Effects of Douglas fir establishment in southwestern Montana mountain big sagebrush communities
by Adam Jay Grove

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

Abstract:
Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) establishment in big sagebrush (Artemisia tridentata Nutt.) communities is often controlled by the use of prescribed fire, which also kills big sagebrush, an important component of wildlife habitat. Knowledge of the effects of Douglas fir establishment in big sagebrush communities is essential to determining when control of establishing Douglas fir by fire or other means may be warranted. Three southwestern Montana mountain big sagebrush (A.t. ssp. vaseyana [Rydb.] Beetle) communities with establishing Douglas fir were selected for study. Twenty-five sites, representing different levels of Douglas fir establishment were selected within each study area. The effects of Douglas fir growth on mountain big sagebrush and herbs were described and quantified. Data were collected on Douglas fir and mountain big sagebrush canopy cover, density, and age, Douglas fir basal area and height, mountain big sagebrush winter forage production, and herbaceous canopy cover. Models were developed for big sagebrush canopy cover and density of "large" sagebrush (average crown cover ≥ 15 cm), grass, and total herbaceous canopy cover. Negative correlation values indicated that as Douglas fir canopy cover, total basal area, and density increased, mountain big sagebrush and herbaceous variables decreased. Overall, Douglas fir canopy cover had the strongest negative relationship with sagebrush canopy cover ($r = -0.86$), density of "large" sagebrush ($r = -0.93$), sagebrush production per plant ($r = -0.87$), and total sagebrush production per transect ($r = -0.84$). While increases in Douglas fir growth caused declines in mountain big sagebrush and herbaceous variables at all study areas, models were often quite variable between study areas. Both linear and curvilinear declines in mountain big sagebrush and herbaceous variables were recorded. Model validation results indicated that individual study area models were generally not precise or accurate. Overall models for density of "large" sagebrush and sagebrush cover did predict well. Douglas fir canopy cover had the greatest impact on mountain big sagebrush and herbaceous variables. Mountain big sagebrush canopy cover declined to < 15%, as Douglas fir canopy cover increased beyond 20%. Sagebrush canopy cover declined to < 5%, as Douglas fir canopy cover increased beyond 35%.

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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.

Dr. Carl Wambolt — Carl L. Wambolt — May 18, 1998
Date

Approved for the Department of Animal and Range Sciences

Dr. Pete Burfening — Peter Burfening — 5-19-98
Date

Approved for the College of Graduate Studies

Dr. Joseph J. Fedock — Joseph J. Fedock — 5/22/98
Date

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ABSTRACT

Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) establishment in big sagebrush (*Artemisia tridentata* Nutt.) communities is often controlled by the use of prescribed fire, which also kills big sagebrush, an important component of wildlife habitat. Knowledge of the effects of Douglas fir establishment in big sagebrush communities is essential to determining when control of establishing Douglas fir by fire or other means may be warranted. Three southwestern Montana mountain big sagebrush (*A.t.* ssp. *vaseyana* [Rydb.] Beetle) communities with establishing Douglas fir were selected for study. Twenty-five sites, representing different levels of Douglas fir establishment were selected within each study area. The effects of Douglas fir growth on mountain big sagebrush and herbs were described and quantified. Data were collected on Douglas fir and mountain big sagebrush canopy cover, density, and age, Douglas fir basal area and height, mountain big sagebrush winter forage production, and herbaceous canopy cover. Models were developed for big sagebrush canopy cover and density of "large" sagebrush (average crown cover ≥ 15 cm), grass, and total herbaceous canopy cover. Negative correlation values indicated that as Douglas fir canopy cover, total basal area, and density increased, mountain big sagebrush and herbaceous variables decreased. Overall, Douglas fir canopy cover had the strongest negative relationship with sagebrush canopy cover ($r = -0.86$), density of "large" sagebrush ($r = -0.93$), sagebrush production per plant ($r = -0.87$), and total sagebrush production per transect ($r = -0.84$). While increases in Douglas fir growth caused declines in mountain big sagebrush and herbaceous variables at all study areas, models were often quite variable between study areas. Both linear and curvilinear declines in mountain big sagebrush and herbaceous variables were recorded. Model validation results indicated that individual study area models were generally not precise or accurate. Overall models for density of "large" sagebrush and sagebrush cover did predict well. Douglas fir canopy cover had the greatest impact on mountain big sagebrush and herbaceous variables. Mountain big sagebrush canopy cover declined to < 15%, as Douglas fir canopy cover increased beyond 20%. Sagebrush canopy cover declined to < 5%, as Douglas fir canopy cover increased beyond 35%.

INTRODUCTION

Conifers have increased dramatically in southwestern Montana over the last 100 years (Arno and Gruell 1986). Wright and Bailey (1982) stated that Douglas fir is becoming established in grassslands throughout its range. Gruell et al. (1986) stated that Douglas fir and other conifers have become established in several million acres of Montana seral grasslands.

The establishment (encroachment, invasion, colonization) of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) in big sagebrush (*Artemisia tridentata* Nutt.) communities poses questions for wildlife habitat management. Establishing Douglas fir may provide additional security cover to mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus nelsoni*) using big sagebrush communities for foraging. The benefits provided by additional cover will be tempered, however, if browse is lost due to Douglas fir encroachment. Land managers must balance the needs for available forage areas, cover for wildlife security, and the reduction of available forage as a result of the negative impacts of increases in tree cover. The dilemma is in ascertaining at what point the benefits provided by cover in wildlife foraging areas are being outweighed by the loss of forage due to establishing conifers.

Natural resource agencies state that establishing conifers are often controlled to maintain or improve forage for domestic livestock and wildlife, and to maintain diverse, healthy and dynamically stable ecosystems (USDA 1986, USDA 1987, BLM 1997). Prescribed burning is often used to control establishing conifers (USDA 1986, USDA 1987). However, the use of prescribed burning in big sagebrush communities where Douglas fir has become established will eliminate big sagebrush and other non-sprouting shrubs (Blaisdell 1953, Harniss and Murray 1973, Wambolt and Payne 1986), while possibly only having a marginal effect on Douglas fir. Because big sagebrush is important wildlife browse (Kufeld1973, Welch and Wagstaff 1990, Wambolt 1996), determining at what point the control of Douglas fir outweighs the loss of big sagebrush is a critical decision for land managers.

My objectives were first to examine and quantify the effects of Douglas fir establishment in mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana* [Rydb.] Beetle) communities, as to my knowledge no other study has quantified the effects of encroaching Douglas fir on mountain big sagebrush. Secondly, to determine the Douglas fir growth variable having the greatest impact on mountain big sagebrush communities, and third, to build regression models that predict the effects of Douglas fir establishment on mountain big sagebrush and herbaceous related variables. My goal was to provide land managers with information as to when control of Douglas fir in mountain big sagebrush habitats might be warranted.

LITERATURE REVIEW

Causes of Tree Establishment

Conifer establishment in mountain big sagebrush communities and rangeland succession can be viewed from 2 schools of thought: 1) the Clementsian theory of ecology (Clements 1916); and 2) the state-and-transition model (Westoby et al. 1989). Under the Clementsian theory of succession, Douglas fir establishment in mountain big sagebrush communities may be thought of as a stage in succession. Clements (1916) referred to succession as a series of invasions by different plant communities, while Sampson (1917) defined succession as "the establishment of 1 plant species by a series of invasions in a given habitat causing the replacement of 1 set of plants by another". Smith (1986) referred to succession as the "replacement of 1 community by another over time". Those who subscribe to the state-and-transition model cite increasing tree dominance as an example of a transition from one "state" (vegetative community) to an alternative "state" (Noy-Meir and Walker 1986, Westoby et al. 1989, Laycock 1991).

