	35	35N	26W	11	0652368	5402026
4	Ant Flat	1	7	34N	25W	11	0656385	5399170
5	Poverty Flat	1	3	36N	28W	11	0631362	5420052
6	Young Cr.	1	12	37N	28W	11	0632179	5428066
7	Dry Cottonwood	2	6	5N	8W	12	0372209	5119110
8	Dry Cr.	2	27	17N	27W	12	0650250	5229614
9	Eddy Cr.	2	31	15N	22W	11	0695736	5209421
10	Ovando Mtn.	2	1	15N	12W	12	0343081	5215972
11	Porcupine Cr.	3	16	7S	4E	12	0481400	5008190
12	Snowflake Spring	3	12	9S	4E	12	0486744	4989828
13	Scudder Cr.	3	17	6S	12W	12	0336004	5018941
14	Hyde Cr.	3	27	9S	1W	12	0443528	4985059
15	Wall Cr.	3	14	10S	1W	12	0446320	4978773
16	Tepee Cr.	3	7	9S	5E	12	0487024	4990773
17	Garden Cr.	3	18	7S	7E	12	0512791	5009718
18	Armstrong	3	25	2N	5E	12	0495331	5083614
19	Johnson Cr.	3	18	1N	1E	12	0342898	5077768
20	Crown Butte	3	8	9S	5E	12	0488378	4990122
21	Pole Cr.	3	11	7S	7E	12	0418630	4955822
22	Deer Hill	4	18	27N	8W	12	0375033	5329034
23	Middle Draw	4	12	27N	9W	12	0375033	5329034
24	Lenstra Cr.	4	1	27N	9W	12	0372937	5329591
25	1500 Acre	4	23	27N	9W	12	0371600	5326967
26	Sun R.	4	5	21N	8W	12	0374413	5274219
27	Sykes Coulee	5	33	9S	28E	12	0713122	4988356
28	Crooked Cr.	5	34	8S	27E	12	0703443	4996600
29	Picket Pin	5	6	5S	15E	12	0583219	5031976
30	South Ranch	6	14	24N	27E	13	0355054	5300371
31	Pine Ridge	6	4	23N	38E	13	0360540	5293948
32	Cottonwood	6	2	31N	30E	13	0294254	5373024

Table 2. Characteristics of the study areas.

Site No.	Aspect	Degrees of slope	Elevation (m)	Sampling Date	Exclosure Age at Sampling (years)
1	SW	1	1023	June 2001	39
2	S	10	918	June 2001	39
3	NE	3	992	June 2001	39
4	SW	10	945	June 2001	39
5	E	2	838	July 2001	43
6	W	2	812	July 2001	43
7	S	17	1728	June 2001	40
8	W	34	1026	June 2001	41
9	SW	3	1055	June 2001	42
10	SW	32	1616	August 2002	45
11	W-SW	4	2113	May, June 2001	56
12	N	1	2046	May 2001	53
13	SE	13	2041	July 2001	48
14	E	8	1972	August 2001	39
15	E	9	1997	August 2001	10
16	S	16	2143	May 2002	46
17	W	5	1712	May 2002	12
18	S	41	1786	June 2002	47
19	S	10	1880	June 2002	35
20	S	30	2218	July 2002	57
21	E	2	2163	August 2002	11
22	NW	10	1477	July 2001	13
23	NE	4	1489	July 2001	13
24	N	2	1416	July 2001	13
25	W	4	1527	July 2001	13
26	SW	12	1363	July 2001	34
27	SE	2	1501	June 2002	38
28	E	8	1930	June 2002	40
29	SW	24	1870	July 2002	40
30	N	21	905	July 2002	15
31	SE	5	740	July 2002	32
32	SE	3	704	August 2002	35

Montana Fish, Wildlife & Parks Region 1

1. Schmitz Mine. The Schmitz Mine site contains a single big game exclosure in Lincoln County, 16.1 km (10 miles) east of Fortine on the Flathead National Forest Land. The exclosure is approximately 0.2 ha in size. Douglas fir (*Pseudotsuga menziesii*

[Mirb.] Franco) dominates the overstory with serviceberry (*Amelanchier alnifolia* [Nutt.] ex M. Roemer), bearberry (*Arctostaphylos uva-ursi* [L.] Spreng.), snowberry (*Symphoricarpus albus* [L.] Blake), spiraea (*Spiraea douglasii* Hook.), Oregon grape (*Berberis repens* Lindl.), rose (*Rosa woodsii* Lindl.), and russet buffaloberry (*Shepherdia canadensis* [L.] Nutt.) in the understory. Cattle were found grazing the site and evidence of elk (*Cervus elaphus nelsoni*), mule deer (*Odocoileus hemionus*) and whitetailed deer (*Odocoileus virginianus*) was found.

2. Thirsty Lake. The Thirsty Lake enclosure is in Lincoln County, approximately 16.1 km (10 miles) southwest of Eureka on the Kootenai National Forest. A single big game enclosure approximately 0.2 ha in size exists at the site. Ponderosa pine (*Pinus ponderosa* P. & C. Lawson) and Douglas fir dominate the overstory. Antelope bitterbrush (*Purshia tridentata* [Pursh] DC.), Oregon grape, bearberry, snowberry, and rose are the dominant understory browse species. Deer and elk sign was found but elk presence was most noticeable.

3. Roberts Mountain. The Roberts Mountain enclosure is in Lincoln County, approximately 24.2 km (15 miles) southeast of Eureka on the Kootenai National Forest. A 0.2 ha big game enclosure exists at the site. Douglas fir and ponderosa pine dominate the overstory. The primary browse species are bearberry, Oregon grape, serviceberry, and russet buffaloberry. Evidence of deer (presumably whitetailed deer) was found.

4. Ant Flat. The Ant Flat enclosure is in Lincoln County, about 8.1 km (5 miles) west of Trego on the Kootenai National Forest. A big game enclosure with an adjacent

livestock exclosure exists just east and uphill from the Ant Flat Forest Service Station. Each are about 0.4 ha. The dominant overstory is Douglas fir and ponderosa pine. Understory browse species are dominated by serviceberry, with russet buffaloberry, bearberry, Oregon grape, snowberry, and rose present. A Forest Service prescribed fire consumed portions of both the livestock and big game exclosures in 1998. Burned areas are characterized by a dense thicket of serviceberry shoots. Presence of deer, presumably mule deer and whitetailed, was found. Minimal evidence of cattle was found.

5. Poverty Flat. The Poverty Flat exclosure is approximately 24.2 km (15 miles) west of Eureka on the west shore of Lake Koocanusa in Lincoln County. The exclosure is on the Kootenai National Forest. A big game exclosure and a livestock exclosure exist, each about 0.4 ha in size. Browse species at the site include serviceberry, russet buffaloberry, antelope bitterbrush, Oregon grape, and bearberry. Limited evidence of cattle was found. Whitetailed deer predominately use the area with minimal elk use in winter.

6. Young Creek. The Young Creek exclosure is in Lincoln County approximately 24.2 km (15 miles) northwest of Eureka on the west shore of Lake Koocanusa on the Kootenai National Forest. A 0.04 ha big game exclosure and a 0.2 ha livestock exclosure are located at the site but on different environment types. Ponderosa pine dominates the overstory at each exclosure. Antelope bitterbrush dominates the livestock exclosure and surrounding area while antelope bitterbrush, serviceberry, bearberry, snowberry and rose are found at the big game exclosure site. The area has had limited use by livestock. The

area serves as important whitetail winter range with a few elk using the area (T. Their, Mont. Fish, Wild. and Parks, unpubl. Data, 7/25/01).

Montana Fish, Wildlife & Parks Region 2

7. Dry Cottonwood. The Dry Cottonwood Creek exclosure is located in Deerlodge County, 32.2 km (20 miles) Southeast of Deerlodge, MT on the Deer Lodge National Forest Land (Appendix G, Fig. 36). There are 2 big game exclosures and 1 nonfunctioning livestock exclosure, each approximately 0.4 ha in size. Dominant browse species include Douglas fir, Rocky Mountain juniper (*Juniperus scopulorum* Sarg.), antelope bitterbrush, and chokecherry (*Prunus virginiana* L.) as well as various understory shrubs. The Forest Service prescribed burned portions of both inside and outside the big game exclosure in 1998. Measurements were taken in both unburned and burned areas. The site is in a Forest Service rest-rotation grazing allotment during the summer and serves primarily as an elk and mule deer winter range.

8. Dry Creek. The Dry Creek exclosure is in Mineral County about 16.1 km (10 miles) west of Superior on the Lolo National Forest. A single functioning big game exclosure 0.4 ha in size is located on the hill slope above the West Fork of Dry creek. Douglas fir is the dominant tree and serviceberry is the dominant shrub. Other browse species include chokecherry, snowbrush ceanothus (*Ceanothus velutinus* Dougl. ex Hook.), and mallow ninebark (*Physocarpus malvaceus* [Greene] Kuntze). Evidence of elk, mule deer and whitetailed deer was found at the site.

9. Eddy Creek. The Eddy Creek exclosure is in Missoula County, located 8.1 km (5 miles) east of Alberton on the Lolo National Forest. A single 0.4 ha big game exclosure exists. The browse community includes a ponderosa pine overstory with serviceberry, bearberry, snowbrush ceanothus, spiraea, and common snowberry in the understory. Past use of elk, mule deer, and whitetailed deer was found at the site.

10. Ovando Mountain. The Ovando Mountain exclosure is located in Powell County, approximately 24.2 km (15 miles) north of Ovando. A 0.4 ha big game exclosure is located on State of Montana land. Browse species include: Rocky Mountain maple (*Acer glabrum* Torr.), serviceberry, chokecherry, snowbrush ceanothus, mountain ash (*Sorbus sp.* L.) and pin cherry (*Prunus pensylvanica* L.F.). The area has historically been a very important elk and mule deer winter range (B. Henderson, Mont. Fish, Wildl. and Parks, unpubl. data 8/6/02). In more recent years, the area has provided moderate winter range for elk, mule deer, and whitetailed deer.

Montana Fish, Wildlife & Parks Region 3

11. Porcupine Creek. The Porcupine Creek exclosure is located in Gallatin County approximately 16.1 km (10 miles) east of Big Sky, MT. It is a single exclosure approximately 0.8 ha in size that excludes big game (Fig. 2). Plant communities at the site support the following dominant browse species: Douglas fir, lodgepole pine (*Pinus contorta* Dougl. ex Loud.), mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana* [Rydb.] Beetle), Geyer's willow (*Salix geyeriana* Anderss.), and aspen (*Populus tremuloides* Michx.). The area serves primarily as an elk winter range for migrating

Yellowstone National Park herds and some resident elk. Evidence of moose (*Alces alces*) and mule deer was also found at the site.



Figure 2. Porcupine Creek big game exclosure (7/02).

12. Snowflake Springs. The Snowflake Springs exclosure is located in Gallatin County on the west side of Highway 191 approximately 40.3 km (25 miles) south of Big Sky. A single big game exclosure approximately 0.1 ha in size is located on the flood plain of the Gallatin River (Fig. 3). The plant community is of a riparian type supporting various willow species including Geyer's willow and Booth's willow (*Salix boothii* Dorn). This area winters elk and moose from Yellowstone National Park and surrounding areas.



Figure 3. Snowflake Springs big game exclosure (5/01).

13. Scudder Creek. The Scudder Creek exclosure is 8.1 km (5 miles) south of Polaris in Beaverhead County on Bureau of Land Management (BLM) land. A big game exclosure, with a portion also excluding rodents, and a small livestock exclosure exists (Fig. 4). The entire exclosure complex is about 0.2 ha. The dominant browse species is curleaf mountain mahogany (*Cercocarpus ledifolius* Nutt. ex Torr. & Gray) with Rocky Mountain juniper, gray horsebrush (*Tetradymia canescens* DC.) and rubber rabbitbrush (*Chrysothamnus nauseosus* [Pall.] Britt.) co-occurring. Mule deer have historically been the primary browsers (South 1957).



Figure 4. Scudder Creek big game exclosure in center on ridge top (7/01).

14. Hyde Creek. The Hyde Creek exclosure is in Madison County, 48.3 km (30 miles) south of Ennis above the Wall Creek Wildlife Management Area (WMA) on the Beaverhead National Forest. A 0.2 ha big game exclosure exists at the site (Fig. 5). The area is a mountain big sagebrush dominated site with gray horsebrush, rubber rabbitbrush, green rabbitbrush (*Chrysothamnus viscidiflorus* [Hook.] Nutt.), and silver sagebrush (*Artemisia cana* Pursh) also present. The site is in a rest-rotation pasture. The area primarily provides elk wintering habitat, but supports elk, mule deer, and antelope (*Antilocapra americana*) yearlong.

15. Wall Creek. The Wall Creek exclosure is in Madison County, about 48.3km (30 miles) south of Ennis. The exclosure is just south of the Wall Creek WMA on the

Beaverhead National Forest Land. A 0.1 ha big game enclosure is at the site. Aspen is the dominant browse species. In 1990, the stand of aspen inside the enclosure as well as 2 aspen stands outside the enclosure were clear cut. Therefore, use of browse is evaluated on the regrowth since 1990. Cattle use the area as a part of a rest-rotation grazing system. The area serves primarily as elk winter range, although elk, mule deer, and whitetailed deer use the area year around.

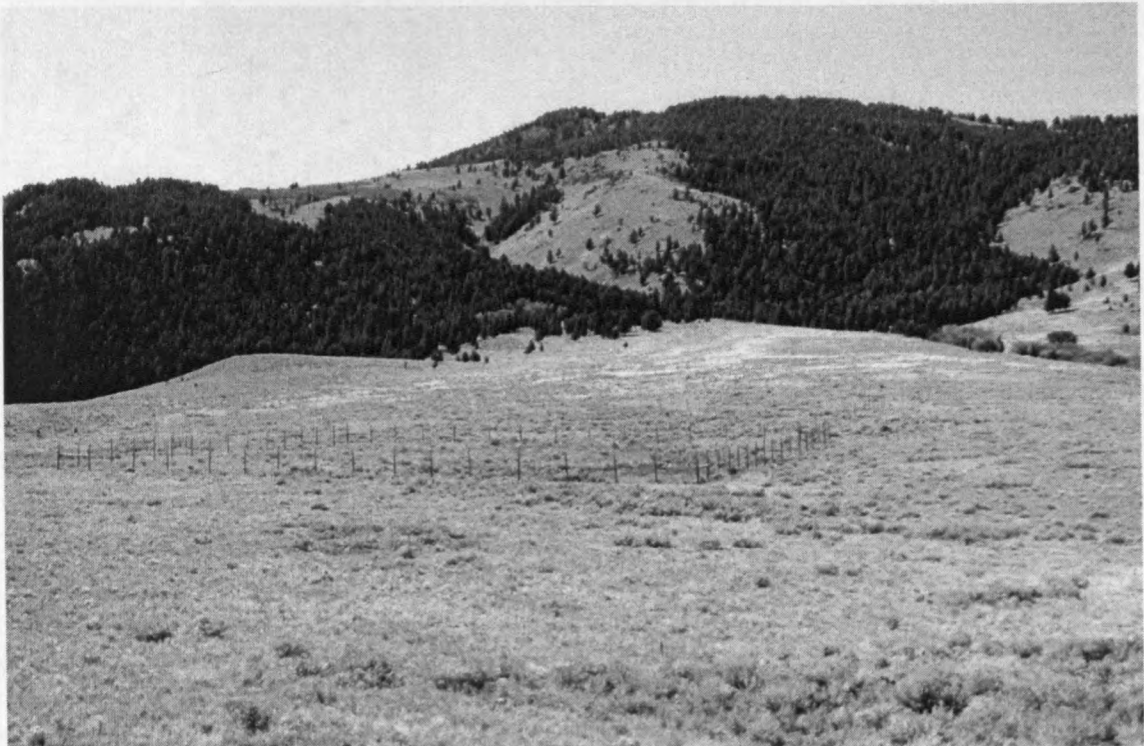


Figure 5. Hyde Creek big game enclosure (8/01).

16. Tepee Creek. The Tepee Creek enclosure is in Gallatin County about 40.3 (25 miles) south of Big Sky. The enclosure is east of Highway 191 in the Tepee Creek drainage. A single big game enclosure, about 0.4 ha in size, exists at the site (Fig. 6). The area is dominated by mountain big sagebrush with gray horsebrush, green

rabbitbrush and Oregon grape also occurring. Portions of the enclosure and adjacent areas outside were subjected to experimental reseeding and contour furrowing treatments in 1956. I only sampled areas that were not treated. The area serves primarily as an elk and mule deer winter range, but also supports a few of these animals year around.



Figure 6. Tepee Creek big game enclosure (5/02). Center of enclosure is the control section that was sampled.

17. Garden Creek. The Garden Creek enclosure is 48.3 km (30 miles) south of Livingston near Daily Lake in Park County. The 0.2 ha big game enclosure is on the Dome Mountain Wildlife WMA managed by MFW&P. The dominant browse species is aspen but various willow species are also present. The area serves primarily as a wintering area for elk migrating out of Yellowstone National Park. Mule deer and whitetailed deer also use the area year around.

18. Armstrong. The Armstrong exclosure is in Gallatin County, 16.1 km (10 miles) north of Bozeman on the Armstrong Ranch. One big game exclosure approximately 0.008 ha in size is located on the site (Fig. 7). Browse species at the site are chokecherry and antelope bitterbrush. The site is a critical mule deer winter range and also supports a few mule deer year round (D. Pac, Mont. Fish, Wildl. and Parks, unpubl. data 6/18/02).



Figure 7. Armstrong big game exclosure (7/02).

19. Johnson Creek. The Johnson Creek exclosure is in Deer Lodge County, 8.1 km (5 miles) west of Wise River on BLM land north of the Big Hole River. A big game and connected livestock exclosure, each about 0.2 ha in size, exist at the site (Fig. 8).

Dominant browse species at the site are mountain big sagebrush, Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young), and basin big sagebrush (*A. t.* Nutt. ssp. *tridentata*). Gray horsebrush and green rabbitbrush also occur in lesser amounts. Cattle and sheep (*Ovis aries*) have historically grazed the area. In more recent years, cattle have grazed the area in a rest-rotation grazing system. The area is an important elk and mule deer winter range.



Figure 8. Johnson Creek 3-phase enclosure (8/02). Big game enclosure on the right with livestock enclosure just left and up from big game enclosure.

20. Crown Butte. The Crown Butte enclosure is in Gallatin County, 40.3 km (25 miles) south of Big Sky on the east side of highway 191. The enclosure is located on the Gallatin National Forest directly north of the Yellowstone National Park boundary line. It is a big game enclosure approximately 0.8 ha in area (Fig. 9). The enclosure is built

across a variety of browse communities including mountain big sagebrush, aspen, and a complex of willow species. The area serves as an important winter range for elk that have migrated out of Yellowstone National Park.



Figure 9. Crown Butte enclosure (7/02).

21. Pole Creek. The Pole Creek enclosure is located in Beaverhead County, about 64.4 km (40 miles) south of Alder on the Beaverhead National Forest land. A 0.4 ha big game enclosure straddles Pole Creek (Fig. 10). Browse present includes various willow species in the creek bottom and silver sagebrush, threetip sagebrush (*Artemisia tripartita* Rydb.), and mountain big sagebrush on the drier portions. Cattle graze the area in a rotation grazing system. Limited evidence of wild ungulates was found, but moose, elk,

mule deer, and antelope are known to use the area. (B. Brannon, Mont. Fish, Wildl. and Parks, unpubl. data, 8/27/02).



Figure 10. Pole Creek big game exclosure (8/02).

Montana Fish, Wildlife & Parks Region 4

22. Deer Hill. The Deer Hill exclosure is in Teton County, approximately 17.7 km (11 miles) west of Dupuyer on the Theodore Roosevelt Memorial Ranch owned by the Boone and Crockett Club. The site contains a big game exclosure and a connected livestock exclosure, each approximately 1 ha in size (Fig. 11). The dominant browse species are horizontal juniper (*Juniperus horizontalis* Moench) and chokecherry. The site receives cattle use during the growing season. Mule deer concentrate on the site during winter months (G. Olson, Mont. Fish, Wildl. and Parks, unpubl. data, 7/16/01). Elk, mule deer and whitetailed deer use the area to a lesser degree year round.



Figure 11. Deer Hill 3-phase enclosure (7/01). Big game enclosure in left foreground and livestock enclosure to the right.

23. Middle Draw. The Middle Draw enclosure is in Teton County, 17.7 km (11 miles) west of Dupuyer on the Theodore Roosevelt Memorial Ranch owned by the Boone and Crockett Club. The site contains a big game enclosure and a connected livestock enclosure, each approximately 1 ha in size (Fig. 12). The enclosures straddle a creek bottom that contains various willow species including Bebb willow (*Salix bebbiana* Sarg.) and aspen. Uplands of the site contain chokecherry. Cattle use the area in a rotation grazing system. Elk, mule deer, and whitetailed deer use the site year round.



Figure 12. Middle Draw 3-phase enclosure (7/01). Big game enclosure to the right and livestock enclosure to the left.

24. Lenstra Creek. The Lenstra Creek enclosure is located in Teton County, approximately 17.7 km (11 miles) west of Dupuyer on the Theodore Roosevelt Memorial Ranch owned by the Boone and Crockett Club. The site contains a big game enclosure and a connected livestock enclosure, each approximately 1 ha in size. Lenstra Creek runs through the enclosure and supports Bebb willow. Aspen dominates the remaining areas of the enclosures. Chokecherry, serviceberry and Rocky Mountain maple also are present. Cattle use the area in a rotation grazing system. Elk, mule deer, and whitetailed deer use the site year round.

25. 1500 Acre. The 1500 Acre enclosure is located in Teton County approximately 17.7 km (11 miles) west of Dupuyer on the Teddy Roosevelt Memorial

Ranch owned by the Boone and Crockett Club. The site contains a big game exclosure and a connected livestock exclosure, each 1 ha in size. Horizontal juniper dominates half of the exclosure while aspen dominates the other half. Cattle use the area in a rotation grazing system. Elk, mule deer, and whitetailed deer use the site year round.