Regardless of the rangeland succession model one adheres to, tree establishment or encroachment generally has been perceived negatively. However, Strang and Parminter (1980) regarded encroachment of trees into grasslands as a natural process fostered by human activities, and that its perception as being "good" or "bad" depended on management objectives. Because encroachment has often been thought of as "bad" or unwanted succession, studies related to Douglas fir or other tree encroachment have generally focused on the cause or causes of encroachment. Research has identified and focused on 4 primary factors working separately or in unison to cause encroachment.

These factors are overgrazing, changes in the microenvironment, fire suppression, and climatic change. Under the state-and-transition model these factors would cause a transition between alternative steady states (Westoby et al. 1989).

Overgrazing has been cited as causing conifer encroachment by a host of researchers (Foster 1917, Rummel 1951, Springfield 1976, Vale 1975, Zimmerman and Neuenschwander 1984, Waugh and Fisser 1986). Overgrazing acts to change the microenvironment by reducing competition from herbaceous species and increasing the amount of bare mineral soil available for conifer establishment (Rummel 1951, Cooper 1960, Vale 1975, Strang and Parminter 1980, Zimmerman and Neuenschwander 1984). Exposed mineral soil is considered a prime seedbed for tree seedling establishment (Miller 1921, Shearer 1974). Shearer (1974) stated that conifer regeneration is dependent on 1) seedbed condition; 2) seed supply; and 3) environmental characteristics affecting seedling survival. Conifer seedling survival is affected by soil moisture and soil temperature (Isaac 1938, Patten 1963). Tree invasions generally occur in pulses when years of good seed production are followed by years of favorable moisture (Rummel 1951, Arnold et al. 1964, Sindelar 1971, Arno and Gruell 1986). Hoffman (1924) stated that in the Pacific Northwest, Douglas fir generally had good seed production every 2-3 years.

Douglas fir encroachment is often preceded by an increase in big sagebrush (Gruell 1983, Arno and Gruell 1983, Gruell et al. 1986). Increases in big sagebrush may be due to overgrazing, fire suppression or a combination of the two. Big sagebrush provides shaded microsites conducive to the establishment of Douglas fir seedlings (Sindelar 1971, Gruell 1983, Gruell et al. 1986). Sindelar (1971) reported that Douglas fir saplings were strongly associated with big sagebrush plants, as the majority of Douglas fir seedlings emerged directly through big sagebrush crowns. Sagebrush has been documented as acting as a "nurse" plant for other tree species as well. Burkhardt (1969) reported that western juniper (*Juniperus occidentalis* Hook.) seedlings were often found under mountain big sagebrush plants. Waugh and Fisser (1986) reported that Utah juniper (*Juniperus osteosperma* (Torr.) Little) seedlings became established predominantly under black sagebrush (*Artemisia nova* Nels.).

Direct fire suppression or the lack of fire plays a major role in tree establishment. Burkhardt (1969) attributed the establishment of western juniper in mountain big sagebrush communities directly to the cessation of periodic fires. Likewise, encroachment by Douglas fir has been attributed to fire suppression (Gruell 1980, Gruell 1983, Arno and Gruell 1986). Even when fire suppression is not considered the primary cause of encroachment, it allows encroachment to continue unabated (Rummel 1951, Cooper 1960, Patten 1963, Sindelar 1971).

Overgrazing may contribute to the lack of fire by reducing the amount or density of herbaceous vegetation, thus reducing the ability of an area to sustain or carry a fire (Foster 1917, Springfield 1976, Zimmerman and Neuenschwander 1984, Arno and Gruell 1986). While overgrazing may reduce the ability of an area to carry a fire, encroachment and the subsequent increases in tree density and canopy cover caused by overgrazing may increase the potential for catastrophic crown fires as ladder fuels increase (Zimmerman 1979, Davis et al. 1980, Gruell et al. 1982).

In addition to overgrazing, changes in the microenvironment, and fire suppression, climatic change has also been cited as a factor contributing to encroachment

(Blackburn and Tueller 1970). Johnsen (1962) stated that long droughts killed grasses and reduced competition with one-seeded juniper (*Juniperus monosperma* (Engelm.) Sarg.) seedlings. Vale (1975) stated that droughts could accentuate plant cover decreases, thereby encouraging tree establishment when more moist conditions return. Patten (1963) stated that forest advance and tree establishment in open areas was in part dependent on optimum climatic conditions.

Fire History in Douglas Fir Forests of the Rocky Mountain Region

The lack of fire in the last 100 years has resulted in extensive areas of Douglas fir and other tree encroachment in the Rocky Mountain region (Gruell 1983, Arno and Gruell 1983, Arno and Gruell 1986). Prior to fire suppression, Douglas fir habitat types were open and patchy as periodic ground fires restricted development of Douglas fir forests (Loope and Gruell 1973, Davis et al. 1980, Gruell 1983). Douglas fir was often restricted to moist sites, rocky outcrops and talus slopes (Arno and Gruell 1983, Gruell 1983, Arno and Gruell 1986). Arno and Gruell (1983) stated that with fire suppression Douglas fir has invaded grass and sagebrush habitats downslope from more rocky areas.

While fire frequency in the Rocky Mountain region is variable to begin with, fire suppression has generally resulted in longer fire-free intervals. Arno and Gruell (1983) stated that prior to 1910, mean fire intervals in the Douglas fir/grassland ecotone of southwestern Montana ranged from 35-40 years, but that no fires had been recorded in their study areas the previous 61 years. Arno and Gruell (1986) recorded a mean fire interval of 26 years in the Galena Gulch area outside of Boulder, Montana for the period 1690-1979, but only 1 fire had occurred in the 94 years prior to their study. The longest fire intervals prior to 1890 were 72-82 years. In the southern Elkhorn Mountains east of Boulder, Lehman (1995) reported post fire suppression mean fire intervals of 13.8 to 25.8 years in 4 study areas. The mean post suppression fire interval for Douglas Fir/Idaho fescue (*Festuca idahoensis* Elmer) habitat types in this area was 13.8 years compared to a historical MFI of 8.2 years (Lehman 1995). Lehman (1995) reported that over much of the study area the time elapsed since the last fire was up to 3x longer than the historic average interval between fires.

Arno (1976) found fire frequencies ranging from 6-19 years in Douglas fir/grassland habitat types on the Bitterroot National Forest of Montana. However, Arno (1976) stated that there has been a marked decrease in fire since 1920, and that in many areas the time elapsed since the last fire now exceeds the longest fire free interval from 1735-1900. Goldblum and Veblen (1992) reported a mean fire interval of 15.2 years for the period 1920-1949 for their entire study area on the Colorado front-range; however, when the time period was increased to cover the whole fire suppression era (1920-1989), the interval was 28 years. Goldblum and Veblen (1992) recorded a mean fire interval of 31.8 years prior to 1859; however, they felt that they probably had underestimated the number of fires that had occurred. Tande (1979) found that Douglas fir forests in Jasper National Park had an average mean fire return interval of 17.6 years for the period 1665-1975, but prior to 1913 when fire suppression began, the interval was only 5.5 years. Tande (1979) reported that fires covering more than 1.2% (500 ha) of the study areas had a mean fire return interval of 8.4 years, while fires covering more than 50% of the study area had a mean fire return interval of 65.5 years.

While fire frequencies historically may have been shorter than they are today, fire intensity was generally lower, and fire size was generally smaller. Loope and Gruell (1973) stated that in the Jackson Hole, WY area, very large fires were rare and crown fires only occurred under the most extreme conditions. Arno (1976) stated that short fire intervals, and the presence of multiple age class conifer stands in his 3 Bitterroot National Forest study areas, indicate that fire intensity usually was not great. Fires generally only covered a portion of the 3 study areas (Arno 1976). Tande (1979) found that only 58.5 % of the recorded fires in his 43,200-ha study area covered more than 1.2% of the study area. Sixty-eight percent of the fires covered less than 5% of the study area. Fires did not kill the entire stand, but rather left many different age classes on the landscape.

Susceptibility of Douglas Fir to Fire Treatment

Knowledge of the potential effects of fire on Douglas fir is needed if prescribed burning is to be considered for treating Douglas fir encroachment. Because of their very thick bark, mature Douglas fir are considered to be very fire resistant (Flint 1925). It takes Douglas fir approximately 40 years on moist sites to develop this corky, fire-resistant outer bark (Arno and Gruell 1983, Fischer and Bradley 1987). While generally fire resistant, mature Douglas fir may be injured by fire because of resin streaks in the bark, and because branches run the full length of the bole (Fischer and Clayton 1983). This branch habit may lead to crown fires, which are generally needed to kill mature Douglas fir (Starker 1934). In addition, dense understories created as a result of a prolonged fire-free period may provide ladder fuels for crown fires (Arno 1976, Fischer and Clayton 1983).

Although mature Douglas fir are resistant to most fires, Gruell et al. (1986) stated that seedling (trees < 1.5 m tall), sapling (2-13 cm Dbh), and pole (18-30 cm Dbh) invasions of Douglas fir may present opportunities for the use of prescribed fire. Ground or low intensity fires will kill Douglas fir seedlings (Gruell et al. 1986), and saplings (5-10 cm Dbh) are vulnerable to fire as well (Davis et al. 1980, Fischer and Clayton 1983, Fischer and Bradley 1987). Pole-sized Douglas fir are more fire resistant, and may survive low to possibly low-moderate intensity fires (Bradley et al. 1992). Kalabokidis and Wakimoto (1992) reported that fire killed 97-100% of the Douglas fir trees under 3 m on their study areas, but that only approximately 10% of the trees taller than 3 m were killed. Bushey (1986) reported that only trees taller than 1.37 m survived after 3 post-burn seasons on 2 study transects, while on another transect, Douglas fir seedlings and saplings had incurred at least 80% mortality after only 1 post-burn growing season. Moderate fires generally result in more open, park-like stands of mature trees as these fires are unlikely to kill large overstory trees (Davis et al. 1980, Fischer and Bradley 1987, Bradley et al. 1992).

While fire may kill existing trees, the use of fire may also result in a mineral seedbed perfect for Douglas fir seedlings (Davis et al. 1980, Fischer and Bradley 1987, Bradley et al. 1992). Therefore, knowledge of how Douglas fir may respond to fire is essential. Fire-related successional pathways for Douglas fir habitat types have been described for much of the Rocky Mountain region (Davis et al. 1980, Fischer and Clayton 1983, Fischer and Bradley 1987, Bradley et al. 1992). Stickney (1980) stated that "a fundamental understanding of forest succession requires basic information on the response of component species to disturbance and subsequent successional change."

Effects of Fire on Mountain Big Sagebrush and Herbaceous Species

Mountain Big Sagebrush

The decision to control Douglas fir establishment in mountain big sagebrush communities with prescribed fire may be influenced by the effects of fire on mountain big sagebrush and herbaceous species. Mountain big sagebrush is easily killed by fire (Blaisdell 1953, Harniss and Murray 1973, Bushey 1986). Because mountain big sagebrush is a non-sprouter and must recover from seed, the time required for recovery to pre-burn levels is extremely variable.

Bunting et al. (1987) stated that mountain big sagebrush might return to pre-burn density and cover levels within 15-20 years; however, no data was provided to support this claim. Studies have indicated that recovery time may be significantly longer. Walhof (1997) reported that burned mountain big sagebrush sites measured up to 16 years after burning had considerably less canopy cover and sagebrush density than paired unburned sites. Fraas et al. (1992) reported that canopy cover of mountain big sagebrush on burned sites 8 years after burning was significantly less than on paired unburned sites. Harniss and Murray (1973) reported that mountain big sagebrush made little increase in production the first 12 years following burning, and that 30 years after burning, density of mountain big sagebrush on burned areas was only 83% of unburned areas. Blaisdell (1953) found that 15 years after burning, mountain big sagebrush density on burned sites was only 50% of unburned sites.

Although it may take many years for mountain big sagebrush to reach pre-burn levels of density and cover, mountain big sagebrush may reestablish rapidly following burning (Blaisdell 1953, Bushey 1986, Walhof 1997). Walhof (1997) showed that in his study areas, peak reestablishment of mountain big sagebrush occurred within the first 4 growing seasons after the burn. Peak reestablishment occurred in either the year of treatment or the year following treatment in 4 out of 7 mountain big sagebrush locations (Walhof 1997).

How quickly mountain big sagebrush plants become reestablished may depend on burn intensity related to how many sagebrush plants survive the burn, as well as seed production prior to burning (Blaisdell 1953). Johnson and Payne (1968) reported that the number of big sagebrush (subspecies not given) surviving spraying and plowing treatments was the most important factor influencing sagebrush re-invasion. Winward (1970) noted that mountain big sagebrush often becomes dense following a disturbance. The rapid reestablishment of mountain big sagebrush may be attributed to the fact that it generally occupies more mesic sites than the other 2 subspecies of big sagebrush (Winward and Tisdale 1977). The fact that mountain big sagebrush may reach reproductive maturity in 3-5 years may also allow it to recover more rapidly in burned areas (Bunting et al. 1987).

Herbaceous Species

Because prescribed fire is often used or recommended to control encroaching Douglas fir (Bushey 1986, USDA 1986), knowledge of the effects of fire on herbaceous species is important for deciding on an individual case basis whether or not to use prescribed fire. Lyon (1971) reported that the number of herbaceous species doubled within 7 years after burning a Douglas fir community in south central Idaho. Bushey (1986) reported that herbaceous production doubled and even tripled following burning of mountain big sagebrush and Douglas fir. Wambolt and Payne (1986) found that basal cover of perennial grasses was over 6 times higher 3 years after burning Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* Beetle and Young), and that production was still 3 times higher than the pre-burn level 17 years after burning. Blaisdell (1953) and Mueggler and Blaisdell (1958) also documented increases in herbaceous production following burning of big sagebrush-grasslands.

While burning may have a positive effect on herbaceous species, the positive effects often decrease over time. Blaisdell (1953) stated that increases in grass and forb production might be short-lived. Fraas et al. (1992) reported that while there were more herbaceous species in burned areas 8 years after burning, total grass canopy cover was similar to unburned sites. Harniss and Murray (1973) reported that herbaceous species increased the first 12 years after burning, but that 30 years after burning, relative yields of various grasses were near pre-burn levels. Walhof (1997) reported that perennial grass canopy cover was not significantly different overall between 13 paired burned and unburned areas of different ages.