26. Sun River. The Sun River exclosure is in Lewis and Clark County, about 32.2 km (20 miles) west of Augusta on the Sun River WMA managed by MFW&P. A single big game exclosure approximately 0.2 ha is on the east side of Burdoff Creek (Fig 13). Browse species in the area are skunkbrush sumac (*Rhus trilobata* Nutt.) and chokecherry. The area serves primarily as a winter elk range but also supports populations of mule deer and whitetailed deer year round.



Figure 13. Sun River exclosure in Burdoff Creek (7/01).

Montana Fish, Wildlife & Parks Region 5

27. Sykes Coulee. The Sykes Coulee exclosure is in Carbon County, 24.2 km (15 miles) east of Warren on the BLM Pryor Mountain Wild Horse Refuge. A big game exclosure approximately 0.4 ha in size exists (Fig. 14). A livestock exclosure is adjacent, but is degraded and appears to not have functioned for many years. The dominant browse is curleaf mountain mahogany with Rocky Mountain juniper also present. The area is used year round by feral horses (*Equus caballus*) and mule deer.



Figure 14. Sykes Coulee exclosure (6/02). Big game exclosure fence in center, to the left is inside and right outside.

28. Crooked Creek. The Crooked Creek exclosure is 20.9 km (13 miles) east of Warren in Carbon County on the Custer National Forest in the Pryor Mountains. A big game and livestock exclosure are on the site, each about 0.2 ha in size. Browse species at

the site are Wyoming big sagebrush, black sagebrush (*Artemisia nova* A. Nels.), and mountain big sagebrush. Cattle have historically grazed the area. Evidence of mule deer was found throughout the area.

29. Picket Pin. The Picket Pin enclosure is in Stillwater County, about 16.1 km (10 miles) south of Limestone on the Gallatin National Forest. A big game and livestock enclosure, each approximately 0.2 ha in size, are at the site (Fig. 15). The dominant browse species is horizontal juniper. Mountain big sagebrush also grows at the site in limited abundance. Cattle have historically grazed the area and are still present. Mule deer rely on the area for winter habitat. Mule deer, whitetailed deer, and elk use was evident at the site.

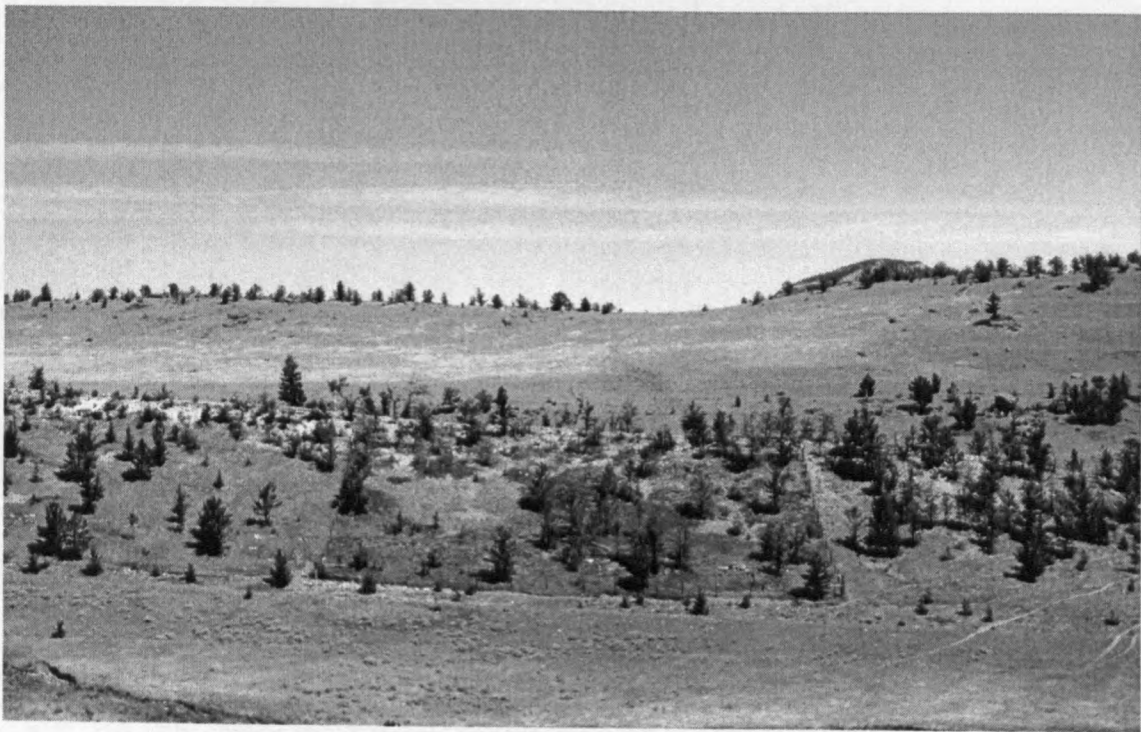


Figure 15. Picket Pin 3-phase enclosure (7/02). Big game enclosure in the center and livestock enclosure to the left. Note horizontal juniper inside big game enclosure.

Montana Fish, Wildlife & Parks Region 6

30. South Ranch. The South Ranch exclosure is located in Valley County, approximately 80.5 km (50 miles) south of Glasgow. The exclosure is on the Paige-Whitman ranch. A big game and connected livestock exclosure, each about 0.4 ha, are at the site. The dominant browse species are aspen and chokecherry. Other browse species present include various willow species, horizontal juniper, skunkbrush sumac, and silver sagebrush. Cattle graze the pasture as part of a rest-rotation grazing system. Mule deer and elk have historically used the area. More recently, the area has become an important elk winter range (P. Gunderson, Mont. Fish, Wildl. and Parks, unpubl. data, 7/10/02).

31. Pine Ridge. The Pine Ridge exclosure is in Valley County about 56.4 km (35 miles) south of Glasgow. The exclosure is located on the Charles M. Russell Wildlife Preserve. A 0.2 ha big game exclosure exists there. Ponderosa pine dominates the overstory. Browse species include Wyoming big sagebrush, rubber rabbitbrush and Rocky Mountain juniper. The area has historically been grazed by cattle. Mule deer and elk use the area year round (P. Gunderson, Mont. Fish, Wildl. and Parks, unpubl. data, 7/10/02).

32. Cottonwood. The Cottonwood exclosure is in Phillips County, 14.5 km (9 miles) north of Malta on the west side of Highway 191 on BLM land. A single 0.8 ha exclosure exists that is unique. The exclosure fence is approximately 1.5 m tall with seven strands of barbed wire. The intent of the fence was to restrict access of both cattle and antelope, but no other ungulate. Browse species present include Wyoming big

sagebrush and winterfat (*Ceratoides lanata* [Pursh] J.T. Howell). Cattle have historically grazed the area. The area serves primarily as a critical antelope winter range.

Field Procedures

Exclosures excluding all ungulates, as well as exclosures excluding only livestock, were compared to adjacent areas unprotected from browsing. All comparisons were made by pairing the protected sites with environmentally similar unprotected sites. Considerations for pairing the sites environmentally were slope and aspect (Coughenour 1991). Pairing the sites by slope and aspect, typically ensures similar soil types and micro-climates. All measurements were taken at least 2 m from the exclosure fence to eliminate exclosure effects such as trailing.

Due to the wide variety of browse species across Montana, browse taxa were classified as short shrubs, tall shrubs, or trees. Some sites contained one or all classes of browse and, therefore, allowed multiple comparisons.

Short Shrub Species

Shrub species typically attaining a height of less than 2.5 m were considered short shrubs. Canopy cover of live shrub and density of juvenile, established, and dead shrubs were estimated for plants inside and outside exclosures at each site. On sagebrush communities, production of winter forage was also estimated.

Canopy Cover. Shrub canopy cover was estimated using the line intercept method (Canfield 1941). Transect lines 30 m in length were established a minimum of

3 m apart. Transects were placed at regular intervals so that each transect represented an equal portion of the area compared (Fig. 16, Coughenour 1991, Wambolt and Sherwood 1999). Exclosures were of varying size, so number of transects varied. Ten transects was the maximum required for an adequate sample on large sites (Wambolt and Sherwood 1999). As few as 3 transects may be adequate on smaller sites (Kay and Bartos 2000). Equal number of transects were established inside and outside each exclosure. Shrub canopy was measured in 3 cm increments along the line. A plumb bob was suspended from the line to accurately measure live shrub tissue intercepting the line. Shrub tissue intercepting less than 3 cm of the line was not included. Canopy cover of live shrub tissue for each species encountered was then calculated as a percent of the total line length.

Density. Density of shrubs was determined in 2 x 30 m belt transects. Line transects used for determining canopy cover provided the center of each belt. Belt transects were formed by measuring 1 meter perpendicular to both sides of the line transect (Fig. 16). The number of juvenile, established, and dead shrubs rooted in the belt transect was recorded. Juvenile shrubs were those having an average crown cover ≤ 15 cm from 4 axis measurements. Dead shrubs were those shrubs having no live tissue. Smaller shrub species such as gray horsebrush were not separated by age so only density of live and dead shrubs was recorded for those species.

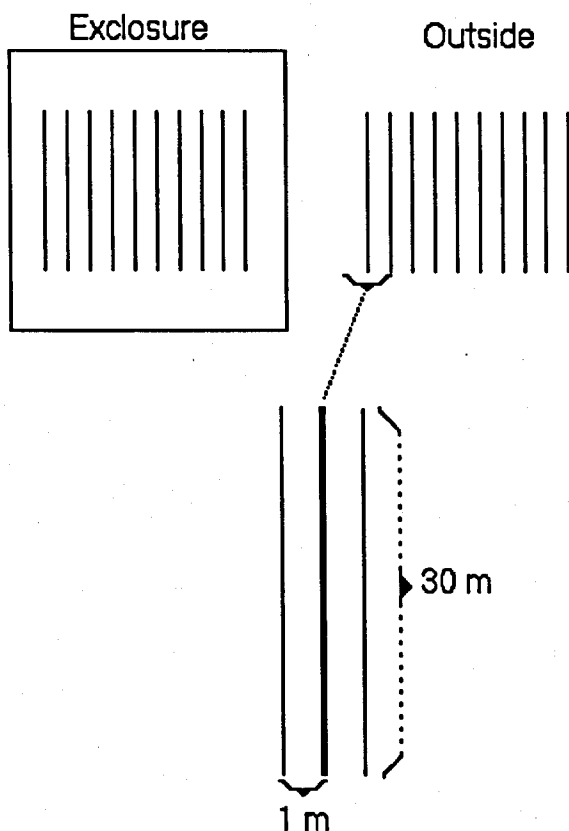


Figure 16. Transect layout with belt transect formed by sampling 1 m on both sides of the line transect.

Sagebrush Winter Forage Production. Production of winter forage by big sagebrush taxa was estimated using models developed by Wambolt et al. (1994). Ten big sagebrush plants within each belt transect were measured for this parameter. Specific parameters measured on sagebrush plants varied by subspecies and form class (Wambolt et al. 1994). Form classes depended upon historic low or high-use of big sagebrush. High use plants exhibit intense browsing by a "hedged" appearance. Models with shrub parameters are included in Table 8, Appendix A. After obtaining density of mature big sagebrush and individual big sagebrush production of winter forage production, the production of winter forage for big sagebrush per belt transect was calculated. The

production inside exclosures was then compared to production outside on a $\text{kg}/60\text{m}^2$ basis.

Tall Shrub Species

Tall shrubs were those typically attaining a height of ≥ 2.5 m when unbrowsed and having multiple stems. Evaluation of tall shrubs follows the methods described in Keigley and Frisina (1998). At each site with tall shrubs, a single indicator species was selected. An indicator species is a preferred browse species that is widely distributed throughout the site. Net annual growth rate and lifespan of indicator species were estimated for stems of indicator species inside and outside exclosures. Models used to predict net annual growth rate and lifespan are included in Appendix A. The growth rate of browsed stems was then compared to lifespan of browsed stems to determine if browsed stems are growing fast enough to escape the browse zone (≤ 2.5 m) before they die. An index (LD index) was used to describe the response of shrubs following browsing and browsing related architecture types described the stature of shrubs and trend in the browsing intensity (Keigley and Frisina 1998).

Net Annual Growth Rate. Two kinds of growth rate were estimated (Total net annual growth rate and net annual growth rate to 1m). Total net annual growth rate (NAGR_T) estimates the growth rate of a stem over the entire lifespan of the plant not including current year growth. Net annual growth rate to 1m ($\text{NAGR}_{1\text{m}}$) estimates the growth rate of a stem as it grew to 1 m in height.

An estimate of $NAGR_T$ entailed selecting 20 stems of an indicator species inside each exclosure. Stems were stratified by diameter in an attempt to include a range of ages. Stems were cut at ground level and height to the top of previous years growth (H_{pyg}) was recorded. A stem section at the base was taken to determine the stem age (A_s). Age was determined by counting annual growth rings with a dissection scope. Net annual growth rate of stems was calculated from: H_{pyg} / A_s . Estimating $NAGR_T$ outside exclosures entailed selecting 20 stems of the same indicator species. Stems were again stratified by stem diameter, but only stems within the browse zone (≤ 2.5 m) were selected. Stems heights and ages were determined in the same manner as inside the exclosure to determine $NAGR_T$.

The stems from the indicator species inside the exclosure used to determine net annual growth rate were also sampled to determine net annual growth rate to 1 m ($NAGR_{1m}$). A section for aging from each stem was taken at 1 m above the ground. This estimate of growth rate of unbrowsed stems as they grew to 1 m was compared to growth rate of browsed stems to detect differences in young stem growth rate.

Lifespan. Lifespan of stems was determined by obtaining the age at which stems died (A_D). Twenty dead stems were randomly sampled within an exclosure to estimate lifespan of unbrowsed stems. Ages of these stems were determined by counting annual growth rings at their bases. Twenty dead stems within the browse zone were also sampled and aged outside exclosures. This provided an estimate of lifespan of browsed stems.

Height of Live and Dead: (LD Index). The LD index describes the response of shrubs following the onset of intense browsing (Keigley et al. 2002). For a given stem, an LD index is calculated by subtracting the height of the oldest stem segment killed by browsing (H_D) from the height of the tallest live stem segment at the base of current year growth (H_{pyg}).

Twenty stems of an indicator species were selected outside each exclosure, while stems inside exclosures were not sampled because of the absence of browsers. Stems with previous year growth in the browse zone (≤ 2.5 m) were selected. An LD index value near zero indicates that ungulates are browsing live stem segments down to the level of mechanical protection afforded by the dead stem segments. A negative LD index value indicates the shrub is dying back to ground level, as a result of continuing intense browsing, or other adverse environmental factors. A positive LD index value indicates that recent growth exceeds the height of stem segments killed by browsing. A positive LD index may result from a decrease in the browsing pressure or a change in the environment that enhances stem growth.

Architecture Types. Browsing related architectures of tall shrubs were described at each site. Architecture typing is a qualitative method of describing current and past level of browsing (Keigley and Frisina 1998). Architecture types develop as the stem grows through the browse zone. The architectures are based on 2 browsing levels; light-to-moderate and intense. Light-to-moderate browsing occurs when only a portion of the current annual segment dies, allowing new growth to originate from the previous year's growth. Intense browsing occurs when browsers remove or cause the death of the

complete current annual segment. Subsequent new growth must develop from a stem segment greater than 1 year old.

The 4 architecture types are uninterrupted-growth-type, arrested-type, retrogressed-type, and released-type (Fig. 17). Stems on plants displaying uninterrupted-growth-type architecture grew through the browse zone under a light-to-moderate browsing level. Arrested-type shrubs have experienced intense browsing since establishment. Stems of arrested-type shrubs grow to a uniform height that is often determined by snow depth. Retrogressed-type shrubs experienced light-to-moderate browsing early in their life; followed by a change to intense browsing. During the period of light-to-moderate browsing, retrogressed-type shrubs grow taller than arrested-type shrubs. Subsequent intense browsing causes the top of the plant to die. Repeated browsing causes clusters of twigs to develop at the end of stems. Because uninterrupted-growth-type shrubs consist of stems of various heights, retrogression of such shrubs causes clusters of twigs to form at tips of accessible stems. A released-type architecture is produced by a change from intense browsing to light-to-moderate browsing. Under intense browsing, an arrested or retrogressed-type shrub is produced. When the browsing pressure diminishes to light-to-moderate, stems are able to grow through the browse zone.

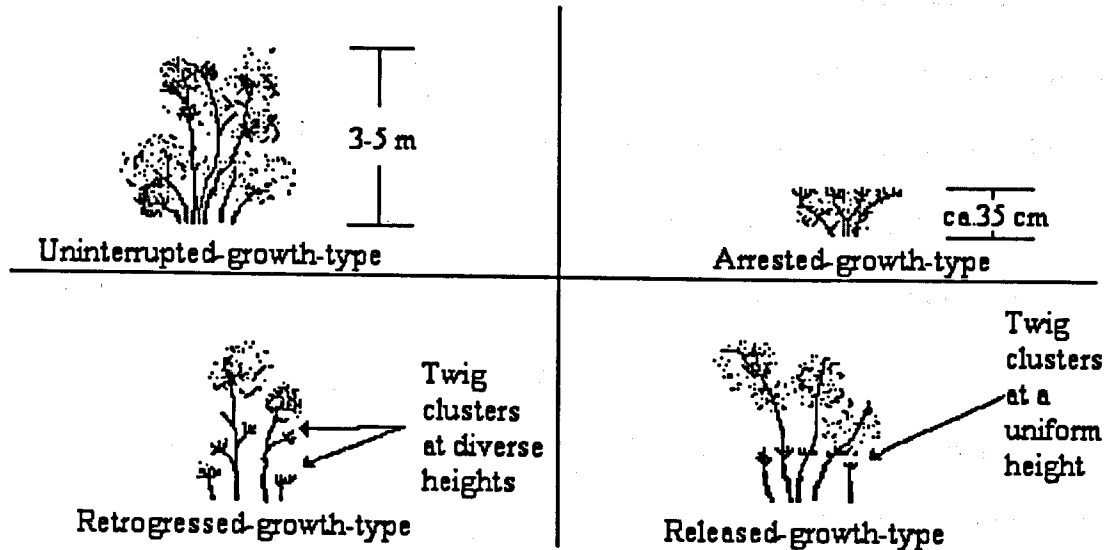


Figure 17. The 4 architecture types.

Trees

Trees were considered those plants that typically attain a tall stature (> 2.5 m) in the absence of browsing and have a single stem. The most frequently encountered tree was aspen. The history of browsing on aspen was described at each site (Keigley and Frisina 1998).

Describing Browsing History. Using the architecture types described above and dendrochronology, I determined periods of intense and light-to-moderate browsing on aspen inside and outside exclosures. Uninterrupted-growth-type aspen outside the exclosures indicate light-to-moderate browsing during the years those stems grew through the browse zone. Arrested and retrogressed-type aspen indicate intense browsing. Because the lifespan of arrested and retrogressed-type aspen is relatively short, the period of intense browsing documented by these architectures is limited. The

absence of aspen establishment could be due to intense browsing or inhibition by growth regulators produced by mature aspen within the same stand. To distinguish between these possibilities, I examined aspen establishment inside adjacent exclosures. The presence of aspen of a given age inside and the absence of the same age outside the exclosure was interpreted as evidence of intense browsing outside as opposed to inhibition by growth regulators.

Sampling inside exclosures determined 20 ages of saplings and trees that were thought to be established in the stand. These stems were stratified by base diameter to sample across the range of ages. An increment borer was used on large trees to obtain a core at 30 cm above the ground for aging. Where heart rot was present at the base, cores were taken higher on the tree. Smaller trees were cut at ground level to remove a stem section taken for aging. Their ages were used to calculate the period of aspen establishment.

Twenty stems displaying an uninterrupted-growth-type outside the exclosure were sampled to determine periods of light-to-moderate browsing in the presence of browsers (Appendix A, Table 9). Sampling was the same as above.

Twenty arrested and retrogressed-type stems outside the exclosure were sampled as direct evidence of intense browsing. Sampling entailed obtaining a stem section or core of live tissue directly below the area of the stem displaying intense browsing. Areas of intense browsing include clusters of stems and dead stem sections apparently killed by browsing. Samples were then aged by counting annual growth rings. The year intense

browsing occurred can then be obtained by subtracting the age at that point from the current calendar year (Appendix A, Table 9).

Photos

A photo record was made at each exclosure. Historical photos, when available, were retaken to illustrate changes at the site.

Statistical Procedures

Each site was treated independently. Browse parameters inside the exclosure(s) were compared to browse parameters outside the exclosure(s) at each site using a Student's t-test. Parameter means for short shrubs, including canopy cover (%), density of shrubs ($N/60m^2$), and sagebrush production of winter forage ($kg/60m^2$), were compared inside and outside of exclosures. Parameter means for tall shrubs, which include total net annual growth rate (cm/yr), net annual growth rate to 1 m (cm/yr), and lifespan (yrs.), were compared inside and outside exclosures. Periods of browsing intensity of trees, LD indexes, and descriptions of architecture types were not suitable for statistical analysis.

The t-test procedure of SAS (2000) was used to determine differences between parameter means. Equality of variances was tested using a Folded F test. Variances were considered unequal when $P \leq 0.05$. When mean variances were unequal, the Satterthwaite t-value was used to determine differences between parameter means. Parameter means were considered significant when $P \leq 0.05$ and highly significant when $P \leq 0.01$. Differences at the 0.1 level were also reported.

CHAPTER 4

RESULTS AND DISCUSSION

Rice and Westoby (1978) point out the difficulties of interpreting exclosures. Quadrats may be replicated inside and outside exclosures, but not samples of the original vegetation subjected to an exclosure treatment. Location of an exclosure is typically arbitrary rather than random and management and grazing patterns vary between exclosures. Mackie (1973) cautioned against any generalizations concerning impacts of browsing due to variations in species, location, time, site or other environmental conditions affecting browse species productivity. For these reasons, results of this study will be discussed on an individual site basis and on a dominant browse species basis. I made no assumptions of pre-exclosure vegetation at the sites. Table 3 contains parameter means for the browse species with $\geq 1\%$ canopy cover at each site.

Individual Site SummariesMontana Fish, Wildlife & Parks Region 1

1. Schmitz Mine. Browsing negatively impacted the growth of serviceberry at the Schmitz Mine site as found by using the tall shrub sampling method. Nearly all serviceberry stems outside the exclosure showed past and current intense browsing as displayed by arrested and retrogressed architecture types. An LD index of 2.3 cm indicates the browsing pressure is limiting growth of stems to near the level of mechanical protection.

Table 3. Parameter means for browse species with $\geq 1\%$ canopy coverage at a site.

Site	Excl. ²	Species ³	Short Shrub Parameters						Tall Shrub Parameters						Tree		
			Canopy Cover ¹ (%)		Density (n/60m ²)		Big Sagebrush Winter Forage (kg/60m ²)		Growth Rate (cm/yr)		Growth Rate to 1m (cm/yr)		Lifespan (yrs)		LD Index (cm)		Intense browsing ⁵ (yrs)
			In	↔ ⁴ Out	In	↔ Out	In	↔ Out	In	↔ Out	In	↔ Out	In	↔ Out	In	Out	G-Out L-In ⁶
1	G	<i>Amal</i>							16.9 **	4.5	28.8 **	4.5	18.1 **	11.5	n/a	2.3	
2	G	<i>Aruv</i>	6.4 *	11.8	10.4 *	27.1											
2	G	<i>Bere</i>	13.4	10.0	288.6	243.6											
2	G	<i>Rowo</i>	2.9 •	1.3	31.3	18.6											
2	G	<i>Syal</i>	0.9 *	2.6	8.7 •	42.4											
3	G	<i>Amal</i>	2.4	0.5	1.7	1.3											
3	G	<i>Aruv</i>	1.2 *	5.6	3.4 **	14.6											
3	G	<i>Bere</i>	6.3	6.4	100.1	105.4											
3	G	<i>Shca</i>	0.7	1.3	1.6	0.4											
4	G	<i>Amal</i>							14.7 **	8.5	20.4 **	8.5	30.0 **	13.0	n/a	0.2	
4	L	<i>Amal</i>							9.1	8.5	11.5 •	8.5	17.6 **	13.0	12.8	n/a	
5	G	<i>Bere</i>	4.2	3.5	173.9	184.8											
5	G	<i>Putr-y</i>	2.4 **	0.0	0.2	0.3											
5	G	<i>Putr-m</i>			5.9 **	0.7											
5	G	<i>Putr-d</i>			1.4	0.7											
5	G	<i>Rowo</i>			18.5 **	1.1											
5	L	<i>Bere</i>	3.9	3.5	176.7	184.8											
5	L	<i>Putr-y</i>	0.0	0.4	0.0 •	0.3											
5	L	<i>Putr-m</i>			0.1 *	0.7											
5	L	<i>Putr-d</i>			0.9	0.7											
5	L	<i>Rowo</i>			0.6	1.1											
6	G	<i>Putr-y</i>	4.0	7.8	1.0	1.7											
6	G	<i>Putr-m</i>			9.0 *	20.6											

Table 3. Continued... (page 2)

Site	Excl. ²	Species ³	Short Shrub Parameters									Tall Shrub Parameters									Tree		
			Canopy Cover ¹ (%)			Density (n/60m ²)			Big Sagebrush Winter Forage (kg/60m ²)			Growth Rate (cm/yr)			Growth Rate to 1m (cm/yr)			Lifespan (yrs)			LD Index (cm)		Intense browsing ⁵ (yrs)
			In	↔ ⁴	Out	In	↔	Out	In	↔	Out	In	↔	Out	In	↔	Out	In	↔	Out	In	Out	
6	G	<i>Putr-d</i>				8.1		19.6															
6	G	<i>Syal</i>				39.3		56.9															
6	L	<i>Putr-y</i>	11.6		11.9	0.1		0.6															
6	L	<i>Putr-m</i>				17.1		22.8															
6	L	<i>Putr-d</i>				5.8 **		1.4															
6	L	<i>Syal</i>				10.3		27.4															
7	G	<i>Putr-y</i>	4.1 *		0.6	0.5		1.3															
7	G	<i>Putr-m</i>				7.2 •		2.7															
7	G	<i>Putr-d</i>				6.2		9.1															
7	G	<i>Rowo</i>	1.8		0.9	18.1		27.3															
7	G	<i>Syor</i>	0.0 *		1.2	0.0 *		10.2															
8	G	<i>Amal</i>										8.3 •	6.5	25.5 **	6.9	27.0 **	17.3	n/a		11.3			
9	G	<i>Amal</i>	3.2 *		0.8	6.0 *		3.3															
9	G	<i>Aruv</i>	9.3 *		5.2	36.8 **		25.9															
9	G	<i>Ceve</i>	1.0		0.5	0.5		1.5															
10	G	<i>Acgl</i>	11.5		11.3																		
10	G	<i>Amal</i>	28.6 *		18.0							15.9 *	11.6	27.2	21.0	24.7	24.3	n/a		40.6			
10	G	<i>Ceve</i>	3.1		1.5																		
10	G	<i>Prpe</i>	1.1		2.3																		
10	G	<i>Prvi</i>	14.6		17.3																		
11	G	<i>Artrv-y</i>	18.3 **		8.8	11.3		7.8															
11	G	<i>Artrv-m</i>				60.6 **		22.7	3.7 *		1.3												
11	G	<i>Artrv-d</i>				21.3 **		10.1															

Table 3. Continued...(page 3)

Site	Excl. ²	Species ³	Short Shrub Parameters						Tall Shrub Parameters						Tree		
			Canopy Cover ¹ (%)		Density (n/60m ²)		Big Sagebrush Winter Forage (kg/60m ²)		Growth Rate (cm/yr)		Growth Rate to 1m (cm/yr)		Lifespan (yrs)		LD Index (cm)		Intense browsing ⁵ (yrs)
			In	↔ ⁴ Out	In	↔ Out	In	↔ Out	In	↔ Out	In	↔ Out	In	↔ Out	In	Out	G-Out L-In ⁶
11	G	<i>Potr</i>															1967 - 2000
11	G	<i>Sage</i>							24.4 **	12.7	35.8 **	12.7	19.2 **	12.7	n/a	3.9	
12	G	<i>Sabo</i>							18.1	18.0	41.9	31.8	20.7 **	16.9		48.6	
13	G	<i>Cele-y</i>	34.9 **	11.0	2.0	0.1											
13	G	<i>Cele-m</i>			31.3 *	14.1											
13	G	<i>Cele-d</i>			3.3 *	1.1											
14	G	<i>Arca-y</i>	1.1	0.5	1.9	1.5											
14	G	<i>Arca-m</i>			9.6	9.4											
14	G	<i>Arca-d</i>			0.1	0.0											
14	G	<i>Artrv-y</i>	9.5	8.7	4.3 *	13.3											
14	G	<i>Artrv-m</i>			24.4	25.7	1.8	1.8									
14	G	<i>Artrv-d</i>			6.3	2.1											
14	G	<i>Chvi</i>	2.0	1.1	32.2	22.4											
14	G	<i>Teca</i>	2.0	1.3	17.2	12.5											
15	G	<i>Potr</i>															1994 - 2001
16	G	<i>Artrv-y</i>	17.0 **	10.3	6.6	6.7											
16	G	<i>Artrv-m</i>			46.5 **	34.7	3.6 **	1.8									
16	G	<i>Artrv-d</i>			11.3 **	6.9											
16	G	<i>Teca</i>	1.0	1.7	24.7	20.5											
17	G	<i>Potr</i>															1987 - 1998
18	G	<i>Prvi</i>							8.1	6.9	8.1	6.9	n/a	n/a	n/a	-2.0	
19	G	<i>Artrv-y</i>	11.1 •	8.4	6.5 **	17.3											
19	G	<i>Artrv-m</i>			50.4 **	36.7	2.5	2.6									

Table 3. Continued...(page 4)

Site	Excl. ²	Species ³	Short Shrub Parameters						Tall Shrub Parameters						Tree		
			Canopy Cover ¹		Density		Big Sagebrush		Growth Rate		Growth Rate to		Lifespan		LD Index		Intense browsing ⁵
			(%)		(n/60m ²)		Winter Forage	(cm/yr)	1m	(cm/yr)	(yrs)	(cm)	(yrs)				
			In	↔ ⁴	Out	In	↔	Out	In	↔	Out	In	↔	Out	In	Out	G-Out L-In ⁶
19	G	<i>Artrv-d</i>	0.0		0.0	5.3	•	2.9									
19	L	<i>Artrv-y</i>				15.3		17.3									
19	L	<i>Artrv-m</i>	7.5		8.4	41.6		36.7	2.3		2.6						
19	L	<i>Artrv-d</i>				2.4		2.9									
20	G	<i>Potr</i>															1949 - 2001
20	G	<i>Sabo</i>							11.1	*	7.8	14.5	**	7.8	31.2	**	5.3 n/a 1.0
21	G	<i>Sabo</i>							29.2	**	18.2	43.9	**	18.2	n/a	n/a	0.1
22	G	<i>Arfr</i>	0.3	**	1.3	11.0	**	60.1									
22	G	<i>Juho</i>	27.3	**	0.3												
22	G	<i>Pofr</i>	11.3	**	3.2	70.2	*	36.4									
22	L	<i>Arfr</i>	0.1	**	1.3	4.1	**	60.1									
22	L	<i>Juho</i>	3.2	*	0.3												
22	L	<i>Pofr</i>	9.9	**	3.2	65.6	*	36.4									
23	G	<i>Potr</i>															1981-2000
23	G	<i>Sabe</i>							15.1	**	6.8	18.7		14.4	37.3	**	18.2 n/a -2.1
23	L	<i>Potr</i>															1988-2000
23	L	<i>Sabe</i>							9.0	•	6.8	14.9		14.4	17.5		18.2 7.7 n/a
24	G	<i>Potr</i>															1978-1998
24	G	<i>Sabe</i>							11.9	**	6.4	15.8	**	6.8	36.7	**	14.5 n/a 3.2
24	L	<i>Potr</i>															1979-2001
24	L	<i>Sabe</i>							9.7	**	6.4	14.9	•	6.8	14.1		14.5 4.2 n/a
25	G	<i>Potr</i>															1991-2001
25	L	<i>Potr</i>															none

Table 3. Continued...(page 5)

Site	Excl. ²	Species ³	Short Shrub Parameters						Tall Shrub Parameters									Tree		
			Canopy Cover ¹ (%)		Density (n/60m ²)		Big Sagebrush Winter Forage (kg/60m ²)		Growth Rate (cm/yr)			Growth Rate to 1m (cm/yr)			Lifespan (yrs)			LD Index (cm)		Intense browsing ⁵ (yrs)
			In	⇔ ⁴ Out	In	⇔ Out	In	⇔ Out	In	⇔ Out	In	⇔ Out	In	⇔ Out	In	⇔ Out	In	Out	G-Out L-In ⁶	
26	G	<i>Arfr</i>	1.7	1.7	9.0	*	21.6													
26	G	<i>Prvi</i>							15.9	*	11.4	22.1	**	11.9	n/a	n/a	n/a	-2.6		
26	G	<i>Rhtr</i>	40.0	30.9																
26	G	<i>Syor</i>	4.1	2.1																
27	G	<i>Cele-y</i>			0.0		1.2													
27	G	<i>Cele-m</i>	14.4	*	9.6		18.6													
27	G	<i>Cele-d</i>			3.4		2.3													
27	G	<i>Jusc-y</i>			0.2		0.2													
27	G	<i>Jusc-m</i>	2.4	2.1	0.9		1.5													
27	G	<i>Jusc-d</i>			0.8	•	0.1													
28	G	<i>Arno-y</i>			11.6	**	25.9													
28	G	<i>Arno-m</i>	5.6	*	8.3		55.0	**	138.7											
28	G	<i>Arno-d</i> ⁷			6.5		7.5													
28	G	<i>Artrv-y</i>			0.1		0.0													
28	G	<i>Artrv-m</i>	2.2	0.7	7.5		3.9													
28	G	<i>Artrv-d</i>			0.0		0.0													
28	G	<i>Artrw-y</i>			4.7		4.5	0.6	**	0.2										
28	G	<i>Artrw-m</i>	4.1	*	2.1		55.0	**	24.9											
28	G	<i>Artrw-d</i> ⁷			6.5		7.5													
29	G	<i>Juho</i>	47.1	**	6.0															
29	L	<i>Juho</i>	18.2	*	6.0															
30	G	<i>Potr</i>																	1993 - 2001	
30	G	<i>Prvi</i>							9.4	**	6.4	9.4	**	6.4	n/a	n/a	n/a	10.0		

1993 - 2001

Table 3. Continued...(page 6)

Site	Excl. ²	Species ³	-----Short Shrub Parameters-----									-----Tall Shrub Parameters-----									---Tree---		
			Canopy Cover ¹			Density			Big Sagebrush			Growth Rate			Growth Rate to			Lifespan			LD Index		Intense
			(%)			(n/60m ²)			Winter Forage			(cm/yr)			1m			(yrs)			(cm)		browsing ⁵
			In	↔ ⁴	Out	In	↔	Out	In	↔	Out	In	↔	Out	In	↔	Out	In	↔	Out	In	Out	G-Out L-In ⁶
30	L	<i>Potr</i>																					1993 - 2001
30	L	<i>Prvi</i>										6.5		6.4	6.5		6.4	n/a		n/a	6.8	n/a	
31	G	<i>Artrw-y</i>	3.9		5.3	2.1 *		5.5															
31	G	<i>Artrw-m</i>				15.6 •		33.2	0.3		0.4												
31	G	<i>Artrw-d</i>				3.6 •		1.6															
31	G	<i>Jusc-y</i>	7.9		12.7	0.1		0.2															
31	G	<i>Jusc-m</i>				0.8		1.3															
31	G	<i>Jusc-d</i>				0.0		0.0															
32	G	<i>Artrw-y</i>	22.4 **		6.2	16.3		11.8															
32	G	<i>Artrw-m</i>				106.1 **		51.7	1.9 **		0.6												
32	G	<i>Artrw-d</i>				16.4 **		7.1															

¹Canopy cover of young and mature plants combined.²Exclosure type: G - Big game, L - Livestock

³Browse species abbreviations: *Acgl* - Rocky Mountain maple, *Amal* - serviceberry, *Arca* - silver sagebrush, *Arfr* - fringed sagewort, *Arno* - black sagebrush, *Artrv* - mountain big sagebrush, *Artrw* - Wyoming big sagebrush, *Aruv* - bearberry, *Bere* - Oregon grape, *Cele* - curl-leaf mountain mahogany, *Ceve* - snowbrush ceanothus, *Chvi* - green rabbitbrush, *Juho* - horizontal juniper, *Jusc* - Rocky Mountain juniper, *Potr* - aspen, *Prpe* - pin cherry, *Prvi* - chokecherry, *Putr* - bitterbrush, *Rhtr* - skunkbrush sumac, *Rowo* - Wood's rose, *Sabe* - Bebb willow, *Sabo* - Booth's willow, *Sage* - Geyer's willow, *Shca* - russet buffaloberry, *Syal* - common snowberry, *Syor* - western snowberry, *Teca* - gray horsebrush, (See appendix D for complete names), y - young, m - mature d - dead.

⇌⁴Comparison of parameters in and out of an exclosure: •, *, ** Significant at the P ≤ 0.1, 0.05, and 0.01 levels respectively.⁵Indicates Julian calendar years that intense browsing occurred.⁶Data are outside when referring to big game exclosures and inside when referring to livestock exclosures.⁷Dead shrubs of *Arno* and *Artrw* are combined.

Serviceberry stems inside the big game exclosure had greater ($P \leq 0.01$) $NAGR_T$ than stems outside. $NAGR_{Im}$ was also greater ($P \leq 0.01$) inside than outside the exclosure. Lifespan of serviceberry stems was 18.1 years inside the exclosure and 11.5 years outside ($P \leq 0.01$). In order for stems to grow through the browse zone (2.5 m) before they die, they would need to grow 21.7 cm/year. In 2000, they were growing at 4.5 cm/yr.

2. Thirsty Lake. Browsing has not impacted browse species at the Thirsty Lake site as found by using the short shrub method. Bearberry and snowberry had greater canopy cover and density outside the Thirsty Lake exclosure. Density of mature Douglas fir in transects inside (7.9/60 m²) and outside (2.4/ 60 m²) the exclosure was different ($P \leq 0.05$) (Appendix G, Fig. 31). Increased shading by Douglas fir may have created a different growing environment inside the exclosure and could have negatively affected bearberry and snowberry inside the exclosure (Martin et al. 1951, Stubbendieck et al. 1997). The data indicate that browsing has been light-to-moderate at Thirsty Lake. Differences in browse species inside and outside the exclosure are attributed to differences in forest succession.

3. Roberts Mountain. The short shrub method was used to evaluate browse species at Roberts Mountain. No differences were measured between canopy cover and densities of protected and unprotected browse species, except for bearberry. Canopy cover and density of bearberry plants was greater outside exclosures ($P \leq 0.05$). As at the Thirsty Lake site, differences may be due to differential shading by Douglas fir inside the

exclosure. The few unprotected serviceberry shrubs were of uninterrupted-growth-type architectures. All data indicate that browsing has been light-to-moderate at the site. Differences in browse species inside and outside the exclosure is a function of differing patterns of forest succession inside and outside.

4. Ant Flat. Sampling at Ant Flat was conducted on non-burned serviceberry using the tall shrub method. Browsing is currently having a negative impact on growth of unburned serviceberry. The browsing trend indicated by architecture types was light-to-moderate browsing in the past with recent intense browsing. Past light-to-moderate browsing is indicated by a few retrogressed-growth-type serviceberry shrubs both in and out of the livestock exclosure. The remaining unburned serviceberry stems within the browse zone inside and outside the livestock exclosure had arrested-growth-type. An LD index of 0.2 cm outside indicated that browsing is limiting growth of stems to the level of mechanical protection. $NAGR_T$, $NAGR_{1m}$, and lifespan of serviceberry stems were greater ($P \leq 0.01$) inside than outside the big game exclosure. No differences in $NAGR_T$ and $NAGR_{1m}$ were detected between stems in and out of the livestock exclosure. The LD index inside the livestock exclosure was 12.8 cm, which indicates stems are growing above the level of mechanical protection. Lifespan of serviceberry stems was greater ($P \leq 0.05$) inside the livestock exclosure than outside. Stems inside and outside the livestock exclosure would need to grow 14.2 cm/year and 19.2 cm/yr, respectively, to grow out of the browse zone before they die. Stems are currently growing in and out of the livestock exclosure at 9.1 cm/yr and 8.5cm/yr, respectively. Browsing has suppressed growth of serviceberry and has not allowed stems to grow to full stature.

5. Poverty Flat. The big game and livestock exclosures were evaluated with the short shrub method. Canopy cover and density of bitterbrush were greater ($P \leq 0.01$) inside than outside the Poverty Flat big game exclosure. Density of Wood's rose was also greater ($P \leq 0.01$) inside the exclosure. Density of mature bitterbrush was higher ($P \leq 0.05$) outside than inside the livestock exclosure. No differences were found between the livestock exclosure and outside for all other browse species. These data are evidence that browsing by wild ungulates has negatively impacted bitterbrush and Wood's rose since the exclosure was built in 1958. Because only a difference in density of mature bitterbrush was found inside and outside the livestock exclosure, impacts of livestock on browse species are considered minor.

6. Young Creek. The Young Creek big game and livestock exclosures were evaluated with the short shrub method. No differences between canopy cover of any browse species inside and outside the big game exclosure were found. Density of mature bitterbrush plants outside the game exclosure was higher ($P \leq 0.05$). No differences were detected between canopy cover inside and outside the livestock exclosure for any species (Appendix G, Fig. 32, 33). Density of dead bitterbrush was higher ($P \leq 0.01$) inside the livestock exclosure. Wild and domestic ungulates have not impacted browse species at this site.

Montana Fish, Wildlife & Parks Region 2

7. Dry Cottonwood. Browsing has impacted bitterbrush at the Dry Cottonwood site as found by using the short shrub method. Bitterbrush had greater ($P \leq 0.05$) canopy

coverage inside than outside the big game exclosure. Density of mature bitterbrush was higher ($P \leq 0.1$) inside the exclosure as well. Canopy cover and density of western snowberry were greater ($P \leq 0.05$) outside the exclosure. Bitterbrush is considered highly valuable forage for elk and mule deer year-round while western snowberry is least valuable to elk and moderately valuable to mule deer (Kufeld 1973, Kufeld et al. 1973). Differential use of bitterbrush and western snowberry may have given snowberry a competitive advantage. Areas unburned and protected had higher ($P \leq 0.05$) canopy coverage of bitterbrush than areas burned and protected. These findings agree with Wambolt et al. (2001) in which bitterbrush was reduced by fire in southwestern Montana. No differences were detected between burned and unburned areas outside. The combination of burning and browsing did not impact bitterbrush more than browsing alone.

8. Dry Creek. Serviceberry has been impacted by browsing at the Dry Creek site as found by using the tall shrub method. Serviceberry stems had a greater $NAGR_T$ ($P \leq 0.1$) and greater $NAGR_{1m}$ ($P \leq 0.05$) inside than outside the exclosure. Lifespan of serviceberry stems was shorter ($P \leq 0.01$) outside than inside the big game exclosure. All serviceberry shrubs at the site had arrested or retrogressed-type architecture (Appendix G, Fig. 40). The LD index (11.3 cm) indicated that new stem growth was slightly higher than the level of mechanical protection. Unprotected stems that grew 6.5 cm/yr will not grow out of the browse zone (2.5 m) before they are killed by browsing. All evidence indicates the browsing pressure continues to suppress growth of serviceberry.

9. Eddy Creek. Browsing has negatively impacted a variety of species at Eddy Creek as found by using the short shrub method. Serviceberry plants were present, but not sufficiently dense to sample by the tall shrub method. Bearberry and serviceberry canopy cover was higher ($P \leq 0.05$) inside the exclosure than outside. Density of bearberry was greater ($P \leq 0.01$) inside as well. All serviceberry outside were arrested. Canopy cover of bearberry and serviceberry increased both inside and outside the exclosure from 1957 to 2001 (Table 4). Snowbrush ceanothus canopy coverage was minor at the site, but declined since 1957. My estimates of canopy cover may be more conservative than previous estimates because I did not include gaps in the interior portions of shrubs. Douglas fir and ponderosa pine appear to have increased inside the exclosure since 1957 and may have contributed to the decline of snowbrush ceanothus due to shading (Appendix G, Fig. 41, 42). Changes in tree canopy are less evident outside as is decline of snowbrush ceanothus (Appendix G, Fig. 43, 44).