The effects of fire on Idaho fescue and bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith) are of particular importance, because these 2 species often form habitat types with big sagebrush and Douglas fir (Pfister et al. 1977, Mueggler and Stewart 1980). These 2 species are also important forage species for both wildlife and cattle. Idaho fescue can be seriously injured by fire (Blaisdell 1953, Countrymen and Cornelius 1957, Conrad and Poulton 1966, Harniss and Murray 1973, Young 1982). The amount of damage to Idaho fescue appears to be related to factors affecting burn intensity such as the amount of sagebrush cover and the amount of dead fescue present (Conrad and Poulton 1966, Gruell et al. 1986). While initially damaged, Idaho fescue may recover from injury fairly quickly, as Antos et al. (1983), in grasslands, and Bushey (1986), in Douglas fir encroached mountain big sagebrush communities, reported that Idaho fescue had recovered to at least pre-burn levels 3 years after burning. Walhof (1997), in southwestern Montana big sagebrush-grasslands, reported that overall Idaho fescue cover did not differ significantly between burned and unburned areas of different ages. Gruell et al. (1986) recommended burning Idaho fescue in the spring or in the fall, after plants are dormant to reduce injury.

Bluebunch wheatgrass appears to be less affected by fire than Idaho fescue in big sagebrush-grasslands (Conrad and Poulton 1966). Antos et al. (1983) reported no significant difference in bluebunch wheatgrass cover between burned and unburned sites 1 growing season after burning. Conrad and Poulton (1966) reported that fire affected bluebunch wheatgrass plant size and not plant density. Blaisdell (1953) reported that bluebunch wheatgrass was slightly affected initially by fire in mountain big sagebrush-grasslands, but responded well following burning. Harniss and Murray (1973) reported that after an initial decline, production of bluebunch wheatgrass was nearly double 12 years after burning of mountain big sagebrush-grasslands. However, Fraas et al. (1992) reported no difference in bluebunch wheatgrass canopy cover between paired burned and unburned sites 8 years after burning of mountain big sagebrush-bluebunch wheatgrass communities.

Importance of Cover to Big Game

Cover, a significant component of big game habitat in the northwestern United States, may influence the microclimate of an area and obstruct visibility, thereby providing security from a distance (Peek et al. 1982). Lyon and Jensen (1980) stated that in the case of clear-cuts, the willingness of animals to enter an opening is influenced by requirements for security. Security (hiding) cover appears to be a requirement for elk in the presence of human disturbance (Peek et al. 1982). Gruell et al. (1982) stated that sparse cover subjects elk to harassment and allows hunters to be more effective. Lyon (1979) found that tree cover modified use of a roaded area by elk, and that increasing tree cover resulted in elk losing less habitat effectiveness due to roads. While elk use of different tree canopy cover classes in northwestern Montana is season and sex dependent, they use areas with no tree canopy cover the least (Marcum 1975, Marcum et al. 1984).

Thomas et al. (1979) defined hiding cover 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 61m (200 feet). The distance away an elk or deer (*Odocoileus* spp.) is seen is called the site distance. Site distance is a function of the horizontal shielding effects of low growing vegetation and tree stems (Skovlin 1982). Lyon and Jensen (1980) stated that elk in western Montana would not fully utilize a clear-cut until vegetation reached a minimum of 1 m in height. Lyon and Jensen (1980) found that deer use of clear-cuts in western Montana dramatically increased after vegetation height exceeded 0.3 m, and then leveled off after vegetation reached 1 m in height. For eastern Montana deer, use of clear-cuts increased as vegetation height in the opening increased (Lyon and Jensen 1980). Maximum use occurred shortly before growth reached 1 m in height. Canfield et al. (1986) stated that steep viewing angles reduce the effectiveness of cover, but that this is buffered by tree height due to a trigonomic layering effect. Taller trees provide better security cover with a threshold appearing to exist at around 7.6-9.1 m.

The security benefits of increases in canopy cover may be tempered by reduced forage amounts. Lyon and Jensen (1980) stated that both elk and deer preferred clear-cuts with cover in the opening except when cover inhibited forage growth. Suring and Vohs (1979) reported that communities that provided both hiding cover and forage were more heavily utilized by Columbian white-tailed deer (*Odocoileus virginianus leucurus*) than communities providing only hiding cover or forage. Loft and Menke (1984) stated that Columbian black-tailed deer (*Odocoileus hemionus columbianus*) used plots that had low tree canopy cover, high amounts of hiding cover from vegetation 0-0.5 m tall, high herbaceous production, and higher amounts of shrubs. Short et al. (1977) and Reynolds (1964) reported that mule deer and elk use of pinyon-pine (*Pinus edulis* Engelm.)-juniper (*Juniperus* spp.) woodlands decreased as tree density increased and shrub and herbaceous production decreased. However, Reynolds (1964) reported that pellet group numbers were lowest where densities of trees and shrubs were the lowest, indicating that some tree presence was desired.

While increasing security cover may benefit elk and mule deer, it has a negative impact on bighorn sheep (*Ovis canadensis*). Visibility is an important habitat variable to bighorn sheep (Risenhoover and Bailey 1980, Wakelyn 1987, Etchberger et al. 1989). Bighorn sheep avoid tall vegetation habitat types that reduce visibility such as Douglas fir habitat types (Risenhoover and Bailey 1985). Wakelyn (1987) stated that encroachment of tall dense shrublands and forest in the absence of fire has led to the loss of bighorn sheep habitat. Lotan and Brown (1985) reported that burning forest canopy improved bighorn sheep habitat conditions in British Columbia.

The Importance of Douglas Fir and Mountain Big Sagebrush to Wildlife

Cover and Habitat

Douglas fir establishment in mountain big sagebrush communities may provide valuable habitat to wildlife. Reports by Schwarzkoph (1973) and Steerey (1979) indicate that Douglas fir and big sagebrush habitat types play an important role for mule deer in the Bridger Mountains of Montana. Douglas fir and mountain big sagebrush may benefit wildlife by providing both security cover and forage. Douglas fir provides good security cover because 1) branches are moderately low and dense in saplings, and run the length of the bole in mature trees (Flint 1925, Fischer and Bradley 1987); and 2) Douglas fir generally forms moderate to dense stands (Flint 1925).

Big sagebrush may provide protective cover for mule deer fawns and elk calves, nesting habitat for songbirds, and habitat for small mammals (Peterson 1995). Sagebrush also provides the dominant nesting cover for sage grouse (Wallestad and Pyrah 1974). Sagebrush habitats are also important during the sage grouse breeding and brood rearing periods (Klebenow 1969, Wallestad and Schladweiler 1974). Roberson (1984) stated that sage grouse are sagebrush obligates.

Forage

The use of big sagebrush as forage by mule deer and elk has been well documented (Wilkins 1957, Schwarzkoph 1973, Kufeld 1973, Kufeld et al. 1973, Steerey 1979, Welch and Wagstaff 1990, Wambolt 1996). Wambolt (1996) and Personius et al. (1987) reported that mountain big sagebrush was the preferred subspecies of big sagebrush. However, Striby (1985) stated that Wyoming big sagebrush was the most preferred subspecies based on form class assessment, with mountain big sagebrush being the second most preferred. In addition to being important to big game, big sagebrush is also the primary staple for sage grouse, especially during the winter (Wallestad et al. 1975).

Mule deer use of small to trace amounts of Douglas fir as forage has been reported in the Bridger and Little Belt Mountains of Montana (Wilkins 1957, Lovass 1958, Schwarzkoph 1973, Steerey 1979). While damage to Douglas fir seedlings by both black-tailed deer and elk (*Cervus elaphus roosevelti*) has been reported in western Washington and Oregon (Campbell and Evans 1975), mule deer generally select needles from larger diameter trees rather than smaller diameter ones (Tucker et al. 1976, Dawson et al. 1990). Mule deer also select needles from trees in openings over those in gullies (Tucker et al. 1976).