Table 4. Trend in percent canopy cover of browse species at Eddy Cr. from 1957 to 2001.

Location and Species	Percent canopy cover by year					Percent change
	1957	1963	1967	1980	2001	1957-2001
Inside Exclosure						
<i>Aruv</i>	20.6	29.5	39.7	33.6	36.8	44
<i>Amal</i>	2.7	5.8	5.3	6.1	6.0	55
<i>Ceve</i>	1.8	3.2	3.5	4.3	0.5	-260
Total	25.3	38.9	49.2	44.0	43.3	42
Outside Exclosure						
<i>Aruv</i>	18.3	16.9	26.0	20.4	25.9	29
<i>Amal</i>	0.2	1.1	0.9	0.9	3.3	94
<i>Ceve</i>	2.3	4.1	3.1	1.7	1.5	-53
Total	20.8	22.2	30.0	23.0	30.7	32

Aruv - bearberry, *Amal* - serviceberry, *Ceve* - snowbrush ceanothus

10. Ovando Mountain. The Ovando Mountain big game exclosure was evaluated with both short shrub and tall shrub methods. Browsing has impacted serviceberry, but

no other species. Serviceberry had greater ($P \leq 0.05$) canopy coverage inside than outside the exclosure. Serviceberry $NAGR_T$ was also greater ($P \leq 0.05$) inside the exclosure. Many serviceberry and Rocky Mountain maple with a released-type architecture at the site indicated past intense browsing. The LD index (40.6 cm) indicated the new stem growth is above the level of mechanical protection. The current growth rate of unprotected stems (11.6 cm/yr) was greater than the threshold growth rate (10.3 cm/yr) required for stems to grow 2.5 m before they die. Differences in growth rate and canopy cover of serviceberry may be residual effects of past intense browsing.

The trends in percent canopy cover for several browse species since 1959 varied (Table 5). Snowbrush ceanothus decreased since 1959 both in and out of the exclosure. Serviceberry and Rocky Mountain maple increased inside the exclosure while chokecherry and Rocky Mountain maple increased outside. Overall, canopy cover of browse inside the exclosure increased 20% since 1959. Canopy cover of browse species outside the exclosure decreased 14%, but this was primarily due to a decrease in snowbrush ceanothus. The change between 1959 and 2001 may include measurement effects. My estimates of canopy cover may be more conservative, because I did not include gaps in the interior portions of shrubs as cover. In addition, I believe much of the change I observed was a result of changes in microclimate at the site due to an increase in tree canopy (Appendix G, Fig. 45, 46). Forest succession may currently have more of an effect on growth of browse species, but the data indicate some residual impacts of browsing.

Table 5. Trend in percent canopy cover of browse species at Ovando Mountain from 1959 to 2002.

Location and Species	Percent canopy cover by year					Percent change
	1959	1965	1969	1973	2002	1959-2002
Inside Exclosure						
<i>Amal</i>	18.5	22.5	28.7	27.8	28.6	35
<i>Prvi</i>	16.9	20.8	25.9	27.9	14.6	-16
<i>Ceve</i>	8.3	11.3	12.9	11.2	3.1	-168
<i>Acgl</i>	2.2	2.8	4.4	7.6	11.5	81
<i>Sorbus</i>	<u>1.0</u>	<u>1.0</u>	<u>1.4</u>	<u>1.3</u>	<u>0.9</u>	-11
Total	46.9	58.4	73.3	75.8	58.7	20
Outside Exclosure						
<i>Amal</i>	21.2	20.0	20.8	22.3	18.0	-18
<i>Prvi</i>	15.2	19.5	24.0	22.1	17.3	12
<i>Ceve</i>	11.3	9.1	7.1	4.2	1.5	-653
<i>Acgl</i>	7.3	7.3	8.5	6.4	11.3	35
<i>Sorbus</i>	<u>1.3</u>	<u>1.0</u>	<u>0.7</u>	<u>2.3</u>	<u>1.1</u>	-18
Total	56.3	56.9	61.1	57.3	49.2	-14

Amal - serviceberry, *Prvi* - chokecherry, *Ceve* - snowbrush ceanothus, *Acgl* - Rocky Mountain maple, *Sorbus* - mountain ash.

Montana Fish, Wildlife & Parks Region 3

11. Porcupine Creek. The big game exclosure was evaluated at Porcupine Creek by using short shrub, tall shrub, and tree methods. All methods supply considerable evidence that past and current browsing by wild ungulates was intense outside the exclosure. Canopy cover of mountain big sagebrush was 18.3% inside and 8.8% outside the exclosure ($P \leq 0.01$). Density of mature mountain big sagebrush was greater ($P \leq 0.01$) inside than outside the exclosure. No difference in density of young mountain big sagebrush was found ($P \leq 0.05$). Snow cover may be allowing young plants to grow for several years before they are browsed outside the exclosure (Rens 2001, Wambolt 1998, Wambolt and Sherwood 1999). Production of winter forage by mountain big sagebrush was 3.7 and 1.3 kg/60 m² inside and outside the exclosure, respectively ($P \leq$

0.05). Browsing on mountain big sagebrush in Porcupine Creek has had an impact (Appendix G, Fig. 47, 48).

$NAGR_T$, $NAGR_{lm}$, and lifespan of Geyer's willow were less ($P \leq 0.01$) outside the exclosure. All Geyer's willow outside was currently being intensely browsed. This was displayed by retrogressed and arrested architectures that were common outside. An LD index of 3.9 cm indicated live stem growth was at a similar height as the level of mechanical protection. Unprotected Geyer's willow stems growing at 12.7 cm/yr did not meet the threshold growth rate (19.7 cm/yr) required to grow out of the browse zone (2.5 m) before they die. Browsing on Geyer's willow at the Porcupine site has been intense.

I found uninterrupted aspen of all ages grow inside the exclosure (Fig. 18, Appendix G, Fig. 51). No aspen have been allowed to establish outside since 1967 (Appendix G, Fig. 51). All young aspen stems outside were arrested and no aspen have established since 1967. This evidence indicates browsing has been intense on aspen since 1967.

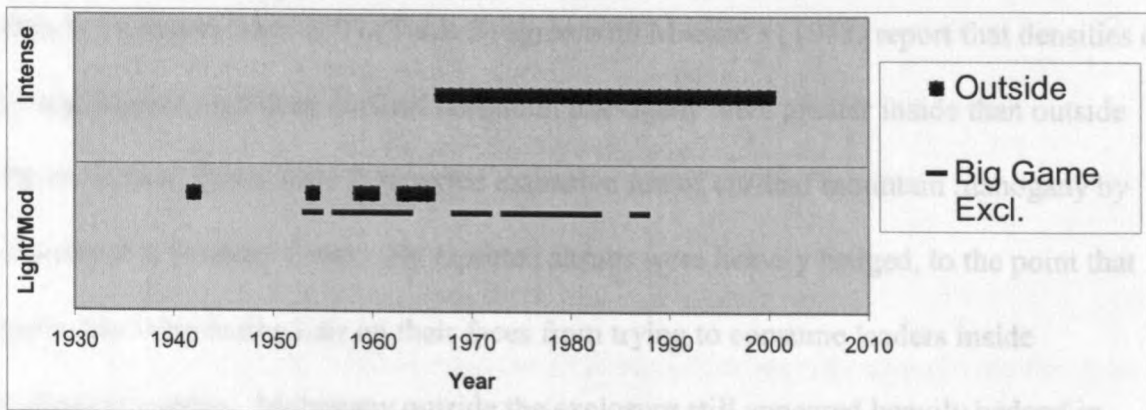


Figure 18. Intensity of browsing on aspen at Porcupine Creek recorded in calendar years.

12. Snowflake Springs. The Snowflake Springs site was evaluated with the tall shrub method. Booth's willow outside the exclosure appears to be recovering in recent years. Many released-type willow stems grow outside the exclosure (Appendix G, Fig. 52). No differences ($P \leq 0.05$) in $NAGR_T$ and $NAGR_{1m}$ were detected between protected and unprotected Booth's willow. However, lifespan was longer inside the exclosure ($P \leq 0.05$). An LD index of 48.6 cm indicates live stem growth is above the level of mechanical protection. Unprotected stems are growing 18.0 cm/yr and surpass the threshold growth rate (14.8 cm/yr) required for stems to grow out of the browse zone (2.5 m) before they die.

13. Scudder Creek. Use of short shrub methods indicated browsing has limited growth of curlleaf mountain mahogany at Scudder Creek. Canopy coverage and density of mature curlleaf mountain mahogany were greater ($P \leq 0.05$) inside than outside the big game exclosure. The livestock exclosure was too small to facilitate adequate sampling, but no visual difference between browse species inside and outside was apparent. My density estimates from 2001 (Table 3) agree with Mackie's (1973) report that densities of young, mature, and dead curlleaf mountain mahogany were greater inside than outside the exclosure. South (1957) reported extensive use of curlleaf mountain mahogany by mule deer at Scudder Creek. He reported shrubs were heavily hedged, to the point that mule deer were losing hair on their faces from trying to consume leaders inside mahogany bushes. Mahogany outside the exclosure still appeared heavily hedged in 2001 (Appendix G, Fig. 53, 54) and wild ungulates continue to impact curlleaf mountain mahogany.

14. Hyde Creek. Browsing is minor at Hyde Creek as found by using the short shrub method. No browse parameters were greater ($P \leq 0.05$) inside the exclosure compared to outside. Density of young mountain big sagebrush was greater ($P \leq 0.05$) outside the exclosure. Mountain big sagebrush winter forage estimates were not different ($P = 0.98$) inside and outside the exclosure. This site may be undesirable for wintering elk due to its higher elevation relative to the adjacent Wall Creek Wildlife Management Area. Winter elk counts with their locations during the first morning hours have been observed by the WMA manager Fred King (unpublished data). These counts indicate elk spend less time near the Hyde creek exclosure than adjacent areas.

15. Wall Creek. Intense browsing on aspen at the Wall Creek site has occurred from 1994 to 2001 (Fig. 19). Before 1992, browsing on aspen was light-to-moderate. The stands inside and outside the exclosure were clearcut in 1990, but my data indicate that some young stems may not have been cut. Stems that established from 1982 to 1989 were found inside the exclosure. These stems were 7 years old or less when the stand was clearcut and must have been left uncut. Similarly, stems that established from 1981 to 1989 were found outside the exclosure. Growing conditions are not allowing recruitment of new stems inside since 1997 and intense browsing outside the exclosure have not allowed recruitment since 1998.

16. Tepee Creek. Browse species at Tepee Creek were evaluated with the short shrub method. My measurements indicate mountain big sagebrush has been most impacted. Canopy cover, density of mature shrubs, and production of winter forage were

greater ($P \leq 0.01$) inside than outside the exclosure. This difference is visually apparent by comparing shrubs inside to shrubs outside the exclosure (Fig. 6, Appendix G, Fig. 57). No difference in other browse species was found. All young aspen growing near the site exhibited arrested architectures. Only mature, tall aspen exhibited uninterrupted-growth - type.

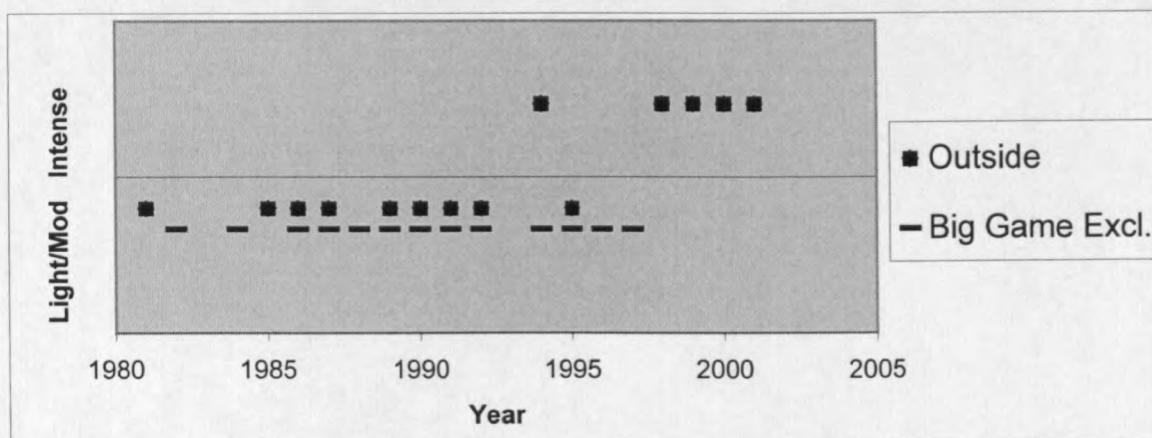


Figure 19. Intensity of browsing on aspen in Wall Creek recorded in calendar years.

17. Garden Creek. Aspen data from Garden Creek implies browsing has been intense since 1987 (Fig. 20). Only 3 young aspen were found growing uninterrupted outside the exclosure. Aspen of all ages are growing uninterrupted inside the exclosure and older stems grew uninterrupted outside. Intense browsing likely occurred before 1987. Several aspen outside the exclosure have crooked stems, which suggests that they were intensely browsed at that point (Appendix G, Fig. 60). Stems inside the exclosure as well as older stems outside grow straight, indicating they grew through the browse zone under light-to-moderate browsing (Appendix G, Fig. 58, 59).

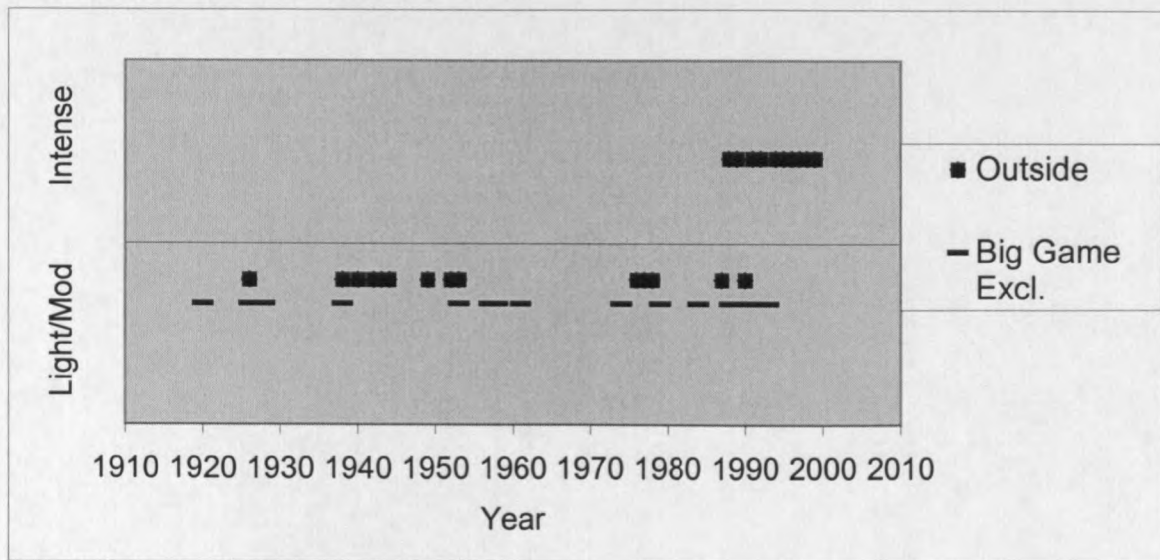


Figure 20. Intensity of browsing on aspen at Garden Creek recorded in calendar years.

A recent breach of the exclosure fence has allowed animal access inside the exclosure. Many aspen have been browsed and rubbing (presumably by antlers) was evident on many young aspen stems. This suggests that ungulates have sought out aspen inside the exclosure because of a lack of young aspen outside. Other browse plants including cottonwood (*Populus* sp. L.) and willow (*Salix* spp. L.) displayed intense browsing.

The Dome Mountain WMA was purchased as a designated wildlife winter range in 1986. Before 1986, the area was run as a private cattle ranch. The Garden Creek exclosure is located near some buildings and a water improvement and was probably frequented by humans, which may have deterred wild ungulates from using the area. Since 1986, wild ungulates have had free use of the entire WMA and are undisturbed by humans from December 15 – May 1. An increase in the browsing intensity in 1987 is recorded with an increase in browsing on aspen.

18. Armstrong. Only chokecherry was evaluated at the Armstrong enclosure by using the tall shrub method. Individual bitterbrush outside appeared to be smaller than protected shrubs, but the small size of the enclosure prevented sampling by use of the short shrub method because an adequate sample could not be obtained. No difference ($P \leq 0.05$) in $NAGR_T$ and $NAGR_{Im}$ of protected and unprotected chokecherry stems was detected. The LD index of -2.0 cm indicates height of live stem sections is near the level of mechanical protection. However, intense browsing was evidenced by some arrested chokecherry stems outside the enclosure.

19. Johnson Creek. Browse species at the Johnson Creek site were evaluated with the short shrub method. Both the big game and livestock enclosures were measured. Canopy cover of mountain big sagebrush was somewhat significantly higher ($P \leq 0.1$) inside the big game enclosure than outside both enclosures. Density of young mountain big sagebrush was higher outside the big game enclosure ($P \leq 0.01$), while density of mature mountain big sagebrush was higher ($P \leq 0.01$) inside the big game enclosure than outside both enclosures. No differences ($P \leq 0.05$) were detected for any browse species between inside and outside the livestock enclosure. These results suggest that browsing by wild ungulates has impacted the sagebrush community, while livestock have had minimal impacts.

20. Crown Butte. The Crown Butte enclosure was evaluated using the tall shrub and tree methods. Intense browsing was evidenced by arrested-type Booth's willow outside the enclosure (Appendix G, Fig. 64). An LD index of 1.0 cm indicated the

browsing pressure is limiting growth of stems to the level of mechanical protection. $NAGR_T$ of stems was 11.1 cm/yr inside and 7.8 cm/yr outside ($P \leq 0.05$). $NAGR_{1m}$ was also greater ($P \leq 0.05$) inside the exclosure. Lifespan was longer ($P \leq 0.01$) inside the exclosure (31.2 yrs) than outside (5.3 yrs). The current growth rate (7.8 cm/yr) is not fast enough to grow 2.5 m before they die at the current lifespan of 5.3 years. The browsing pressure has limited growth of Booth's willow.

Aspen outside the exclosure have not been able to grow uninterrupted since 1949 (Fig. 21). Aspen of all ages were growing inside the exclosure (Appendix G, Fig. 61). Only a few, old, uninterrupted-growth-type aspen were established outside the exclosure (Appendix G, Fig. 62). Aspen did not establish outside the exclosure from 1949 to 1997, while intense browsing has arrested aspen that have established since 1997. This evidence indicates that browsing on aspen outside the exclosure has been intense since 1949.

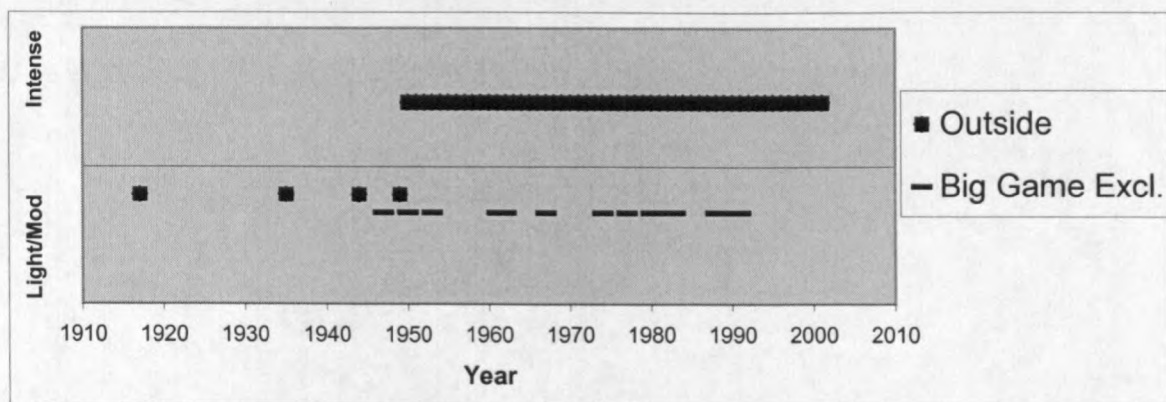


Figure 21. Browsing intensity on aspen at Crown Butte recorded in calendar years.

21. Pole Creek. Booth's willow at the Pole Creek exclosure was evaluated with the tall shrub method. Many arrested and retrogressed-growth-type willow outside the

exclosure indicate current intense browsing (Appendix G, Fig. 66). An LD index outside of 0.1 cm represents stem growth was limited to the level of mechanical protection.

$NAGR_T$ and $NAGR_{1m}$ were greater ($P \leq 0.01$) inside than outside the exclosure.

Manoukian (1994) reported a 0.9 m^3 increase in volume of willows inside the exclosure following its construction 2 years previous. Manoukian (1994) stressed the need for further assessment of willow browsing. Booth's willow growth is still being suppressed by ungulates.

Montana Fish, Wildlife & Parks Region 4

22. Deer Hill. Browse species at the Deer Hill site were evaluated with the short shrub method. Both the big game and livestock exclosures were evaluated. Visual differences in horizontal juniper were noticeable in 2001. Canopy cover of horizontal juniper was 27.3% inside the big game exclosure, 3.2% inside the livestock exclosure, and 0.3% outside both exclosures. All means were different from each other ($P \leq 0.05$). Presence of both wild ungulates and cattle has had the most detrimental effect on horizontal juniper at Deer Hill.

Horizontal juniper is important to the winter diets of mule deer, bighorn sheep and elk (Kasworm et al. 1984). Cattle may not actively consume juniper, but grass cover was noticeably less outside which may expose juniper to browsers. Juniper canopy cover inside the livestock exclosure was higher than outside, which may be due to grasses concealing horizontal juniper. Wild ungulates may also be more hesitant to cross into the livestock exclosure when some browse species are still available outside the exclosures (Gross and Knight 2000). Density of fringed sagewort was greater ($P \leq 0.01$) outside

both exclosures. Fringed sagewort often increases with grazing, but it is a component of bighorn sheep late winter diets in this area (Kasworm et al. 1984).

23. Middle Draw. Bebb willow and aspen were evaluated at the Middle Draw site using tall shrub and tree methods. Both the big game and livestock exclosures were evaluated. Willows outside both exclosures displayed arrested and retrogressed-type architectures. Retrogressed stems were taller than 2.5 m and had large diameter bases, which suggests they grew through the browse zone many years ago. Stems growing inside and outside the livestock exclosure that were shorter than 2.5 m were arrested or retrogressed. The LD index inside the livestock exclosure was 7.7 cm and -2.1 cm outside. Willow stems inside the big game exclosure grew at a faster NAGR_T (15.1 cm/yr) and live longer (37.3 yrs) than outside both exclosures ($P \leq 0.01$). Only a slight difference ($P \leq 0.1$) in NAGR_T was detected between stems inside the livestock exclosure and outside. These data indicate that wild ungulates have had the most impact on Bebb willow (Appendix G, Fig. 71). Cattle may be having a small impact as shown by a slight difference in NAGR_T between stems inside and outside the livestock exclosure.

Aspen outside the Middle Draw exclosures has been intensely browsed since 1981 (Fig. 22). The most recent year light-to-moderate browsing occurred outside was 1989 and only intense browsing has occurred since then. Similarly, aspen inside the livestock exclosure has been only intensely browsed since 1991. Light-to-moderate browsing occurred inside the livestock exclosure from 1970 to 1991. Inside the big game exclosure, stems have established as recently as 1996. No stems have established since then, indicating that the stand is maturing and ceasing to produce new stems. These data

indicate that browsing has been intense in and out of the livestock enclosure since around 1990, which is not allowing stems to grow to their full stature. As older stems mature and die inside and outside of the livestock enclosure, intense browsing may not allow new, younger stems to replace them.

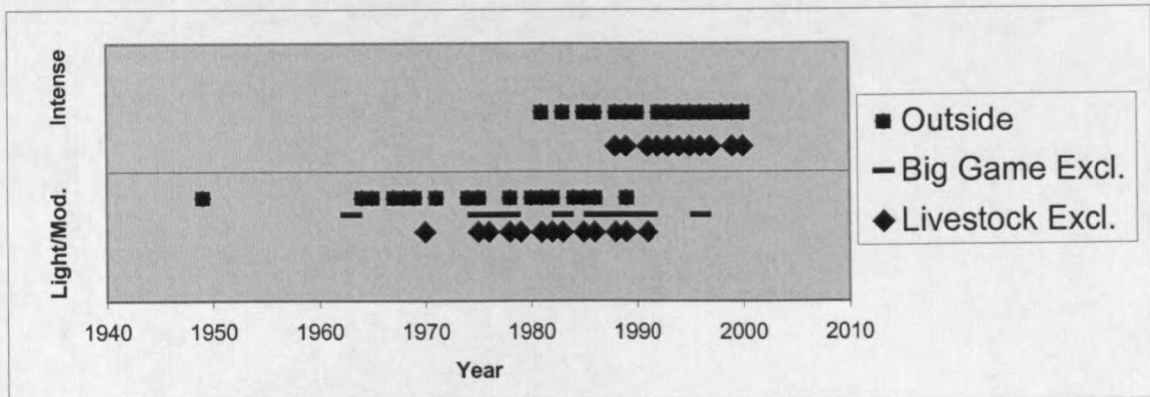


Figure 22. Periods of browsing intensity in Middle Draw recorded in calendar years.

24. Lenstra Creek. Bebb willow and aspen at the Lenstra Creek big game and livestock exclosures were evaluated using tall shrub and tree methods. Most young Bebb willow within the browse zone inside and outside the livestock exclosure were arrested. Older, retrogressed-type Bebb willow growing throughout the site indicated past light-to-moderate browsing. An LD index of -2.1 cm outside both exclosures indicates that live stems are growing to the level of mechanical protection afforded by dead stem segments. $NAGR_T$ and $NAGR_{1m}$, and lifespan were greater ($P \leq 0.01$) inside than outside the big game exclosure. These data suggest that ungulates are negatively impacting growth of Bebb willow. $NAGR_T$ and $NAGR_{1m}$ were greater inside the livestock exclosure than outside at the $P \leq 0.05$ and 0.1 levels, respectively. The LD index inside the livestock

exclosure was +7.7 cm. These results indicate that livestock are contributing to the suppression of willow at Lenstra Creek.

Aspen outside and adjacent to both exclosures has been intensely browsed since 1978 (Fig. 23). The last year a stem outside was light-to-moderately browsed was 1986. Since 1986, aspen outside have been intensely browsed. Aspen inside the livestock exclosure have been intensely browsed since 1979. Light-to-moderate browsing last occurred in 1986. Aspen stems inside the big game exclosure had established from 1919 to 1989. The period from 1949 to 1974, no aspen stems were recruited into the stand. Intense browsing or unfavorable growing conditions during this time may have restricted aspen recruitment. Stems inside and outside the livestock exclosure had been intensely browsed from 1978 to 2001. Intense browsing is attributed to wild ungulates because the period of browsing is similar inside the livestock exclosure and outside both exclosures.

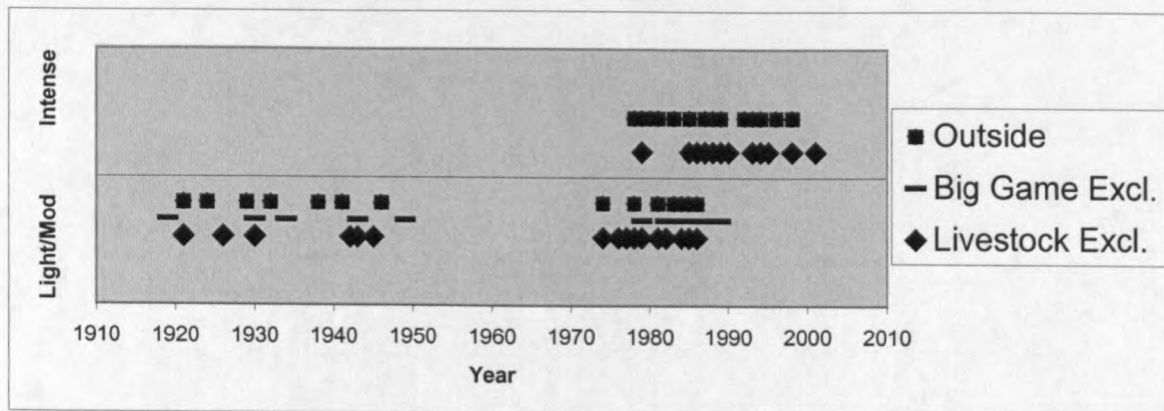


Figure 23. Intensity of browsing on aspen at Lenstra Creek recorded in calendar years.

25. 1500 Acre. Aspen was evaluated at the 1500 Acre big game and livestock exclosures using the method for trees. The aspen stand sampled at this site is large and expands across several different growing environments. Intensely browsed aspen were

found on the exterior portions of the aspen stand outside both exclosures. Intense browsing has been occurring outside from 1991 to 2002 (Fig. 24). Intensely browsed aspen were rare inside the livestock exclosure. Aspen stems in all areas were light-to-moderately browsed from 1944 to 1994. No aspen have established since 1994 inside either exclosure and may indicate that the aspen stand is limiting further recruitment in its interior. Evidence of only intense browsing outside the exclosures indicates that livestock are browsing on aspen. There are many trails (presumably formed by cattle) outside the exclosures. If wildlife were intensely browsing aspen, I would have expected evidence of browsing inside the livestock exclosure as well as outside.

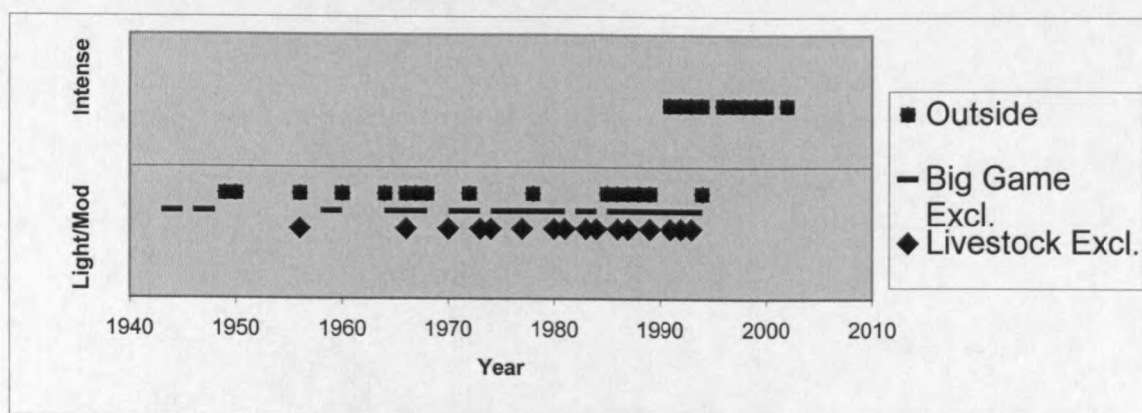


Figure 24. Intensity of browsing on aspen at the 1500 Acre site recorded in calendar years.

26. Sun River. The Sun River exclosure was evaluated using the tall shrub method on chokecherry and the short shrub method on the remaining browse species. All unprotected chokecherry were intensely browsed as displayed by arrested-type architecture. $NAGR_T$ and $NAGR_{1m}$ were greater outside the exclosure ($P \leq 0.05$). Browsing is limiting growth of live stems near the level of mechanical protection (LD index = -2.6 cm). No differences were detected between all other browse species inside

and outside the exclosure ($P \leq 0.05$). These data indicate that wild ungulates are suppressing growth of chokecherry, but no other browse species at the Sun River site.

Montana Fish, Wildlife & Parks Region 5

27. Sykes Coulee. Browse species at the Sykes Coulee site were evaluated using the short shrub method. Canopy cover of curleaf mountain mahogany was greater ($P \leq 0.05$) inside than outside the big game exclosure; however, density was not different for any age class (Fig. 14). This suggests that ungulates are impacting size but not number of shrubs. Density of dead Rocky Mountain juniper was greater ($P \leq 0.1$) inside than outside the exclosure. Mule deer feces were most prominent, though wild horse manure was found at the site. I would attribute impacts on mountain mahogany to wintering mule deer because it is a highly valuable component of their fall, winter, and spring diet (Kufeld et al. 1973).

28. Crooked Creek. Browse species at the Crooked Creek exclosure were evaluated using the short shrub method. Exclusion of all ungulates for 40 years has altered the cover and abundance of Wyoming big sagebrush and black sagebrush (Table 3). Canopy cover and density of mature Wyoming big sagebrush were greater ($P \leq 0.05$) inside the exclosure. Canopy cover and density of young and mature black sagebrush were greater ($P \leq 0.05$) outside the exclosure. These differences in cover and density of the 2 sagebrushes suggest that ungulate browsing is decreasing Wyoming big sagebrush outside, which is allowing black sagebrush to increase. These data agree with Sheehy and Winward (1981) and Wambolt (1996) where they reported Wyoming big sagebrush

was preferred over black sagebrush by mule deer, elk, and sheep. No differences in mountain big sagebrush were detected between inside and outside the exclosure ($P \leq 0.05$). This does not agree with the findings of Sheehy and Winward (1981) and Wambolt (1996) because they reported mountain big sagebrush was the most preferred sagebrush taxa by mule deer and elk.

29. Picket Pin. The Picket Pin big game and livestock exclosure was evaluated with the short shrub method. Exclusion of all ungulates and only livestock, both showed impacts on canopy cover of horizontal juniper (Table 3, Fig. 15). Canopy cover of horizontal juniper was highest (47.1%) inside the big game exclosure, which was higher than in the livestock exclosure (18.2%) and outside both exclosures (6.0%) ($P \leq 0.01$). Additionally, canopy cover of juniper inside the livestock exclosure was greater ($P \leq 0.01$) than outside (Fig. 15). Wild ungulates alone have negatively impacted horizontal juniper, but the combined presence of wild ungulates and livestock has been the most detrimental. These results agree with findings at Deer Hill. Grass cover outside appeared to be less than inside either exclosure. Reduced grass cover outside may allow free recognition and access to horizontal juniper. Grass cover inside the livestock exclosure appeared the highest and may conceal horizontal juniper.

Montana Fish, Wildlife & Parks Region 6

30. South Ranch. Chokecherry and aspen were evaluated at the South Ranch site using tall shrub and tree methods. Both the big game and livestock exclosures were evaluated. I found wild ungulates are impacting browse species. Nearly all unprotected

chokecherry plants inside the livestock enclosure and outside both enclosures displayed arrested-type architecture. The LD indexes outside (10.0 cm) and inside the livestock enclosure (6.8 cm) indicate live stem segments are growing just slightly above the level of mechanical protection. Negative impacts of browsing by wild ungulates are indicated by greater $NAGR_T$ and $NAGR_{lm}$ ($P \leq 0.01$) inside the big game enclosure than outside, but no difference in these parameters between chokecherry stems inside the livestock enclosure and outside both enclosures.

My data indicate intense browsing on aspen is recent (Fig. 25). Before 1984, only light-to-moderate browsing occurred on aspen in all portions of the site. Light-to-moderate browsing and intense browsing simultaneously occurred in and out of the livestock enclosure from 1992 to 1997. Since 1997, aspen has been only intensely browsed in and out of the livestock enclosure. This trend indicates a shift in the browsing pressure since 1992, and a further increase in browsing since 1997. Years of intense browsing are similar inside and outside the livestock enclosure and indicate that wild ungulates are having the most impact on aspen.

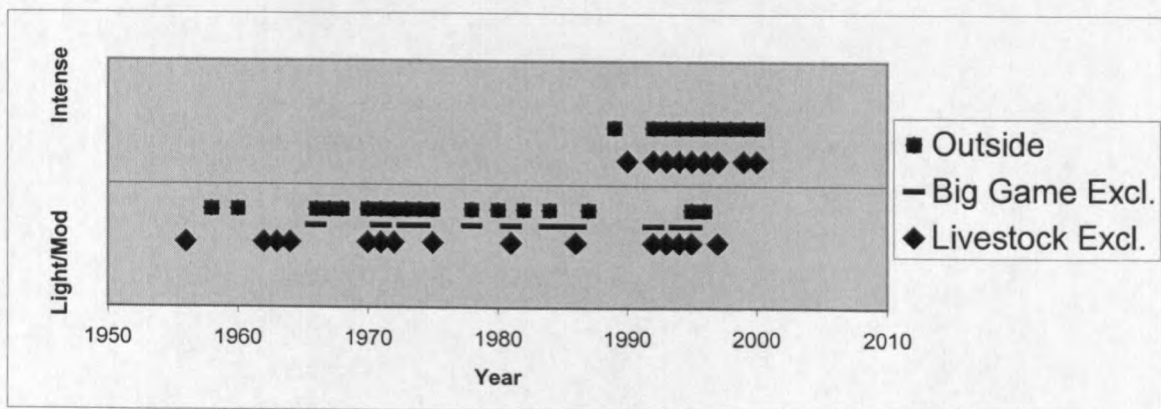


Figure 25. Intensity of browsing on aspen at South Ranch recorded in calendar years.

31. Pine Ridge. Browse species at the Pine Ridge site were evaluated with the short shrub method. Wyoming big sagebrush canopy cover and production of winter forage were not different in and out of the exclosure ($P \leq 0.05$). Density of mature Wyoming big sagebrush was greater ($P \leq 0.05$) outside the exclosure, as was density of young and dead sagebrush ($P \leq 0.1$). Sweet clover (*Melilotus officinalis* (L.) Pallas) cover appeared to be greater inside the exclosure and may have a negative impact on canopy cover and density of Wyoming big sagebrush. Impact of browsers is evident (Appendix G, Fig. 76, 77), but may be a secondary factor or have only minor effects on browse species on Pine Ridge.

32. Cottonwood. Browse species at the Cottonwood site were evaluated using the short shrub method. Canopy cover and density of mature and dead Wyoming big sagebrush were greater ($P \leq 0.01$) inside than outside the exclosure. This difference is obvious in fenceline photos (Appendix G, Fig. 80). Production of Wyoming big sagebrush winter forage inside the exclosure was 3 times that of the area outside the exclosure. This difference is attributable to absence of antelope and cattle for the last 35 years inside the exclosure. No differences in canopy cover or density of winterfat were detected ($P \leq 0.05$). Wyoming big sagebrush appears to be largely impacted by ungulates in this area (Appendix G, Fig. 78, 79). This area is noted as critical for wintering antelope and receives heavy use in winter (Martinka 1967).

Dominant Short Shrub Species

Bearberry

Bearberry was evaluated at 3 sites (2, 3, 9) using the short shrub method (Table 6). Canopy cover and density of bearberry plants was greater ($P \leq 0.05$) inside than outside the big game enclosure at site 9. At the other 2 sites, canopy cover and density of bearberry were greater ($P \leq 0.05$) outside than inside both big game enclosures. At these 2 sites, I observed greater densities of conifer trees inside enclosures. I often found bearberry growing in only partially shaded areas and in forest canopy openings, which indicates that bearberry may respond better to an increase in sunlight. Thus, greater canopy cover and density of bearberry outside enclosures at 2 sites may be due to more favorable growing conditions outside than inside and not ungulate browsing.

Bearberry is considered moderately valuable to elk in the fall and moderately valuable to mule deer in fall, winter and spring (Kufeld 1973, Kufeld et al. 1973). Food habits analysis for whitetailed deer diets in the Swan Valley, an area with similar vegetation to sites 2 and 3, indicated bearberry made up $< 4\%$ of their winter diet. (Mackie et al. 1977). Sites 2 and 3 may receive more use from whitetailed deer because it is a closed canopy, Douglas fir/snowberry habitat type, while site 9 is a more open site that may be favored by wintering mule deer. If this theory is logical, mule deer at site 9 may be intensely browsing bearberry, while whitetailed deer at the other 2 sites may not be impacting bearberry.

Table 6. Parameter means of dominant short growing (< 2 m) shrub species inside and outside exclosures.

Species	Canopy Cover (%)			Density of Mature Shrubs (n/60m ²)			Production of Sagebrush Winter Forage (kg/60m ²)		
	Mean	N ¹ /N ²	Range	Mean	N ¹ /N ²	Range	Mean	N ¹ /N ²	Range
Bearberry									
In	5.6	1/3	1.2-9.3	16.9	1/3	3.4-36.8			
Out	7.5		5.2-11.8	22.5		14.6-27.1			
Big sagebrush									
In	12.3	4/7	4.1-22.4	51.2	5/7	15.6-106	2.1	4/7	0.3-3.7
Out	7.1		2.1-10.3	32.8		22.7-51.7	1.2		0.2-2.6
Bitterbrush									
In	3.5	2/3	2.4-4.1	7.4	1/3	5.9-9.0			
Out	2.8		0-7.8	11.7		0.7-20.6			
Curl-leaf mountain									
In	24.7	2/2	14.4-34.9	25.0	1/2	18.6-31.3			
Out	10.3		9.6-11.0	15.6		14.1-17.0			
Horizontal juniper									
In	37.2	2/2	27.3-47.1		n/a				
Out	3.2		0.3-6.0						
Oregon grape									
In	7.9	0/3	4.2-13.4	187.5	0/3	100-289			
Out	6.6		3.5-10.0	177.9		105-244			

N¹Number of sites where means of the given species were greater ($P \leq 0.05$) inside the game enclosure.

N²Total number of sites the parameter was estimated for the given species.

Big Sagebrush

Big sagebrush taxa were evaluated at 7 sites (Table 6). Protection from all ungulates over periods from 32 to 56 years allowed big sagebrush to attain greater ($P \leq 0.01$) canopy coverages at 4 sites (11, 16, 28, and 32). Differences in canopy cover of big sagebrush between unprotected and protected areas were not restricted to one subspecies. Mountain big sagebrush was greater inside exclosures at 2 sites and Wyoming big sagebrush at 2 sites. The 3 sites with no differences ($P \leq 0.05$) inside and outside contained mountain big sagebrush at 2 sites and Wyoming big sagebrush at 1 site.

Rens (2001) reported canopy cover of mountain big sagebrush at 5 sites on the Northern Yellowstone Winter Range was greater ($P \leq 0.0001$) inside than outside exclosures. Average canopy cover inside and outside big game exclosures was 20.0% and 9.7%, respectively. Wambolt and Sherwood (1999) on other portions of the Northern Yellowstone Winter Range reported average canopy cover of big sagebrush at 19 sites was 19.7% inside big game exclosures and 6.5% outside. Areas protected from browsing had 3.0 times greater ($P \leq 0.0027$) canopy cover of big sagebrush than unprotected areas. Results of canopy cover from my study are very similar to both Rens (2001) and Wambolt and Sherwood (1999). Sites with canopy cover differences inside and outside exclosures averaged 15.5% and 6.9%, respectively. The overall average was 12.3% inside and 7.1% outside.

Ungulate browsing also had an affect on a number of big sagebrush plants. Four sites that had greater ($P \leq 0.01$) canopy cover of big sagebrush inside the exclosure also had greater ($P \leq 0.01$) density of mature big sagebrush inside the exclosure (sites 11, 16, 28, and 32). At site 19, density of mature big sagebrush inside the exclosure was greater ($P \leq 0.01$) than density outside, but canopy cover differences were less significant ($P \leq 0.1$). My results agree with Wambolt and Sherwood (1999), as they reported a high association between big sagebrush cover and density ($r = 0.92$; $P \leq 0.000$). Density of mature Wyoming big sagebrush at site 31 was slightly higher ($P \leq 0.1$) outside the exclosure, which is attributed to competition with sweet clover inside the exclosure.

Density of young big sagebrush was not different ($P > 0.05$) inside and outside the exclosures at any of the sites where big sagebrush canopy cover differed inside and

outside exclosures (sites 11, 16, 28, and 32). Snow may be protecting these young shrubs for several years, allowing them to grow to mature size before they are browsed (Mehus 1995, Wambolt and Sherwood 1999). Density of young big sagebrush was greater ($P \leq 0.05$) outside the exclosure at all sites where no differences in canopy cover were detected (sites 14, 19, 31). Protection afforded by snow and less overall impact by browsers may be allowing more young shrubs to grow than at sites where ungulates are impacting the sagebrush community. This may indicate recovery of big sagebrush at these sites (14, 19, 31), as indicated by an increase in recruitment.