METHODS

Study Areas

Selection

Three mountain big sagebrush communities with encroaching Douglas fir were selected for study. Aerial photographs taken over a number of years verified that encroachment was actually occurring. Study areas were geographically separated to increase the study's range of inference. The minimum distance between study areas was 41 km, while the maximum distance was 148 km. The areas exhibited the following characteristics: 1) levels of encroachment that were characterized by a range of Douglas fir canopy cover from low to high; 2) an area large enough to contain 25 study sites 30.5 x 30.5 m in size; and 3) no recent impacts on the communities from burning, spraying or cutting.

Description

Study areas were located in southwestern Montana (Fig. 1). Legal descriptions and sampling dates for each study area are in Table 1. All study areas were classified as Douglas fir/Idaho fescue habitat types (Pfister et al. 1977). The Douglas fir/Idaho fescue habitat type is part of the cool-dry Douglas fir habitat types fire group (Fischer and Clayton 1983).

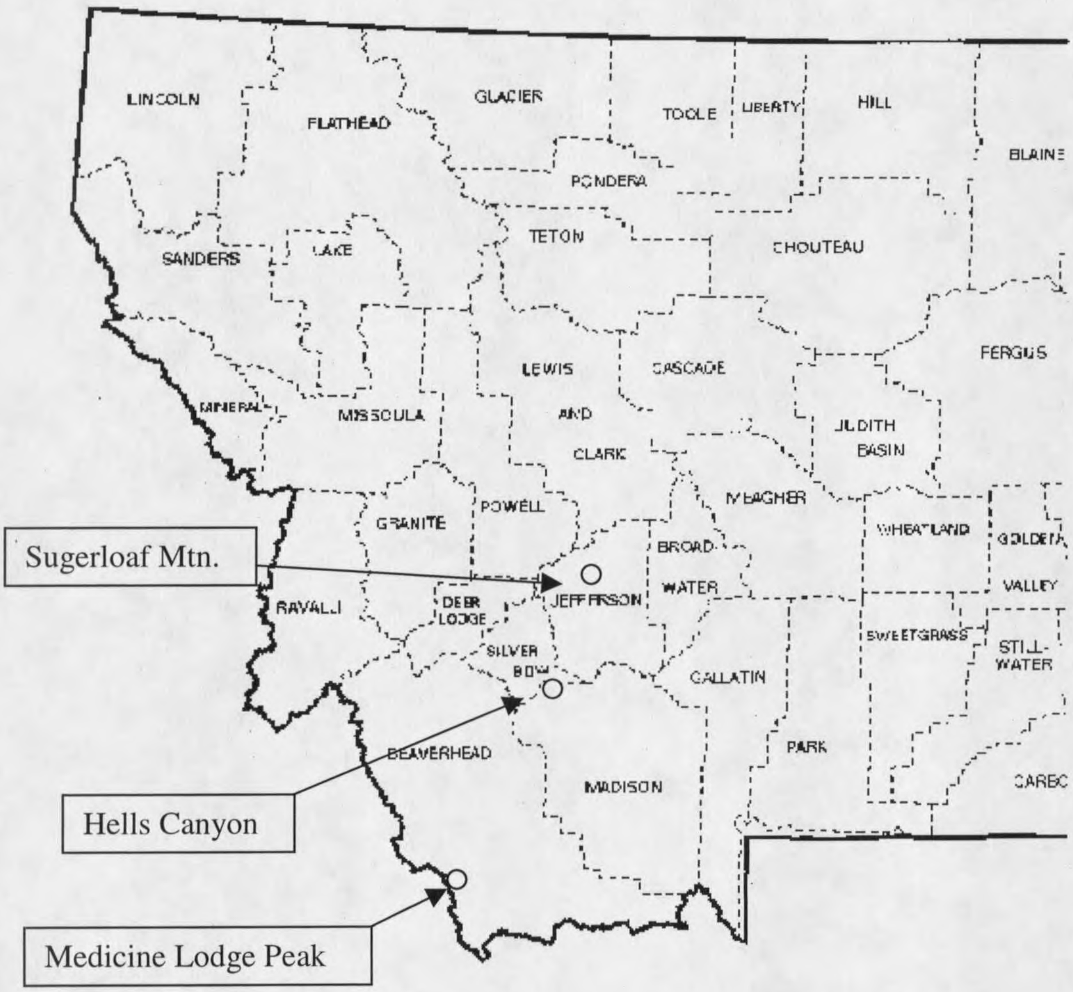

Figure 1. Map of 3 study areas in southwestern Montana.

Table 1. Legal descriptions and sampling dates for 3 study areas.

SITE	Legal Description	Date Sampled
Sugerloaf Mountain	6N 4W SW S7, NW S18 6N 5W SE S12, NE NE S13	July, August, 1996
Medicine Lodge Peak	12S 12W S SE S10, SE SE SW S10 12 S 12W NE S15, NE NE NW S15	June, July, 1997
Hells Canyon	1S 6W NW SW S32, SW NW S32 1S 6W NW S31	July, August, 1997

Sugerloaf Mountain Study Area

The Sugerloaf Mountain (SLM) study area is located in Jefferson County approximately 6 km northwest of Boulder, MT on Bureau of Land Management (BLM) land. The area is part of the Boulder Batholith formation and is several kilometers north of Arno and Gruell's (1986) Galena Gulch study area. Parent material is intrusive igneous rock (Montagne et al. 1982). The soil was classified as a sandy, mixed Typic Cryoboroll (Soil Survey Staff 1994). Slope, aspect, elevation and A horizon soil texture for each of the 25 study sites are given in Table 2. Mean annual air temperature is 3.9° C (Caprio et al. 1994). The length of the freeze-free season is 70-90 days with an annual precipitation of 357-406 mm, with most of this occurring May-July (Caprio et al. 1994). A vegetation species list for the area is provided in Appendix A. Cattle graze the area in the summer. Mule deer appears to be the primary big game species using the area, although some elk fecal pellets were seen in the study area.

Table 2. Slope, aspect, elevation, and A horizon soil texture of Sugerloaf Mountain study sites.

Site#	Degree of Slope	Aspect	Elevation (m)	Soil Texture of A Horizon
1	12	E	1820	Loamy Medium Sand
2	9	E-NE	1829	Loamy Medium Sand
3	14	E	1823	Loamy Medium Sand
4	9	E	1817	Loamy Medium Sand
5	10	SE	1811	Loamy Medium Sand
6	12	E	1811	Loamy Coarse Sand
7	11	E-SE	1804	Loamy Medium sand
8	7	S	1792	Loamy Medium Sand
9	6	S	1817	Loamy Medium Sand
10	9	S	1817	Loamy Medium Sand
11	10	S	1823	Loamy Medium Sand
12	14	E-SE	1826	Medium Sandy Loam
13	12	E	1826	Loamy Coarse Sand
14	14	E	1826	Loamy Medium Sand
15	14	E	1835	Loamy Medium Sand
16	16	E	1841	Loamy Medium Sand
17	17	NE-E	1853	Medium Sandy Loam
18	11	SE	1841	Loamy Medium Sand
19	9	SE-S	1841	Loamy Medium Sand
20	12	SE	1853	Coarse Sandy Clay Loam
21	10	SE	1853	Loamy Coarse Sand
22	9	S	1823	Loamy Coarse Sand
23	13	E-SE	1865	Coarse Sandy Loam
24	14	NE-E	1871	Coarse Sandy Loam
25	14	E	1868	Coarse Sandy Loam

Medicine Lodge Peak Study Area

The Medicine Lodge Peak (MLP) study area is located in Beaverhead County approximately 24 km south of Grant, MT on BLM land. The study area lies in the foothills of the Beaverhead Mountains. Parent material is intrusive igneous rock (Montagne et al. 1982). The soil was classified as a clayey-skeletal, mixed Argic Cryoboroll (Soil Survey Staff 1994). Slope, aspect, elevation and A horizon soil texture for each of the 25 study sites are given in Table 3. The mean annual air temperature is 1.7° C (Caprio etal., 1994). The length of the freeze-free season is 10-30 days with

Table 3. Slope, aspect, elevation, and A horizon soil texture of Medicine Lodge Peak study sites.

Site#	Degree of Slope	Aspect	Elevation (m)	Soil Texture of A Horizon
1	10	288	2231	Silty Clay Loam
2	11	344	2231	Clay Loam
3	10	324	2231	Clay Loam
4	9	344	2243	Clay Loam
5	11	304	2237	Clay Loam
6	12	324	2256	Clay Loam
7	18	314	2268	Clay Loam
8	7	357	2231	Clay Loam
9	10	352	2256	Clay Loam
10	9	346	2237	Clay Loam
11	18	328	2268	Clay Loam
12	14	318	2243	Clay Loam
13	12	332	2237	Silty Clay Loam
14	14	320	2249	Clay
15	14	342	2280	Clay Loam
16	10	0	2286	Silty Clay Loam
17	9	334	2259	Silty Clay Loam
18	10	0	2261	Clay Loam
19	9	0	2261	Clay Loam
20	9	356	2268	Silty Clay Loam
21	7	354	2262	Clay Loam
22	7	4	2274	Clay Loam
23	8	348	2274	Clay Loam
24	7	24	2280	Sandy Clay Loam
25	14	342	2280	Clay Loam

annual precipitation of 357-406 mm, with most of this occurring from April-July. A vegetation species list for the area is provided in Appendix A. Cattle graze the area in the summer. Mule deer were seen in the study area, and elk were seen in the vicinity of the study area. Mule deer, elk, and moose fecal pellets were seen in the study area.

Hells Canyon Study Area

The Hells Canyon (HC) study area is located in Madison County approximately 20 km northwest of Twin Bridges, MT on BLM and Big Sky Lumber Company land.

The study area lies in the foothills of the Highland Mountains. Parent material is intrusive igneous rock (Montagne et al. 1982). The soil was classified as a coarse-loamy, mixed Argic Cryoboroll (Soil Survey Staff 1994). Slope, aspect, elevation and A horizon soil texture for each of the 25 study sites are given in Table 4. Mean annual air temperature is 2.2° C. The length of the freeze-free season is 70-90 days with an annual precipitation of 254-305 mm, with most of this coming from April-July (Caprio et al. 1994). The annual precipitation level is probably higher than that reported based on the plant species composition of the area. A vegetation species list for the area is provided in Appendix A. Cattle graze the area in the summer. Both mule deer and elk were seen in the study area, although very few fecal pellets were seen in the area. Moose were seen in the vicinity of the study area, and moose fecal pellets were seen in the study area.

Field Procedures

Twenty-five study sites were subjectively selected in order to sample across a continuum of Douglas fir establishment levels from low to high. Areas that were severely impacted by livestock such as bedding areas were avoided. At each site Douglas fir canopy cover, density, diameter at breast height (Dbh) [breast height = 1.5 m], height, and age were measured along with mountain big sagebrush canopy cover, density, winter forage production, and age. Herbaceous canopy cover was also determined.

Canopy Cover

Douglas fir and mountain big sagebrush canopy cover was measured using the line intercept method (Canfield 1941). At each study site, canopy cover was measured along 6 stratified 30.5-m transect lines. Transect lines were placed approximately 4.6 m

Table 4. Slope, aspect, elevation, and A horizon soil texture of Hells Canyon study sites.

Site#	Degree of Slope	Aspect	Elevation (m)	Soil Texture of A Horizon
1	5	192	2134	Sandy Clay Loam
2	6	194	2140	Sandy Clay Loam
3	9	202	2134	Sandy Clay Loam
4	9	196	7040	Sandy Clay Loam
5	7	196	2134	Sandy Clay Loam
6	8	184	2164	Sandy Clay Loam
7	9	172	2156	Sandy Clay Loam
8	6	180	2182	Sandy Clay Loam
9	7	170	2188	Sandy Clay Loam
10	8	166	2195	Sandy Clay Loam
11	6	173	2200	Sandy Clay Loam
12	5	182	2207	Sandy Clay Loam
13	8	185	2158	Sandy Clay Loam
14	14	126	2207	Sandy Clay Loam
15	12	109	2231	Clay Loam
16	16	89	2237	Clay
17	15	117	2237	Sandy Clay Loam
18	6	158	2173	Clay
19	18	100	2207	Clay Loam
20	18	97	2219	Clay Loam
21	14	106	2219	Sandy Clay Loam
22	16	74	2231	Sandy Clay Loam
23	13	90	2280	Sandy Clay Loam
24	10	169	2146	Sandy Clay Loam
25	10	187	2128	Sandy Clay Loam

apart on a 30.5-m baseline transect starting at the 4.6 m mark. Canopy cover was measured in 3-cm increments. Only Douglas fir and mountain big sagebrush live, actively growing tissue was measured. Gaps in the canopy ≥ 3-cm were not counted. A 1.8-m metal rod was placed perpendicular to the transect line to determine where Douglas fir intercepted the line. A visual vertical projection of the rod was required when the rod did not make physical contact with the Douglas fir foliage.

Density

Density of mountain big sagebrush and Douglas fir was determined at each site using 6 belt transects 2 x 30.5 m in size. Belt transects were centered on the line intercepts used for estimating shrub and tree canopy cover. These belt transects were also used for height, Dbh, age, winter forage production, and herbaceous canopy cover measurements. Douglas fir density was determined for total trees and for trees ≥ 1.5 m in height. Big sagebrush density was measured for "little" sagebrush (average crown cover <15 cm), "large" big sagebrush (average crown cover ≥ 15 cm), and for dead plants. Average crown cover was determined by taking the average of 4 live canopy cover measurements. Measurements were made along the major axis of the plant (the maximum horizontal distance across the plant canopy from living plant tissue to living plant tissue), the minor axis (the maximum crown width perpendicular to the major axis, also measured from living tissue to living tissue), and 2 perpendicular measurements taken at 45 degree angles to the intersection of the major and minor axis (Wambolt et al. 1994). Canopy cover was defined as actively growing plant material such as leaves, current growth twigs and reproductive stalks (Creamer 1991). Gaps of non-actively growing plant material ≥ 3 cm were excluded for the Sugerloaf Mountain study area, while gaps ≥ 1 cm were excluded for the other study areas. I did not realize this discrepancy in measurements until after my field sampling was completed. I believe that its impact on the number of sagebrush in each size class was insignificant, as the appropriate size class for most plants was easily recognized. Plants were defined as being dead when live crown cover was < 25% of total crown cover.

Tree Height

The height of all trees occurring in the belt transects was measured or estimated to the nearest 0.15 m for the Medicine Lodge Peak and Hells Canyon study areas. Tree heights were measured if they were short enough to measure with a meter stick. A 1.8-m metal rod was used to help estimate tree height when it could not be measured with a meter stick. For the Sugerloaf Mountain study area all tree heights were measured or estimated in those belt transects having ≤ 7 trees. In those transects having > 7 trees, 5 tree heights were measured or estimated to the nearest 0.15 m. Taller tree heights were estimated with a clinometer for the Sugerloaf Mountain study area. I did not use this technique for the other study areas, as I felt comfortable in my ability to accurately estimate tree heights without a clinometer. Trees selected for height measurements when more than 5 trees were present were selected in an attempt to get the best average height possible.