Density of dead big sagebrush was greater ($P \leq 0.01$) inside the exclosure at 3 sites (11, 16, 32) where big sagebrush canopy cover was also greater ($P \leq 0.01$) inside. Because cover and density are usually highly correlated, it is logical that density of dead would also be higher. Additionally, dead shrubs may remain more recognizable and deteriorate slower in the absence of trampling by ungulates, thus estimation of their density may be higher.

Production estimates for winter forage by big sagebrush were greater ($P \leq 0.05$) inside big game exclosures than outside at 4 of 7 sites (11, 16, 28, 32). These sites also had greater percent canopy cover and density of mature big sagebrush inside the exclosure. Sites where differences were detected produced 60% more big sagebrush forage for winter per 60 m² inside than outside exclosures. Wambolt and Sherwood (1999) on the NYWR reported similar results. They reported protected mountain big sagebrush produced 88% more forage for winter than unprotected sagebrush. Rens

(2001) reported more than twice that (176%) when protected and unprotected mountain big sagebrush were compared.

Ungulates have negatively impacted big sagebrush at 4 sites of 7 sites. Big sagebrush communities at the remaining 3 sites appeared to be recovering. These sites had increased recruitment of young shrubs and no differences in canopy coverage and production of big sagebrush winter forage inside and outside exclosures.

Bitterbrush

Bitterbrush condition was evaluated at 3 sites. Wild ungulate browsing had a negative impact on 2 of the 3 sites (Table 6). At sites 5 and 7, bitterbrush canopy cover and density of mature shrubs were greater ($P \leq 0.05$) inside big game exclosures. At site 6, density was greater ($P \leq 0.05$) outside the exclosure, while there was no difference in canopy cover. Bitterbrush differences at site 6 may reflect apparent greater canopy cover and density of conifer trees inside the exclosure than outside rather than a lack of response to ungulate browsing.

Presence of only livestock did not affect bitterbrush, indicated by comparisons inside and outside livestock exclosures at sites 5 and 6. No differences in canopy cover of bitterbrush inside and outside both livestock exclosures were detected ($P \leq 0.05$).

Density of mature bitterbrush was greater outside at 1 site, while density of dead bitterbrush was greater inside 1 livestock exclosure ($P \leq 0.05$). These differences are probably related to individual site conditions.

My findings imply that wild ungulates have negatively impacted bitterbrush, while livestock have had little impact. Game impact is probably from winter and fall use

of bitterbrush by elk and deer because it is considered a highly valuable component of their diet at this time (Kufeld 1973, Kufeld et al. 1973).

Sites 6 and 7, along with 3 other sites were evaluated in 1972 (Mackie 1973). Mackie (1973) also found greater density of bitterbrush outside at site 6 and greater inside at site 7. Unprotected areas had greater production of bitterbrush twigs than inside the exclosures at all 7 sites Mackie (1973) sampled. Mackie (1973) concluded differences in bitterbrush parameters were determined primarily by individual site characteristics and secondly by ungulate browsing. Kay (1995) found bitterbrush growing in the Greater Yellowstone Ecosystem, had less ($P \leq 0.05$) canopy cover, height, size, and volume outside a big game exclosure. He attributed this difference to repeated use by wild ungulates.

Curlleaf Mountain Mahogany

Canopy cover of curlleaf mountain mahogany was greater ($P \leq 0.05$) inside the exclosure at both sites (13, 27) where it was sampled. Domestic ungulates have not actively used either area so any impacts must have been due to use by wild ungulates. Differences in densities were not consistent between sites (Table 6). Density of young mahogany were not different ($P \leq 0.05$) inside and outside exclosures at either site. Browsing was not limiting recruitment of new mahogany plants. Density of mature and dead mahogany were greater ($P \leq 0.05$) inside the exclosure at site 13, but no differences were detected at site 27. Browsing impacted only the size of shrubs at site 27, while canopy cover and number of mature shrubs were altered by wild ungulate browsing at

site 13. Mackie (1973) studied site 13 and reported similar densities and canopy coverages but he emphasized that production of twigs was greater outside the enclosure.

Horizontal Juniper

Both sites where horizontal juniper was evaluated had a big game and livestock enclosure. Results from the 2 sites (22, 29) were similar (Table 6). Exclusion of all ungulates at site 22 for 13 years and at site 29 for 40 years allowed horizontal juniper to attain very high canopy coverages (27.3% and 47.1%). Areas with exclusion of livestock only yielded canopy coverages of 3.2% and 18.2%. Areas accessible to all ungulates had canopy coverages of 0.3% and 6.0%. Differences between canopy coverages of each phase of both enclosures were significant ($P \leq 0.01$). These results found that the combined presence of wild ungulates and domestic ungulates has had the most detrimental effect on horizontal juniper, but wild ungulates alone have negatively impacted horizontal juniper.

Kasworm et al. (1984) studying ungulate diets near site 22, reported horizontal juniper as being very important forage to wintering elk, bighorn sheep, and mule deer. Presence of horizontal juniper in fecal samples of cattle (0.9%) suggest they consume only a small amount of it (Kasworm et al. 1984). Cattle are much larger animals and consume greater quantities of forage than elk, bighorn sheep, and mule deer, so the actual amount of horizontal juniper consumed by cattle may be similar to that of wild ungulates. I also observed greater cover of grasses inside the livestock enclosures, which may conceal horizontal juniper and prevent some use by wild ungulates. Outside the enclosures, livestock consume grasses which may expose horizontal juniper and allow

wild ungulates to browse juniper more readily than inside the livestock exclosure. This theory contradicts Keigley and Olson (2001) where they observed horizontal juniper was more abundant inside a big game exclosure and outside, compared to inside the livestock exclosure. They suggest that a combination of reduced light availability during the growing season due to tall grass, and browsing by wild ungulates in winter is restricting growth of horizontal juniper inside the livestock exclosure. Although my theory and that of Keigley and Olson (2001) contradict each other, they agree with the findings of Kasworm et al. (1984) that wild ungulates are heavily using horizontal juniper.

Oregon grape

Oregon grape was evaluated at 3 sites (2, 3, 5) using the method for short shrubs. No differences ($P \leq 0.05$) were detected between Oregon grape inside and outside any big game exclosure or livestock exclosure (Table 6). Wild ungulates have not impacted Oregon grape at these sites.

Oregon grape is a valuable component of mule deer diets in fall, spring, and winter, as well as elk diets in fall and winter (Kufeld 1973, Kufeld et al. 1973). Guenther (1989) in southwest Montana, reported mule deer and elk feces contained 22% and 11% Oregon grape, respectively. Bitterbrush was the only browse species with higher percent content in feces than Oregon grape (Guenther 1989). Wild ungulates on 2 sites with Oregon grape, did not impact any browse species. At the third site, bitterbrush was negatively impacted by wild ungulates. Following Guenther's (1989) findings, wild ungulates may be using bitterbrush more than Oregon grape at site 5.

Dominant Tall Shrub Species

Chokecherry

Chokecherry was evaluated at 3 sites (18, 26, 30) by using the tall shrub method (Table 7). Additionally, canopy cover of chokecherry at a fourth site (10) was estimated, but no differences were detected between inside and outside the enclosure ($P \leq 0.05$). At the 3 sites I used the tall shrub method, chokecherry outside enclosures and inside the livestock enclosure at site 30 displayed intense browsing (arrested architecture type). Negative LD indexes outside enclosures at sites 18 and 26 indicate browsing is limiting growth of stems below the level of mechanical protection. LD indexes at site 30 were 10.0 cm and 6.8 cm outside and inside the livestock enclosure, respectively. Dead chokecherry stems were mostly absent from all sites; therefore, an estimate of lifespan could not be made. $NAGR_T$ and $NAGR_{lm}$ were less ($P \leq 0.05$) outside the enclosure at sites 26 and 30. These parameters were not different between inside and outside the enclosure at site 18, as well as between stems in and out the livestock enclosure at site 30 ($P \leq 0.05$). This indicates that wild ungulates are suppressing growth of chokecherry stems at sites 26 and 30, while livestock are not contributing to growth rate suppression at site 30. This contradicts Frisina and Kujala (2001) where wild ungulates alone were not intensely browsing chokecherry stems, but a combination of use by wild and domestic ungulates did result in intensely browsed stems. Keigley and Olson (2001) reported that browsing was reducing growth rate of chokecherry but did not differentiate between wild and domestic ungulate browsing.

Table 7. Parameter means of dominant tall growing (> 2m) shrub species inside and outside exclosures.

Species	Growth Rate (cm/yr)			Growth Rate to 1m (cm/yr)			Lifespan (yrs)		
	Mean	N ¹ /N ²	Range	Mean	N ¹ /N ²	Range	Mean	N ¹ /N ²	Range
Chokecherry									
In	11.1	2/3	8.1-15.9	13.2	2/3	8.1-22.1	n/a		
Out	8.2		6.4-11.4	8.4		6.9-11.9			
Serviceberry									
In	14.0	3/4	8.3-16.9	25.5	3/4	20.4-28.8	25.0	3/4	18.1-30.0
Out	7.8		4.5-11.6	10.2		4.5-21.0	17.7		11.5-24.3
Willow									
In	18.3	5/6	11.1-29.2	28.4	4/6	14.5-43.9	29.0	4/5	19.2-37.3
Out	11.7		6.8-18.2	15.3		6.8-31.8	11.8		3.9-18.2
Total		10/13			9/13			7/9	

N¹Number of sites where means of the given species were greater ($P \leq 0.05$) inside the game exclosure.

N²Total number of sites the parameter was estimated for the given species.

Kay (1995) evaluated exclosures in the Greater Yellowstone Ecosystem and reported unprotected areas had less ($P \leq 0.05$) canopy cover, height, size, and number of berries per chokecherry plant than areas protected by exclosures. Chokecherry produced virtually no fruits outside these exclosures. Chokecherry outside an ungulate exclosure in central Washington did not grow, but inside canopy cover was 4.6% (Tiedemann and Berndt 1972). These studies generally agree with my findings in that wild ungulates apparently have reduced growth and sustainability of chokecherry.

Serviceberry

Serviceberry was evaluated at 6 sites. However, at 2 sites, the taxon was not sufficiently dense to cut the number of stems required for tall shrub sampling, so canopy cover and density were estimated with short shrub methods. The remaining 4 sites (1, 4, 8, 10) were evaluated using the tall shrub method. Evidence of current intense browsing

(arrested and retrogressed architecture types) was found outside exclosures at 5 sites. Released-growth-type stems were mostly found at site 10. $NAGR_T$, $NAGR_{lm}$, and lifespan were less ($P \leq 0.05$) outside exclosures at 3 sites (Table 7). Current net annual growth rates at these 3 sites did not meet the required threshold growth rate required for stems to grow through the browse zone before they die. LD indexes outside exclosures ranged from 0.2 to 40.6 cm. This would indicate that the level of browsing is limiting growth of stems at the level of mechanical protection, while at other sites, browsing is allowing stems to grow above the level of mechanical protection. Canopy cover of unprotected serviceberry was less ($P \leq 0.05$) than protected stems at 2 sites (9, 10). Density was less ($P \leq 0.01$) outside at site 9.

Site 4 included a livestock exclosure, of which only a difference in lifespan was detected between serviceberry stems inside and outside it. Stems inside were growing 9.1 cm/yr, which did not meet the required 14.2 cm/yr required to grow through the browse zone before they die. Because only wild ungulates have access to the livestock exclosure, I attribute growth suppression to them. The LD index of 12.8 cm inside the livestock exclosure indicates live stems are growing to levels slightly higher than the level of mechanical protection. These results indicate that livestock are impacting only lifespan on serviceberry stems. Lack of livestock sign at the entire site but still a difference between serviceberry inside and outside the livestock exclosure suggests that wild ungulates hesitate to cross into the livestock exclosure and may use areas outside more (Gross and Knight 2000).

Overall, browsing is negatively impacting serviceberry at 5 of the 6 sites I evaluated. Kay (1995) reported similar intense use of serviceberry by ungulates in the Greater Yellowstone Ecosystem (GYE). Mean canopy cover, height, volume and number of berries per serviceberry plant were greater ($P \leq 0.05$) inside big game exclosures than on adjacent unprotected areas. Most of the growth from the previous summer on serviceberry is removed by winter browsing in the GYE (Houston 1982), as in the same manner at 4 of my study sites.

Mackie (1973) reported browse species (including serviceberry) protected by exclosures generally were larger, but serviceberry twig production was similar inside and outside exclosures. Twig growth was determined primarily by site condition, and secondarily by browsing (Mackie 1973). My findings do not agree with Mackie (1973). Growth rate of serviceberry stems was lower in the presence of browsers.

Willow

Willow species were evaluated with the tall growing shrub method at 6 sites (11, 12, 20, 21, 23, 24). Evidence that presence of all ungulates have had a negative impact on growth of willow was recorded at 5 sites (Table 7). Willow species at these sites included Geyer's willow, Booth's willow and Bebb willow. Current intense browsing was occurring at the 5 sites, as displayed by arrested architecture types. $NAGR_T$ was greater ($P \leq 0.05$) inside big game exclosures than outside at all sites except site 12 (Table 3). $NAGR_{1m}$ was greater ($P \leq 0.01$) inside big game exclosures at 4 of these sites (11, 20, 21, 24). Lifespan was greater ($P \leq 0.01$) inside the big game exclosures at 4 sites (11, 12, 20, 24), while site 21 did not contain adequate numbers of dead stems required

for sampling. Only a difference in lifespan was detected at site 12 ($P \leq 0.01$). I attribute this difference to past impacts of ungulate browsing. At the time of sampling, willow stems at site 12 were growing under light-to-moderate browsing and displayed released architectures, which indicate past intense browsing. LD indexes outside big game exclosures at 5 of the 6 sites were close to 0, which indicates live stem growth was restricted to the level of mechanical protection. Site 21 had a remarkable LD index of 48.6 cm, which indicates live stems growth is above the level of mechanical protection. Willow stems outside exclosures at 5 of the 6 sites (all except 21) were not growing fast enough to grow through the browse zone before they die.

Comparisons of tall shrub parameters between willow stems inside livestock exclosures and outside were possible at 2 sites. No differences were detected between all willow parameter means in the livestock exclosure and outside at site 23. $NAGR_T$ of stems was greater ($P \leq 0.01$) inside the livestock exclosure than outside at site 24. Lifespan was not different ($P \leq 0.05$) suggesting that livestock did not impact the number of years willow stems live. Growth rate of willow inside both livestock exclosures was not rapid enough to allow stems to grow through the browse zone before they die. My results found that livestock have contributed to suppression of willow growth at site 24 while livestock have had only minor impacts on willow growth at site 23. Wild ungulates continued to have a negative impact inside both livestock exclosures. Schultz and Leininger (1990) found canopy coverage, but not density of willow, was greater ($P \leq 0.05$) inside a livestock exclosure than outside. Willows were not able to grow tall where cattle had access to them (Shultz and Leininger 1990). They determined that cattle would

have to be fenced out of riparian areas to allow willow establishment. Results at 1 of 2 sites with livestock exclosures in my study agree with Shultz and Leininger (1990), while impacts from cattle were not differentiated from those of big game at the remaining sites.

Keigley and Gale (2001) evaluated Geyer's willow at a big game and livestock exclosure in southwest Montana. As at 5 of my sites, $NAGR_T$ inside the big game exclosure was greater ($P = 0.00$) than inside and outside the livestock exclosure. LD indices at their site agreed with growth rate estimates in that live stems of protected stems grew 52 cm above dead stems, while unprotected stems had negative LD indexes. Willow browsing by wild ungulates was thought to be the major impact on willow growth, but livestock browsing was reported to be a contributing factor in suppression of willow stem growth (Keigley and Gale 2001). My results generally agree with these conclusions.

Maschinski (2001) reported 33% of Arizona willows (*Salix arizonica* Dorn) died when exposed to wild and domestic ungulates for 30 days. No willow deaths were reported inside exclosures. Plant height and branch length of willow were less ($P \leq 0.05$) outside exclosures than inside. These results may be more extreme than mine because Maschinski (2001) studied Arizona willow on the extreme southern edge of its range where growing conditions may not be optimal.

Dominant Tree Species

Aspen

Reconstructed browsing histories on aspen varied across the 8 sites where it was found. The earliest year intense browsing occurred outside the enclosure at any site was 1949. There was an overlap of intense and light-to-moderate browsing outside from 1949 to 1996. Since 1996, only intense browsing has occurred outside at all sites (Fig. 26). Browsing inside livestock enclosures has been intense since 1979 (Fig. 27). There was an overlap of intense and light-to-moderate browsing outside from 1979 to 1997. Since 1997, only intense browsing has occurred inside livestock enclosures. The periods of intense browsing inside and outside the livestock enclosure are very close. This may indicate that wild ungulates are mostly responsible for intensely browsing aspen, because they have access to both inside and outside livestock enclosures.

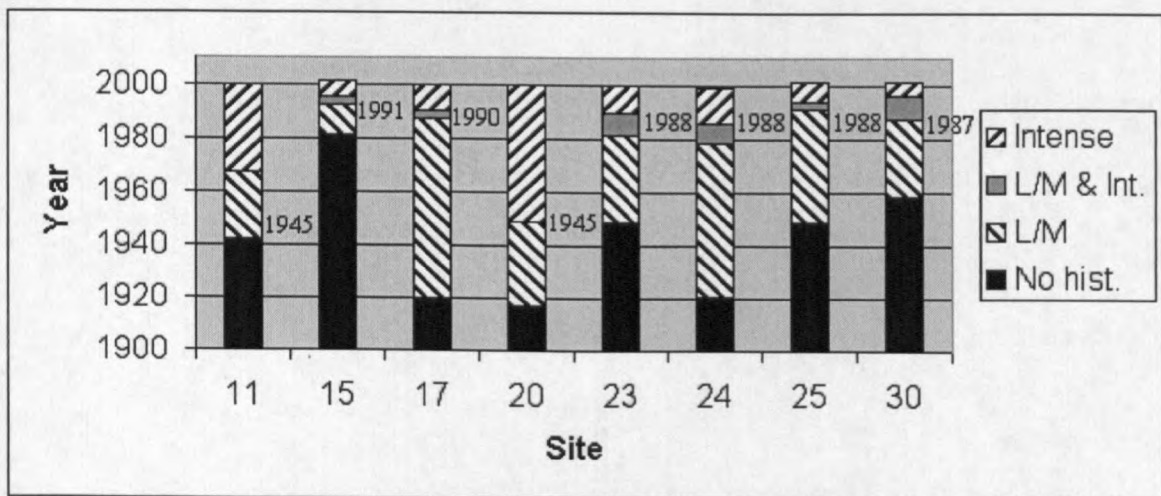


Figure 26. Reconstructed browsing history for aspen outside enclosures. Date each enclosure was built is to the right of each bar.

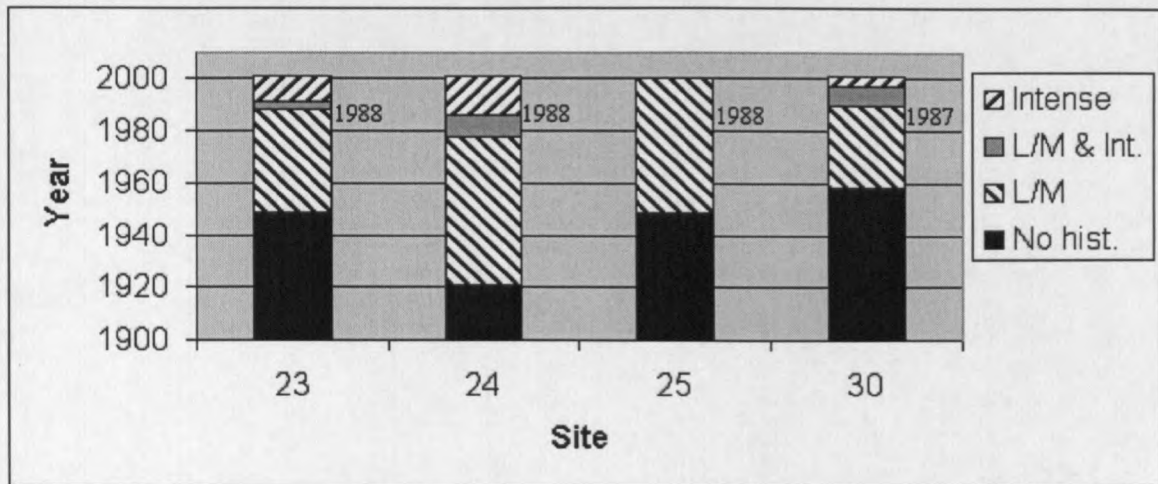


Figure 27. Reconstructed browsing history for aspen inside livestock exclosures. Date each exclosure was built is to the right of each bar.

The earliest accounts of intense browsing on aspen (1949 and 1967) were at the 2 sites in the Gallatin Canyon (Fig 26, Appendix F, Fig. 29). Both exclosures were constructed in 1945, which has enabled aspen stems of various ages to grow inside the exclosures. Outside the exclosures, few aspen have established since construction of the exclosures. These older exclosures have enabled earlier periods of intense browsing to be identified. I found more recent periods of intense browsing at the remaining sites. Each of these exclosures was constructed between 1987 and 1991. The earliest onset of intense browsing at these sites was 1978, and the latest was 1994 (Fig. 26, Appendix F, Fig. 29). Earlier intense browsing on these exclosures is harder to identify because as stems grow tall, evidence of intense browsing diminishes. Some older stems grow crooked which may indicate that intense browsing did not allow the stem to grow from previous years growth, but growth originated from stem segments greater than 1 year old (Appendix G, Fig. 60). Comparisons can be made between crooked stems outside exclosures to straight stems of the same age inside exclosures (Appendix G, Fig. 58).