Basal Area

Dbh was measured in centimeters using a meter stick for all trees ≥ 1.5-m in height in the belt transects. Dbh readings were later converted to basal area using the formula for area of a circle ($A = \Pi r^2$). Total basal area per transect was determined by summing individual tree basal areas.

Mountain Big Sagebrush Winter Forage Production

Winter forage production of mountain big sagebrush was estimated using models developed for specific browse form classes (Wambolt et al. 1994). The equations used are given in Appendix B. Heavily browsed plants had a dense, hedged, club-like appearance, while lightly browsed plants had a more bushy appearance and exhibited longer leaders. Browse form classes are the result of browsing pressure over a number of years.

Where possible, 10 mountain big sagebrush plants in each belt transect were selected for estimating winter forage production. Mountain big sagebrush plants were selected in an attempt to proportionately sample plants of different sizes (Creamer 1991). An initial measurement was made along the major axis of the plant using a meter stick. This measurement was the maximum distance across the plant from photosynthetic tissue to photosynthetic tissue in centimeters and included non-photosynthetic gaps. Four canopy cover measurements were taken with a meter stick to determine average crown cover, as previously described in the sagebrush density section. The initial major axis measurement (MJ) and average crown cover were used in the formulas found in Appendix B. After field sampling was completed, I discovered that the original technique did not exclude canopy gaps in the measurement of average crown cover. My mistake was the result of a misinterpretation of the original technique description in Creamer (1991). Due to my mistake, I effectively shrunk the size of each individual plant measured, which resulted in an underestimation of winter forage production/plant. Only "large" mountain big sagebrush plants (average crown cover $\geq$ 15 cm) were used for determining winter forage production (Creamer 1991). Total sagebrush production/transect was determined by multiplying the density of "large" mountain big sagebrush by the average winter forage production/plant.

<u>Age</u>

Douglas fir and mountain big sagebrush were aged in the field by counting annual growth rings. An increment borer was used to collect core samples in larger trees. Smaller Douglas fir trees and big sagebrush were cut with a saw as close to the ground as possible. Where present at least 5 Douglas fir trees and 5 big sagebrush plants were selected for aging in each density transect. Douglas fir of varying heights were selected for aging when more than 5 trees were present in an attempt to get the best average age estimate. Big sagebrush plants were selected for aging by selecting the plant closest to given increment marks (intervals of 6 m) on the line transect tape.

Herbaceous Understory Cover

Herbaceous canopy cover was determined using the Daubenmire (1959) canopy cover method with modification. I only measured canopy cover of plants rooted inside the quadrat. Ten 20 x 50 cm plots were recorded in each belt transect for a total of 60/study site. Plots were placed along the line intercept transect every 3 m starting at the 1.5 m mark. Estimates for total herbaceous canopy cover (grasses and forbs), grass canopy cover, and forb canopy cover were placed into 1 of 6 canopy cover classes. The 6 canopy cover classes were 0-5%; 5-25%, 25-50%, 50-75%, 75-95%, 95-100%, with the mid-point of each class used in data analysis.

Statistical Procedures

Site means were used in all statistical analysis (n = 25). Summary statistics for site means were obtained by using PROC MEANS (SAS 1988). Site means were generally determined by taking the average of the data collected from the 6 line/belt transects; however, weighted averages were used for Douglas fir age and height, and sagebrush age and winter forage production per plant. Weighted averages were required because transect averages for the variables were based on different numbers of observations. Weighted averages were determined by adding the data from all 6 belt transects together and dividing by the total number of observations.

Individual regression models for each study area were developed for 4 dependent variables: 1) mountain big sagebrush canopy cover; 2) the density of "large" mountain big sagebrush; 3) grass canopy cover; and 4) total herbaceous canopy cover. Models were also developed for mountain big sagebrush winter forage production per plant and total mountain big sagebrush winter forage production per transect. However, because of the error in measuring average crown cover, which resulted in the underestimation of these variables, I decided to drop these models. I felt that any predictions from these models would be inaccurate.

Correlation matrices for all independent and dependent variables were produced using PROC CORR (SAS 1988) for each study area and for overall. In order to reduce the potential for multicollinearity and variable redundancy, it was arbitrarily decided, after consultation with a statistician, that any 2 independent variables having an $r \geq 0.70$ would not be used in the same model. Because the independent variables Douglas fir canopy cover, total Douglas fir basal area, total Douglas fir density and density of

Douglas fir $\geq$ 1.5 m in height were highly correlated, each of these 4 predictor variables was used with the tree height variables, average total tree height and average height of trees $\geq$ 1.5 m in height, and Douglas fir age to create 4 variable groups for model development. In addition, independent variables were plotted against dependent variables to determine if a curvilinear relationship existed. When a potential curvilinear relationship existed, a quadratic term was added to the list of predictor variables for that response variable. While some models might contain a quadratic term, all models were linear in form in that they were linear in the variables; that is, no regression coefficients occurred as exponents (Neter et al. 1996). The list of predictor variables for each response variable is given by study area in Tables 5-7.

Models for each response variable were run using PROC REG (SAS 1988) for each study area. Models were selected for final diagnostic analysis based on having the highest R^2_a values. The R^2_a value is derived by dividing each sum of squares by its associated degrees of freedom, and thereby adjusts for the number of predictor variables in the model (Neter et al. 1996). When there were models for a given response variable with similar R^2_a values, diagnostic procedures were done on all selected models. When more than one model was considered, the final "best" model was determined by evaluating the $Press_p$ statistic for each model. The $Press_p$ statistic is a measure of how well the fitted values for a given model predict the observed response values (Neter et al. 1996). The model with the lowest $Press_p$ statistic was generally selected. If models had similar $Press_p$ statistics, then problems with non-constant variance, normality, or highly influential observations were also taken into consideration.

The presence of any highly influential observations was determined by examining

Table 5. Predictor variables used in models for the Sugerloaf Mountain study area.

Response Variable	DF Cover Group	Total Basal Area Group	Total DF Density Group	DBH Density Group
SAGELINT	DFLINT $DFLINT^2$ TOTREEHT DFAGE	TOBAREA TOTREEHT DFAGE	TDFDENS $TDFDENS^2$ TOTREEHT DFAGE	DBHDENS $DBHDENS^2$ TOTREEHT DFAGE
ARTRG15	DFLINT $DFLINT^2$ TOTREEHT DFAGE	TOBAREA TOTREEHT DFAGE	TDFDENS $TDFDENS^2$ TOTREEHT DFAGE	DBHDENS $DBHDENS^2$ TOTREEHT DFAGE
GRASSCOV	DFLINT $DFLINT^2$ TOTREEHT DFAGE	TOBAREA $TOBAREA^2$ TOTREEHT DFAGE	TDFDENS $TDFDENS^2$ TOTREEHT DFAGE	DBHDENS TOTREEHT DFAGE
HERBCOV	DFLINT TOTREEHT DFAGE	TOBAREA TOTREEHT DFAGE	TDFDENS TOTREEHT DFAGE	DBHDENS TOTREEHT DFAGE

Variable abbreviations: DFLINT - DF cover, TOBAREA - total DF basal area, TDFDENS- total DF density, DBHDENS - density of DF $\geq$ 1.5 m in height, TOTREEHT - average height of DF, (*Note: the variable HTG15M - average height of DF $\geq$ 1.5 m in height was not measured for this study area), DFAGE - DF age, SAGELINT - big sagebrush cover, ARTRG15 - density of "large" big sagebrush plants ($\geq$ 15 cm average crown cover), GRASSCOV - grass cover, HERBCOV - total herbaceous cover. Note: TOTREEHT & DFAGE were not used in the same model as $r > 0.70$.

studentized residuals, Cook's D value, DFFITS values, and DFBETAS values. Studentized residuals detect outlying response values; Cook's D values determine influence on all fitted values; DFFITS values determine influence on a single value; and DFBETAS values determine influence on regression coefficients (Neter et al. 1996). If an observation in a "best" model was highly influential overall then it was omitted, and the model was run without that observation. An observation was considered to be highly influential, if dropping it from the model resulted in an average change of > 5% in the fitted values.