Similar findings in Utah reported wild and domestic ungulates outside exclosures were intensely browsing aspen (Kay and Bartos 2000). They reported aspen failed to regenerate outside exclosures at 4 sites. In most cases, failure to regenerate was due to combined livestock and wild ungulate use. Aspen regeneration was lower ($P \leq 0.08$) outside exclosures at the remaining 4 sites and regeneration was typically higher ($P \leq 0.08$) inside than outside livestock exclosures (Kay and Bartos 2000). I reported that periods of intense browsing were similar inside and outside livestock exclosures, indicating that wild ungulates were mostly responsible for browsing. At only one site (25) was there evidence that livestock and not wild ungulates were responsible for intensely browsing aspen. Dieni et al. (2000) also reported wild ungulates (elk) were responsible for suppressing aspen regeneration. Following clear-cutting aspen stands 9 years earlier, density of aspen stems > 2 m tall inside exclosures was 9943 stems/ha. Outside exclosures density of aspen > 2 m tall was 590 stems/ha. Density means were greater ($P < 0.05$) inside exclosures and Dieni et al. (2000) concluded that in the presence of dense populations of wild ungulates, clear cutting aspen will not be effective in promoting aspen regeneration.

On a much larger scale, Ripple and Larsen (2000) reported aspen in Yellowstone National Park regenerated successfully from the middle 1700's to the 1920's. Following the 1920's, no aspen regenerated, which was primarily due to intense browsing by elk (Ripple and Larsen 2000). These findings agree with my report of intense and light-to-moderate browsing occurring outside exclosures from 1978 to 1996, which would allow some stems to establish. Since 1996, intense browsing has restricted recruitment of any

new aspen. If this trend continues, aspen stands may slowly die out. Several years of light-to-moderate browsing will be required to allow stems to grow tall enough to escape browsing.

Summary of Results

My evaluation of browse species at 32 study sites throughout Montana determined that ungulates have negatively impacted this important habitat component at 22 sites (Fig. 28). At an additional 5 sites, there was mixed evidence of impacts (Fig. 28). These areas are either entering a period of intense browsing or coming out of a period of intense browsing. At least 1 of the following parameters: canopy cover, density, big sagebrush production of winter forage, growth rate, or lifespan was greater ($P \leq 0.05$) inside than outside exclosures in order for browsing to be considered to be an impact. At sites with aspen, browsing was intense outside exclosures as determined by arrested and retrogressed architecture types or lack of stem establishment. Parameters were greater inside than outside of exclosures for canopy cover and density of bearberry, big sagebrush, bitterbrush, curlleaf mountain mahogany, and horizontal juniper. In big sagebrush communities, greater production of big sagebrush winter forage was found. Growth rate and lifespan of serviceberry and willow were lower outside, as was growth rate of chokecherry. Current intense browsing was found at all 8 sites with aspen.

Browsing at 2 sites has not impacted the browse community (Fig. 28).

Parameters were not different inside and outside exclosures at these sites and evidence of intense browsing was not found outside these exclosures. Additionally, 3 sites have been

influenced by differential plant succession inside and outside the exclosure (Fig. 28).

Browsing was not considered to be influencing the browse community at these 3 sites.

Forest succession had yielded greater tree overstory inside exclosures at 2 sites, while sweet clover had greater canopy cover inside the exclosure at the 3rd site.

Ten sites included livestock exclosures in addition to big game exclosures.

Differences in browse parameters in and out of livestock exclosures were found at 5 sites.

Browse species that were impacted by cattle were serviceberry, horizontal juniper, Bebb willow and aspen.

Exclosures where differences were detected were not restricted to specific regions of Montana (Fig. 28). The age of exclosures was not directly related to finding significant differences in and out of them. I found differences in browse parameters between inside and outside of the most recently constructed exclosure (1990) as well as the oldest exclosure (1945).

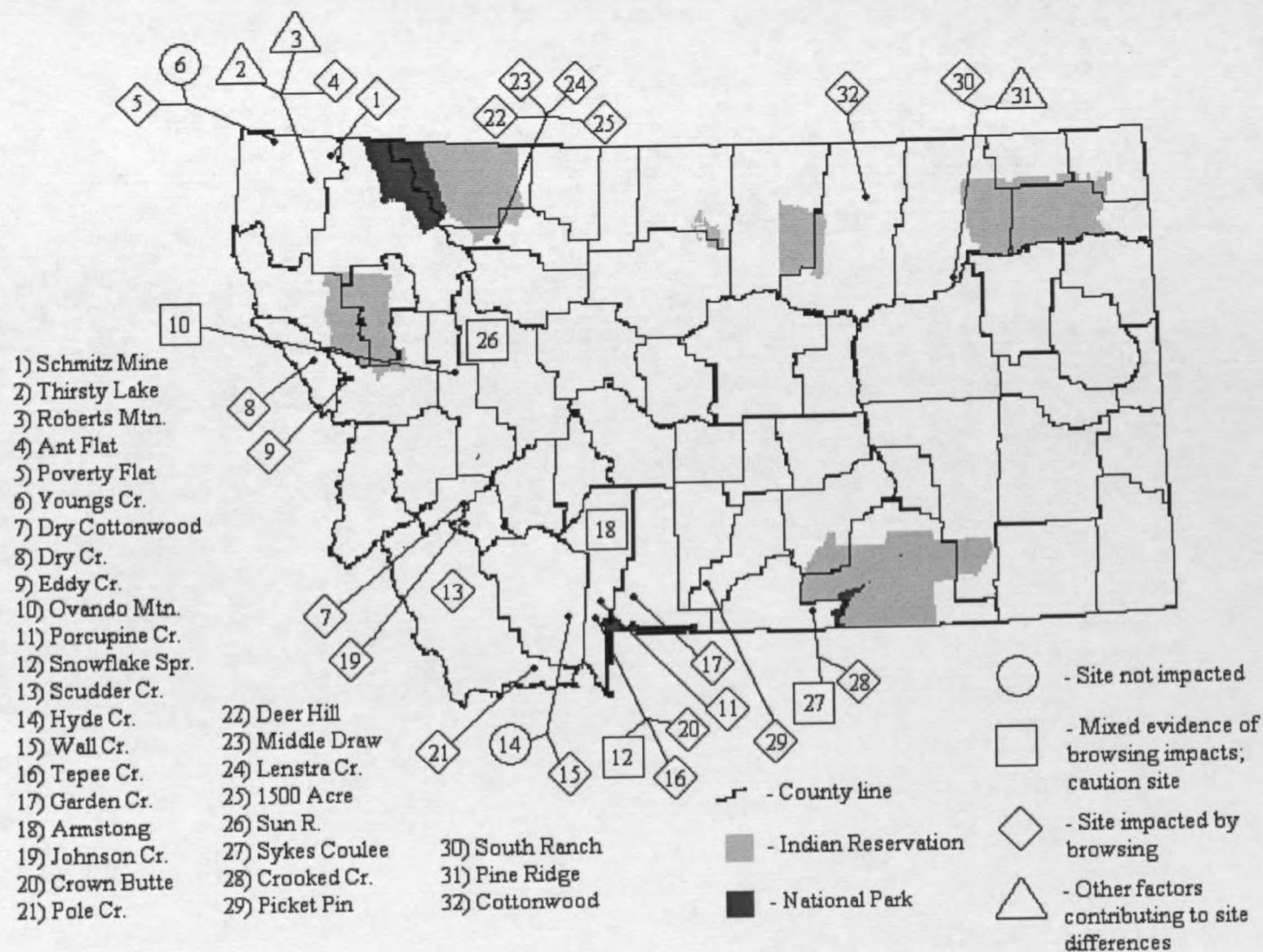


Figure 28. Summary of impacts at each site.

CHAPTER 5

CONCLUSIONS AND IMPLICATIONS

Concerns about browsing impacts have typically been centered on areas of special interest such as Yellowstone National Park (Kay 1995, Rens 2001, Ripple and Larsen 2000, Wambolt and Sherwood 1999). Because browse condition and trend studies in Montana have not been a high priority for several decades, current data are needed. My study did not consider specific areas or taxa, rather, all browse species and areas with functional exclosures were included. Thus, this study included the impacts of various ungulates across many environmental and management scenarios.

Twenty-seven of the 32 exclosures sampled provided evidence that long term browsing by ungulates is limiting the growth of numerous woody species. Logically, we would expect individual plants of landscape dominants to receive lighter levels of use, while plants of uncommon species might be more intensely used due to their rarity. I found this was not necessarily the case. Plant species impacted by browsing ranged from landscape dominants such as big sagebrush, to relatively uncommon species such as chokecherry.

I found wild ungulates were more likely to impact browse species than were livestock. When both big game and livestock exclosures were present, wild and domestic ungulate impacts could be separated. At most of the remaining sites with no livestock exclosures, evidence of wild ungulate use was found, while evidence of livestock use was uncommon. Evidence was usually pellet groups or manure. Additionally, many big

game exclosures were located on areas that were not as likely to sustain cattle grazing due to steeper slopes or lack of water.

There were fewer sites providing evidence that livestock have impacted browse species. Differences were detected in browse parameter means between inside and outside of livestock exclosures at 5 of 10 sites. Livestock were thought to be impacting browse species at several other sites that did not have a livestock exclosure. I based this conclusion on seeing livestock in the area or concentrations of manure piles in the browse community. Cattle have been the primary class of livestock on most sites, while domestic sheep historically grazed several sites. Percentage of browse in diets of cattle is typically small, but because cattle are much larger than many wild ungulates, the actual amount of browse they consume may approach that of wild ungulates. Whether livestock are impacting browse species through herbivory, trampling, or by somehow facilitating browse use by wild ungulates is hard to determine. This is an area that needs further research.

Differences in vegetation between excluded and protected areas developed from many years of exclusion. Intensity of ungulate browsing outside exclosures has probably been quite variable at some locations due to ungulate populations fluctuating through the years. A period of decreased browsing pressure may allow these communities to partially recover before the next period of intense browsing. Browse communities outside exclosures have evolved in such a manner, while browsing inside exclosures is not a consideration in development of plants and their communities. The value in comparing protected to unprotected vegetation is to understand the site and community potential. In

extreme cases, browse communities inside exclosures resulted in identification of a community that had been lost outside. Further impacts may result in loss of more browse communities.

Wild and domestic ungulate populations in some of these areas should be reevaluated. Impact on browse species has altered the vegetation of some ungulate ranges, which in turn may prove to be a long-term detriment to ungulate populations. Other species depending on these browse communities may have also been impacted. Consideration for browse communities should be emphasized when managing ungulate populations.

This study further proves the value of exclosures in natural resource management. Without the comparison allowed from exclosures, loss of browse species might often go undetected. If existing exclosures are lost, it will be many years before researchers have an opportunity to make similar comparisons of long-term impacts and trends. Effort put into maintenance of exclosures would enable continuation of these rare, long-term study areas that in many cases have been developing for a half a century.

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APPENDICES

APPENDIX A: THE HISTORY OF THE

APPENDIX A

MODELS AND FORMULAS

Table 8. Models for production of big sagebrush winter forage

 Low use mountain big sagebrush

$$\ln(F) = .647 + .034(MJ) + .031(AC) - .0002(C1)$$

High use mountain big sagebrush

$$\ln(F) = .311 + .037(MJ) + .047(AC) - .0003(C1) + .0179(CD)$$

Low use Wyoming big sagebrush

$$\ln(F) = .322 + .048(MJ) + .017(AC) - .0003(C1)$$

High use Wyoming big sagebrush

$$\ln(F) = .535 + .008(MJ) + .026(AC) + .029(HT) + .025(CD)$$

Model abbreviations: F - Forage (g), MJ - Major axis (cm), AC - Average crown cover (cm), C1 - Circular area for the major axis (cm²) [$C1 = \pi(MJ/2)^2$], CD - Crown depth (cm), HT - Height (cm).

Table 9. Formulas used in tall shrub and tree methods

 Net annual growth rate

$$NAGR = H_{pyg} / (A_s - 1)$$

Net annual growth rate to 1m

$$NAGR_1 = 100 / [(A_s - 1) - (A_1 - 1)]$$

Height of live to dead index

$$LD \text{ index} = H_{pyg} - H_D$$

Year of intense browsing

$$Y_I = \text{Collection year} - (A_c + 1)$$

Year of light/moderate browsing

$$Y_{LM} = \text{Collection year} - A_s$$

Formula abbreviations - H_{pyg} - Height to previous years growth (cm), A_s - Age of stem (yrs), A_1 - Age of stem at 1 m (yrs), H_D - Height to dead (cm), A_c - Age at cluster (yrs).

APPENDIX B

TRACE BROWSE SPECIES MEANS

Table 10. Parameter means for browse species < 1% canopy cover.

Site	Exclosure ²	Species ³	Canopy cover ¹ (%)			Density (n/60m ²)		
			In	↔ ⁴	Out	In	↔ ⁴	Out
6	G	<i>Amal</i>	0.5		0.0	1.4	**	0.0
6	G	<i>Rowo</i>	0.8	*	0.0	8.4	*	1.1
6	L	<i>Amal</i>	0.0		0.0	0.1		0.1
6	L	<i>Rowo</i>	0.0		0.0	0.5		0.0
7	G	<i>Arfr</i>	0.0	*	0.5	0.4	**	16.1
7	G	<i>Chna</i>	0.0		0.3	0.0		0.7
7	G	<i>Chvi</i>	0.8		0.2	3.7		1.5
9	G	<i>Phma</i>	1.0		0.0	2.1		0.5
9	G	<i>Rice</i>	0.3		0.3	0.2		0.2
9	G	<i>Syal</i>	0.4		0.3	2.5		3.6
10	G	<i>Sorbus</i>	0.9		1.1			
11	G	<i>Chvi</i>	0.9	•	0.0	5.1	**	1.0
11	G	<i>Teca</i>	0.4		0.5	3.7		0.3
13	G	<i>Arfr</i>	0.1		0.0	0.3		0.0
13	G	<i>Chvi</i>	0.0		0.1	0.0		1.3
13	G	<i>Teca</i>	0.1		0.7	3.3		7.3
14	G	<i>Arfr</i>	0.0		0.1	0.7	*	4.9
14	G	<i>Chna</i>	0.3		0.0	0.3		0.2
16	G	<i>Chvi</i>	0.0		0.0	2.2		0.1
19	G	<i>Arfr</i>	0.0		0.0	2.0		1.4
19	G	<i>Artrt-y</i>	0.0		0.0	0.0		0.3
19	G	<i>Artrt-m</i>				0.0		0.6
19	G	<i>Artrt-d</i>				0.0		0.0
19	G	<i>Artrw-y</i>				0.0		0.0
19	G	<i>Artrw-m</i>	0.2		0.1	0.4		0.7
19	G	<i>Artrw-d</i>	0.0		0.0	0.0		0.0
19	G	<i>Chvi</i>	0.0		0.0	0.0		0.0
19	G	<i>Teca</i>	0.0		0.0	0.0		0.2
19	L	<i>Arfr</i>	0.0		0.0	0.4		1.4
19	L	<i>Artrt-y</i>	0.0		0.0	0.0		0.3
19	L	<i>Artrt-m</i>				0.1		0.6
19	L	<i>Artrt-d</i>	0.0		0.0	0.0		0.0
19	L	<i>Artrw-y</i>				0.2		0.1
19	L	<i>Artrw-m</i>	0.1		0.4	0.7		0.7
19	L	<i>Artrw-d</i>				0.0		0.0
19	L	<i>Chvi</i>	0.0		0.0	0.0		0.0
19	L	<i>Teca</i>	0.0		0.0	0.2		0.2

Table 10. Continue (page 2)

Site	Exclosure ²	Species ³	Canopy cover ¹ (%)		Density (n/60m ²)		
			In	↔ ⁴	Out	In	↔ ⁴
22	G	<i>Elco</i>	0.1		0.0	4.0	0.0
22	G	<i>Rowo</i>	0.0		0.3	0.9	5.6
22	G	<i>Syor</i>	0.6		0.0	10.2	0.0
22	L	<i>Elcl</i>	0.2		0.0	3.0	0.0
22	L	<i>Rowo</i>	0.1		0.3	1.6	5.6
22	L	<i>Syor</i>	0.2		0.0		
26	G	<i>Juho</i>	0.0		0.5		
28	G	<i>Arfr</i>	0.0		0.0	1.1	0.0
29	G	<i>Arfr</i>	0.3	*	0.8	11.8	** 54.5
29	G	<i>Artrv-y</i>	0.6	*	0.0		
29	G	<i>Artrv-m</i>				1.9	** 0.4
29	G	<i>Artrv-d</i>				0.0	0.0
29	L	<i>Arfr</i>	0.6		0.8	24.9	** 54.5
29	L	<i>Artrv-y</i>	0.0		0.0	0.3	0.3
29	L	<i>Artrv-m</i>				0.4	0.4
29	L	<i>Artrv-d</i>				0.1	0.0
31	G	<i>Arca-y</i>	0.1		0.0	0.1	0.1
31	G	<i>Arca-m</i>				0.3	0.1
31	G	<i>Arca-d</i>				0.0	0.0
31	G	<i>Chna</i>	0.0		0.2	0.3	0.3
32	G	<i>Arfr</i>	0.2		0.3	29.5	27.4
32	G	<i>Cela</i>	0.8		0.1	3.7	3.6

¹Canopy cover of young and mature plants of a species are combined.

²Exclosure type: G - Big game, L - Livestock

³Browse species abbreviations: *Amal* - serviceberry, *Arca* - silver sagebrush, *Arfr* - fringed sagewort, *Artrv* - mountain big sagebrush, *Artrw* - Wyoming big sagebrush, *Artrt* - Basin big sagebrush, *Cela* - winterfat, *Chna* - rubber rabbitbrush, *Chvi* - green rabbitbrush, *Elco* - silverberry, *Juho* - horizontal juniper, *Phma* - ninebark, *Rice* - wax currant, *Rowo* - Wood's rose, *Sorbus* - mountain ash, *Syal* - common snowberry, *Syor* - western snowberry, *Teca* - gray horsebrush, y - young, m - mature d - dead.

↔⁴Comparison of parameters in and out: *, **, ** Significant at the P ≤ 0.1, 0.05, and 0.01 levels respectively.

APPENDIX C

DESCRIPTIONS OF ALL ENCLOSURES VISITED

Table 11. List of all exclosures visited

Site/Name	Location (UTM or Legal)			Established	Type (s) ¹	Key Species	Status ²
	Zone or S	mE or T	mN or R				
Region 1							
Ant Flat	11	656385	5399170	1962	G/L	AMAL	MF
Dodge-Poverty	11	631362	5420052	1958	G/L	PUTR-AMAL	MF
Mud Lake	S24	36N	28W	1934	G	PUTR	D
Schmitz Mine	11	655965	5408356	1962	G	AMAL	F
Roberts Mt.	11	652368	5402026	1962	G	AMAL-ARUV-BERE	F
Thirsty Lake	11	641675	5412134	1962	G	PUTR-BERE	F
Youngs Cr.	11	632179	5428066	1958/59	G/L	PUTR	F
Ten Mile	S27	33N	28W	1963	G	AMAL	D
Rondo	S5	35N	28W	1961	L	PUTR	D
Cripple Horse	S5	31N	28W	1958	G/L	AMAL	D
Big Cr.	S22	33N	20W	?	G	AMAL	D
Whitefish L.	S33	32N	22W	?	G	AMAL-ACGL	D
Region 2							
Dry Cr.	11	650250	5229614	1960	G	AMAL	F
Dry Cottowood	12	372209	5119110	1961	G/L	PUTR	F
Eddy Cr.	11	695736	5209421	1959	G	ARUV-ARUV	F
Ovando Mt.	12	343081	5215972	1957	G	AMAL-ACGL-PRVI	F
Rye Cr.	11	732140	5096574	1954	G	PUTR	NF
Salmon Lake	12	315979	5220302	1951	G	AMAL	NF
Region 3							
Porcupine Cr.	12	481511	5008063	1945	G	ARTR-SAGE-POTR	F
Snowflake Spr.	12	486744	4989828	1948/58	G	SABO	F
Scudder Cr.	12	336004	5018941	1953/63	G	CELE	F
Hyde Cr.	12	443528	4985059	?	G	ARTR-SAGE-POTR	F
Wall Cr.	12	445320	4978773	1990	G	POTR	F
Tepee Cr.	12	487024	4990773	1991	G	ARTR-SAGE-POTR	F
Garden Cr.	12	512791	5009718	1990	G	POTR	F
Armstong 1	12	495331	5083614	1955	G	PUTR-PRVI	F
Armstong 2	12	495127	5083557	1955	G	PUTR	F
Johnson Cr.	12	342898	5077768	1967	G/L	ARTR	F
Crown Butte	12	488378	4990122	1945	G	SABO-POTR	F
Pole Cr.	12	418630	4955822	1991	G	SABO-SAGE	F
Basin Cr.	12	388614	4956424	?	G	SABO-SAEX	F
Long Cr.	12	361520	5039046	1991	G	SABO-SAGE	NF
Limestone Hills	12	454127	5129691	1963	G	CELE	F
Lost Cr.	12	419772	4955584	1953	G	CELE	F
Pass Cr.	12	495756	5091227	1963	G	ARTR-AMAL	F
Fleecer 1	12	362078	5074166	1989	G	TECA	F
Fleecer 2	12	361487	5074266	1989	G	SALIX	F
Region 4							
Deer Hill	12	375033	5329034	1987	G/L	JUHO-PRVI	F
Middle Draw	12	375033	5329034	1987	G/L	SABE-POTR-PRVI	F
Lenstra Cr.	12	372937	5329591	1987	G/L	SABE-POTR	F
1500 Acre	12	371600	5326967	1987	G/L	JUHO-POTR	F
Burdoff Cr.	12	374413	5274219	1967	G	RHTR-PRVI	F
Hunters Gulch	12	437957	5186521	1960	G	PUTR	D

Table 11. Continued. (page 2)

Site/Name	Location (UTM or Legal)			Established	Type (s) ¹	Key Species	Status ²
	Zone or S	mE or T	mN or R				
Region 5							
Sykes Coulee	12	713122	4988356	1964	G/L	CELE	F
Crooked Cr.	12	703443	4996600	1962	G/L	ARTR-ARNO	F
Picket Pin	12	583219	5031976	1962	G/L	JUHO	F
Main Boulder	S4	6S	12E	1960	G	RHTR-PRVI	D
Region 6							
South Ranch	13	355054	5300371	1987	G/L	PRVI-POTR-SALIX	F
Pine Ridge	13	360540	5293948	1970	G	ARTR-CHNA	F
Cottonwood	13	294254	5373024	1967	G	ARTR-CELA	F
Nichols Coulee	12	712986	5277009	1965	G/L	ARTR-ATGA	F
Nichols Coulee	12	710680	5277654	1965	G/L	ARCA-SAVE	F
Region 7							
McClary	S1	3S	61E	1960	G/L	PRDI-AMAL	D
Capitol Rock	S2	3S	61E	1959	G	PRDI-AMAL	D
Upper Home Cr.	22	3S	47E	1960	G/L	PRDI-AMAL	NL
Little Pumpkin	13	423934	5054537	1961	G/L	PRDI	NF
Cow Cr.	13	404912	5017373	1961	G/L	RHTR-ARCA	NF

¹G- Big game exclosure L- Livestock exclosure²F- Functioning, MF- Mostly Functioning, NF- Not Functioning, D- Destroyed, NL- Not able to Locate

APPENDIX D

BROWSE SPECIES LIST

Table 12. List of browse species at all sites.

Scientific Name	Abbreviation	Common Name	Site(s) Species Occured
<i>Acer glabrum</i>	<i>Acgl</i>	Rocky Mountain maple	10
<i>Amelanchier alnifolia</i>	<i>Amal</i>	serviceberry	1,3,4,6,8,9,10
<i>Artemisia cana</i>	<i>Arca</i>	silver sagebrush	14,31
<i>Artemisia frigida</i>	<i>Arfr</i>	fringed sagewort	7,13,14,19,22,26,28,29,32
<i>Artemisia nova</i>	<i>Arno</i>	black sagebrush	28
<i>Artemisia tripartita</i>	<i>Artr3</i>	threetip sagebrush	32
<i>Artemisia tridentata</i> ssp. <i>tridentata</i>	<i>Artrt</i>	basin big sagebrush	19
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i>	<i>Artrv</i>	mountain big sagebrush	11,14,16,19,28,29
<i>Artemisia tridentata</i> ssp. <i>wyomingensis</i>	<i>Artrw</i>	Wyoming big sagebrush	19,28,31,32
<i>Arctostaphylos unva-ursi</i>	<i>Aruv</i>	bearberry	2,3,9
<i>Berberis repens</i>	<i>Bere</i>	Oregon grape	2,3,5
<i>Ceratoides lanata</i>	<i>Cela</i>	winterfat	32
<i>Cercocarpus ledifolius</i>	<i>Cele</i>	curl-leaf mountain mahogany	13,27
<i>Ceanothus velutinus</i>	<i>Ceve</i>	snowbrush ceanothus	9,10
<i>Chrysothamnus nauseosus</i>	<i>Chna</i>	rubber rabbitbrush	7,14,31
<i>Chrysothamnus viscidiflorus</i>	<i>Chvi</i>	green rabbitbrush	7,11,13,14,16,19
<i>Eleagnus communis</i>	<i>Elco</i>	silverberry	22
<i>Juniperus horizontalis</i>	<i>Juho</i>	horizontal juniper	22,26,29
<i>Juniperus scopulorum</i>	<i>Jusc</i>	Rocky Mountain juniper	27,31
<i>Physocarpus malvaceus</i>	<i>Phma</i>	ninebark	9
<i>Potentilla fruticosa</i>	<i>Pofr</i>	shrubby cinquefoil	22
<i>Populus tremuloides</i>	<i>Potr</i>	quaking aspen	11,15,17,20,23,24,25,30
<i>Prunus pensylvanica</i>	<i>Prpe</i>	pin cherry	10
<i>Prunus virginiana</i>	<i>Prvi</i>	chokecherry	10,18,26,30
<i>Purshia tridentata</i>	<i>Putr</i>	antelope bitterbrush	5,6,7
<i>Rhus trilobata</i>	<i>Rhtr</i>	skunkbrush sumac	26
<i>Ribes cereum</i>	<i>Rice</i>	wax currant	9
<i>Rosa woodsii</i>	<i>Rowo</i>	Wood's rose	2,5,6,7,22
<i>Salix bebbiana</i>	<i>Sabe</i>	Bebb willow	23,24
<i>Salix boothii</i>	<i>Sabo</i>	Booth's willow	12,20,21
<i>Salix geyeriana</i>	<i>Sage</i>	Geyer's willow	11
<i>Shepherdia canadensis</i>	<i>Shca</i>	russet buffaloberry	3
<i>Sorbus</i> sp.	<i>Sorbus</i>	mountain ash	10
<i>Symphoricarpos albus</i>	<i>Syal</i>	common snowberry	2,6,9
<i>Symphoricarpos orbiculatus</i>	<i>Syor</i>	western snowberry	7,22,26
<i>Tetradymis canadensis</i>	<i>Teca</i>	gray horsebrush	11,13,14,16,19

APPENDIX E

MODELS FOR PREDICTING ASPEN AGE

Table 13. Regression models to predict age of aspen from stem circumference at ground level.

Site	Model with y intercept	R ²	Model without y intercept	R ²
11	AGE = 20.7 + 0.297CIR ¹	0.70	AGE = 0.626CIR	0.78
15	AGE = 1.5 + 0.758CIR	0.80	AGE = 0.882CIR	0.94
17	AGE = 15.1 + 0.325CIR	0.68	AGE = 0.449CIR	0.87
20	AGE = 6.2 + 0.485CIR	0.91	AGE = 0.561CIR	0.93
23	AGE = 8.5 + 0.470CIR	0.69	AGE = 0.748CIR	0.86
24	AGE = 8.6 + 0.685CIR	0.89	AGE = 0.836CIR	0.93
25	AGE = 7.4 + 0.865CIR	0.76	AGE = 1.118CIR	0.94
30	AGE = 5.9 + 0.547CIR	0.86	AGE = 0.699CIR	0.92
Combined	AGE = 10.0 + 0.462CIR	0.74	AGE = 0.619CIR	0.83

CIR¹ - circumference of stem at ground level

Note – models were not used in this research, but were developed from the data collected.

APPENDIX F

SUMMARY MAPS FOR ASPEN AND TALL SHRUBS

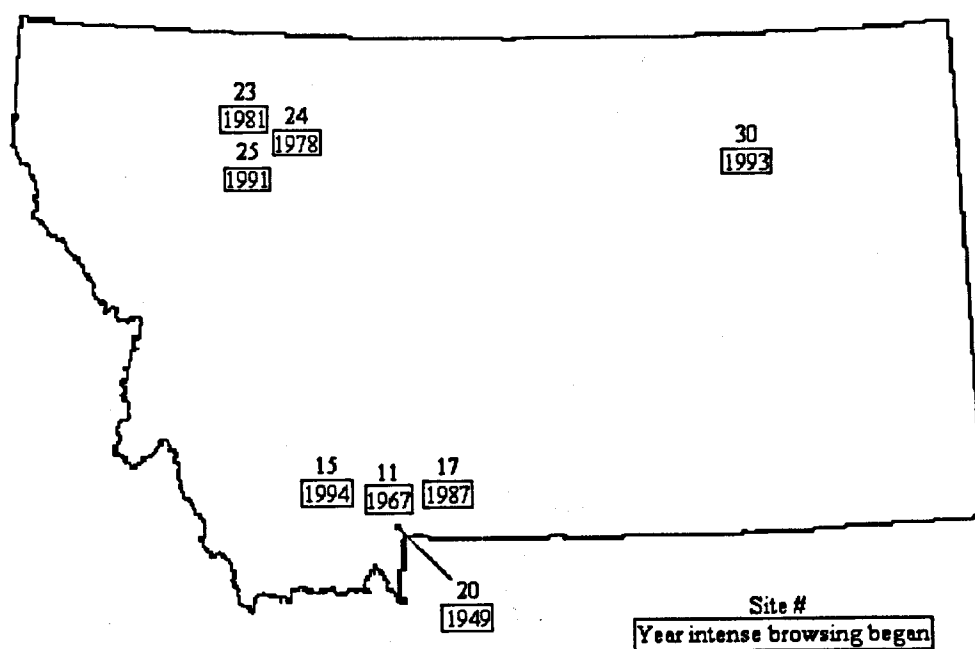


Figure 29. Locations and dates intense browsing on aspen began.

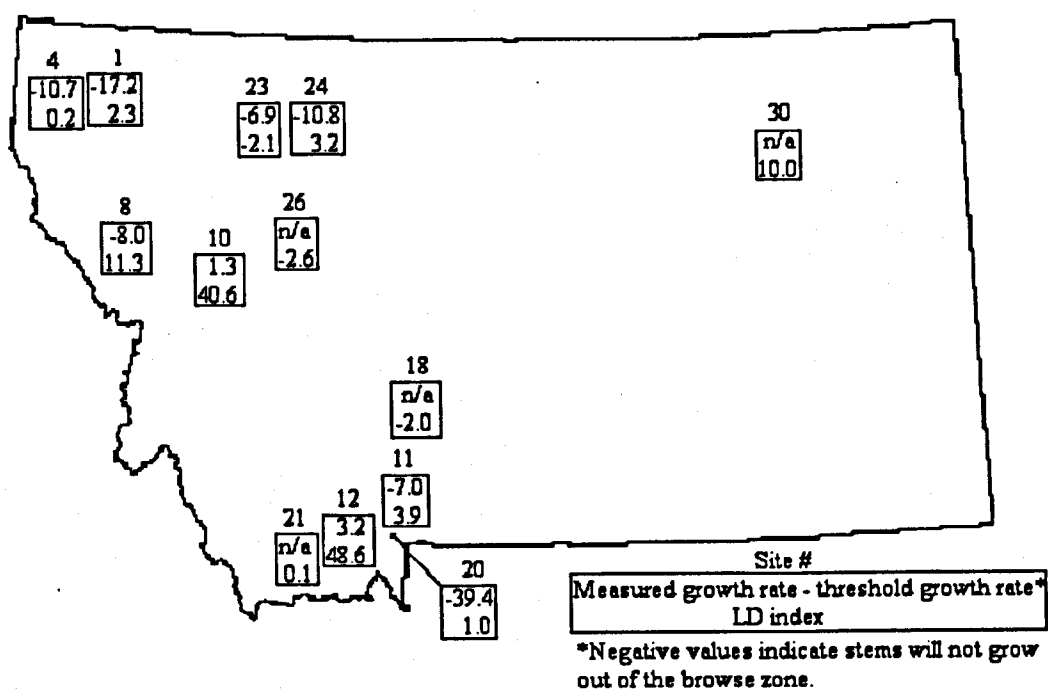


Figure 30. Browsing impacts on tall shrubs by site location.

APPENDIX G

SITE PHOTOS



Figure 31. Thirsty Lake enclosure with thick conifer overstory (6/01).



Figure 32. Bitterbrush inside the Young Creek livestock enclosure (7/01).



Figure 33. Bitterbrush outside the Young Creek livestock exclosure (7/01).



Figure 34. Dry Cottonwood exclosure (1961).



Figure 35. Dry Cottonwood exclosure (9/71).



Figure 36. Dry Cottonwood exclosure (6/01).



Figure 37. Serviceberry inside Dry Creek exclosure (4/63).



Figure 38. Serviceberry inside Dry Creek exclosure (6/01).



Figure 39. Serviceberry outside Dry Creek exclosure (4/73).



Figure 40. Serviceberry outside Dry Creek exclosure (6/01).

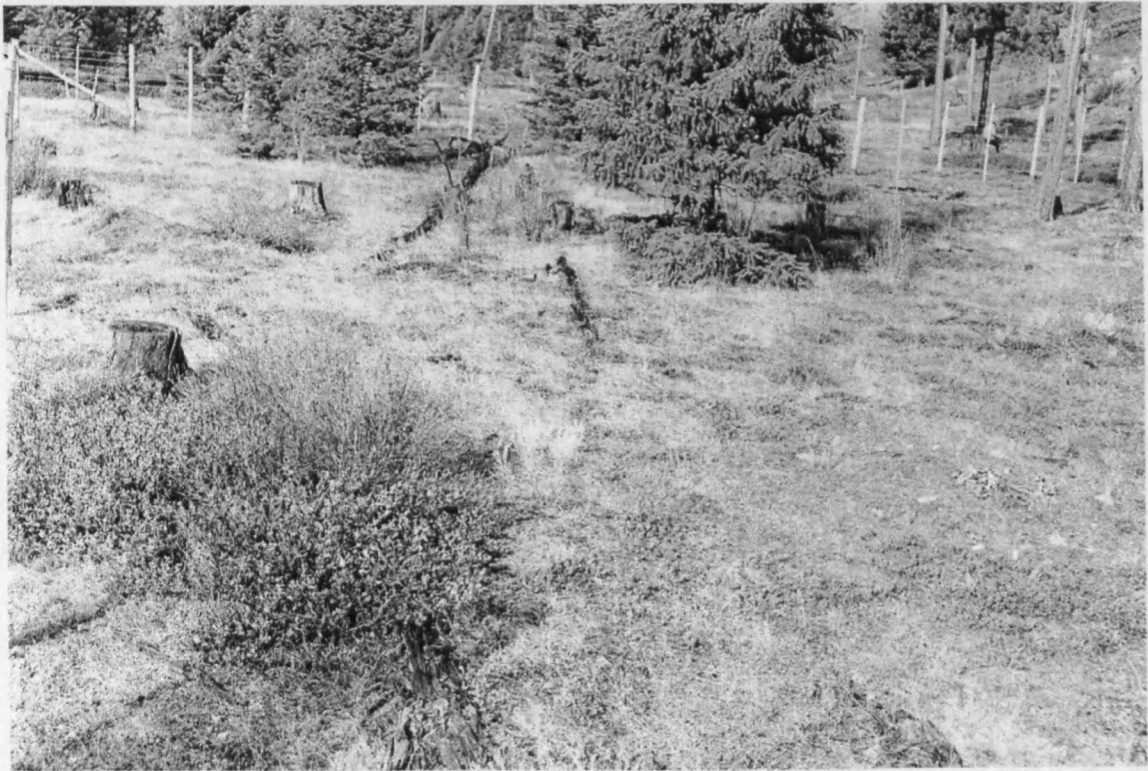


Figure 41. Inside Eddy Creek exclosure (1957).



Figure 42. Inside Eddy Creek exclosure (6/01).



Figure 43. Outside Eddy Creek exclosure (1957).



Figure 44. Outside Eddy Creek exclosure (6/01).

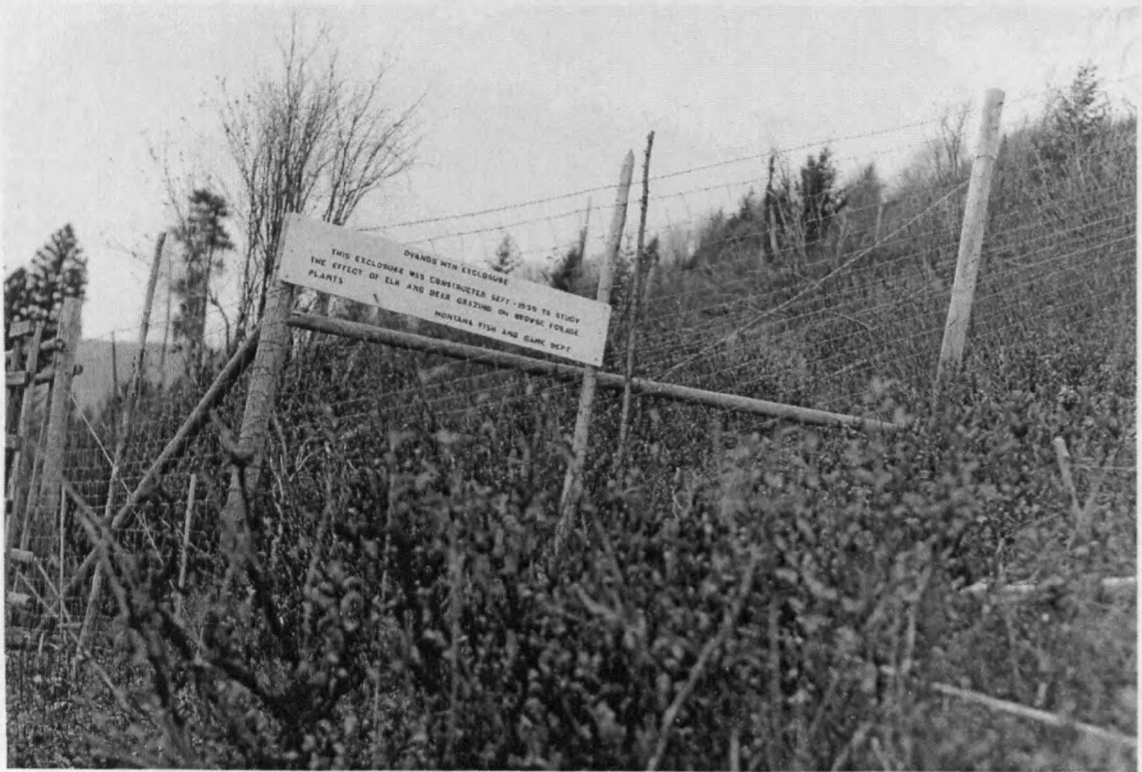


Figure 45. Ovando Mountain enclosure (10/60).



Figure 46. Ovando Mountain enclosure (8/02).



Figure 47. Mountain big sagebrush at Porcupine Creek exclosure (1957).



Figure 48. Mountain big sagebrush at Porcupine Creek exclosure (7/02).



Figure 49. Aspen and Geyer willow inside Porcupine Creek exclosure (1957).



Figure 50. Aspen and Geyer willow inside Porcupine Creek exclosure (7/02).



Figure 51. Porcupine Creek exclosure (5/01). Inside exclosure is left of fence, outside is right of fence.



Figure 52. Snowflake Springs exclosure (5/01). Left of fence is outside, right inside.



Figure 53. Curlleaf mountain mahogany inside Scudder Creek exclosure (7/01).

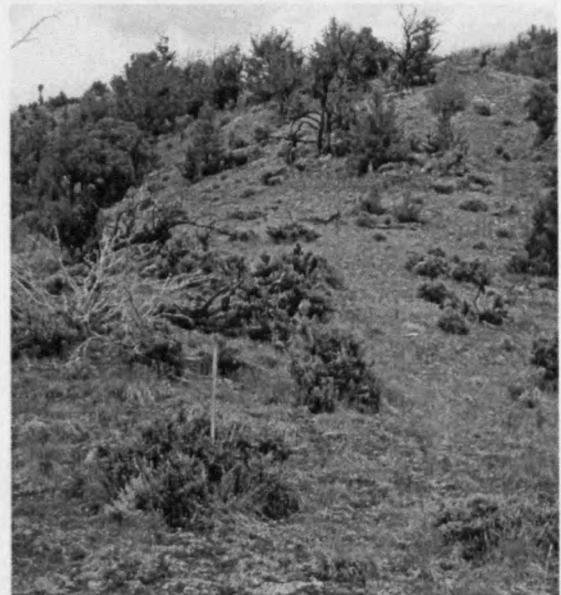


Figure 54. Curlleaf mountain mahogany outside Scudder Creek exclosure (7/01).



Figure 55. Aspen inside Wall Creek exclosure (8/93).



Figure 56. Aspen inside Wall Creek exclosure (8/01).



Figure 57. Tepee Creek exclosure (5/02). Left of fence is inside, right is outside. Sampling occurred in control section in center of photo.



Figure 58. Aspen inside Garden Creek exclosure (5/02).



Figure 59. Older aspen outside the Garden Creek exclosure (5/02).



Figure 60. Aspen outside Garden Creek exclosure growing crooked (5/02).



Figure 61. Aspen inside the Crown Butte exclosure (7/02).



Figure 62. Aspen outside the Crown Butte exclosure (7/02).



Figure 63. Booth's willow inside the Crown Butte exclosure (7/02).



Figure 64. Booth's willow outside the Crown Butte exclosure (7/02).



Figure 65. Booth's willow inside the Pole Creek exclosure (8/02).



Figure 66. Booth's willow outside the Pole Creek exclosure (8/02).



Figure 67. Limestone Hills exclosure (5/73). See Appendix C, Table 11.



Figure 68. Limestone Hills exclosure (5/02). See Appendix C, Table 11.

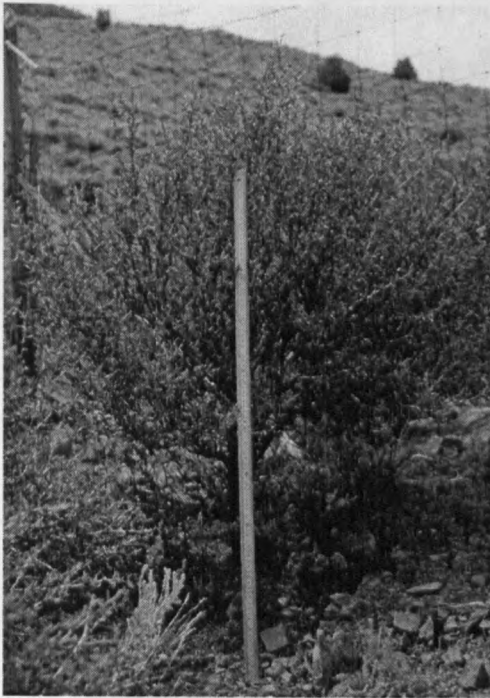


Figure 69. Curlleaf mountain mahogany inside Lost Creek exclosure (6/01). See Appendix C, Table 11.



Figure 70. Curlleaf mountain mahogany outside Lost Creek exclosure (6/01). See Appendix C, Table 11.



Figure 71. Middle Draw exclosure (7/01). Right of fence is inside exclosure, left is outside. Bebb willow in the foreground and aspen in background.



Figure 72. Picket Pin exclosure (9/71). Left of fence inside, right outside.



Figure 73. Picket Pin exclosure (7/02). Left of fence inside, right outside.



Figure 74. Horizontal juniper inside Picket Pin exclosure (9/71).



Figure 75. Retake of horizontal juniper plant in figure 74 (7/02).



Figure 76. Wyoming big sagebrush inside Pine Ridge enclosure (7/02).



Figure 77. Wyoming big sagebrush outside Pine Ridge enclosure (7/02).



Figure 78. Wyoming big sagebrush inside Cottonwood exclosure (8/02).



Figure 79. Wyoming big sagebrush outside Cottonwood exclosure (8/02).



Figure 80. Cottonwood enclosure (8/02). Left of fence inside, right outside.

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