The “best” models were validated by comparing the 80% prediction intervals for

Table 6. Predictor variables used in models for the Medicine Lodge Peak study area.

Response Variable	DF Cover Group	Total Basal Area Group	Total DF Density Group	DBH Density Group
SAGELINT	DFLINT $DFLINT^2$ TOTREEHT HTG15M DFAGE	TOBAREA TOTREEHT HTG15M DFAGE	TDFDENS $TDFDENS^2$ TOTREEHT HTG15M DFAGE	DBHDENS $DBHDENS^2$ TOTREEHT HTG15M DFAGE
ARTRG15	DFLINT $DFLINT^2$ TOTREEHT HTG15M DFAGE	TOBAREA $TOBAREA^2$ TOTREEHT HTG15M DFAGE	TDFDENS $TDFDENS^2$ TOTREEHT HTG15M DFAGE	DBHDENS $DBHDENS^2$ TOTREEHT HTG15M DFAGE
GRASSDAU	DFLINT $DFLINT^2$ TOTREEHT HTG15M DFAGE	TOBAREA $TOBAREA^2$ TOTREEHT HTG15M DFAGE	TDFDENS $TDFDENS^2$ TOTREEHT HTG15M DFAGE	DBHDENS $DBHDENS^2$ TOTREEHT HTG15M DFAGE
HERBDAU	DFLINT $DFLINT^2$ TOTREEHT HTG15M DFAGE	TOBAREA TOTREEHT HTG15M DFAGE	TDFDENS TOTREEHT HTG15M DFAGE	DBHDENS TOTREEHT HTG15M DFAGE

Variable abbreviations: DFLINT - DF cover, TOBAREA - total DF basal area, TDFDENS- total DF density, DBHDENS - density of DF ≥ 1.5 m in height, TOTREEHT - total average DF height, HTG15M - average height of DF ≥ 1.5 m in height, DFAGE - DF age, SAGELINT - big sagebrush cover, ARTRG15 - density of "large" big sagebrush plants (≥ 15 cm average crown cover), GRASSDAU - grass cover, HERBDAU - total herbaceous cover.
Note: TOTREEHT & HTG15M were not used in the same model as $r > 0.70$.

an individual observation with the observed values from the other study areas. The 80% prediction intervals were generated by rerunning the models with the statistical package MINITAB (1996), as SAS (1988) could not generate prediction intervals at that confidence level. Models were also validated by comparing a graph of the predicted values versus observed values with a line representing perfect prediction (slope = 1).

In addition to developing individual “best” models for each of the 3 study areas,

Table 7. Predictor variables used in models for the Hells Canyon study area.

Response Variable	DF Cover Group	Total Basal Area Group	Total DF Density Group	DBH Density Group
SAGELINT	DFLINT $DFLINT^2$ TOTREEHT HTG15M DFAGE	TOBAREA TOTREEHT HTG15M DFAGE	TDFDENS $TDFDENS^2$ TOTREEHT HTG15M DFAGE	DBHDENS $DBHDENS^2$ TOTREEHT HTG15M DFAGE
ARTRG15	DFLINT $DFLINT^2$ TOTREEHT HTG15M DFAGE	TOBAREA TOTREEHT HTG15M DFAGE	TDFDENS $TDFDENS^2$ TOTREEHT HTG15M DFAGE	DBHDENS TOTREEHT HTG15M DFAGE
GRASSDAU	DFLINT TOTREEHT HTG15M DFAGE	TOBAREA TOTREEHT HTG15M DFAGE	TDFDENS TOTREEHT HTG15M DFAGE	DBHDENS TOTREEHT HTG15M DFAGE
HERBDAU	DFLINT $DFLINT^2$ TOTREEHT HTG15M DFAGE	TOBAREA $TOBAREA^2$ TOTREEHT HTG15M DFAGE	TDFDENS $TDFDENS^2$ TOTREEHT HTG15M DFAGE	DBHDENS $DBHDENS^2$ TOTREEHT HTG15M DFAGE

Variable abbreviations: DFLINT - DF cover, TOBAREA - total DF basal area, TDFDENS- total DF density, DBHDENS - density of DF ≥ 1.5 m in height, TOTREEHT - total average DF height, HTG15M - average height of DF ≥ 1.5 m in height, DFAGE - DF age, SAGELINT - big sagebrush cover, ARTRG15 - density of "large" big sagebrush plants (≥ 15 cm average crown cover), GRASSDAU - grass cover, HERBDAU - total herbaceous cover.
Note: TOTREEHT & DFAGE were not used in the same model as $r > 0.70$.

variable by combining the data from the 3 study areas. Overall "best" models were developed by the same method as that used for the individual study areas. However, instead of running many different models, a "best subsets" procedure was used to determine the models with the highest R^2_a values for each response variable. This was accomplished by using the model selection procedure in PROC REG (SAS 1988). Predictor variables used for generating overall regression models are given in Table 8. Models with the highest R^2_a values were run through diagnostic analyses like the

Table 8. Predictor variables used in overall models.

Response Variable	DF Cover Group	Total Basal Area Group	Total DF Density Group	DBH Density Group
SAGELINT	DFLINT $DFLINT^2$ TOTREEHT DFAGE	TOBAREA $TOBAREA^2$ TOTREEHT DFAGE	TDFDENS $TDFDENS^2$ TOTREEHT DFAGE	DBHDENS $DBHDENS^2$ TOTREEHT DFAGE
ARTRG15	DFLINT TOTREEHT DFAGE	TOBAREA TOTREEHT DFAGE	TDFDENS TOTREEHT DFAGE	DBHDENS TOTREEHT DFAGE
GRASSDAU	DFLINT $DFLINT^2$ TOTREEHT DFAGE	TOBAREA $TOBAREA^2$ TOTREEHT DFAGE	TDFDENS $TDFDENS^2$ TOTREEHT DFAGE	DBHDENS $DBHDENS^2$ TOTREEHT DFAGE
HERBDAU	DFLINT $DFLINT^2$ TOTREEHT DFAGE	TOBAREA $TOBAREA^2$ TOTREEHT DFAGE	TDFDENS $TDFDENS^2$ TOTREEHT DFAGE	DBHDENS $DBHDENS^2$ TOTREEHT DFAGE

Variable abbreviations: DFLINT - DF cover, TOBAREA - total DF basal area, TDFDENS- total DF density, DBHDENS - density of DF ≥ 1.5 m in height, TOTREEHT - total average DF height, (*Note: HTG15M - average height of trees ≥1.5 m in height was not used in the models since, it was not measured in all three study areas), DFAGE - DF age, SAGELINT - big sagebrush cover, ARTRG15 - density of "large" big sagebrush plants (≥ 15 cm average crown cover), GRASSDAU - grass cover, HERBDAU - total herbaceous cover.
Note: TOTREEHT & DFAGE were not used in the same model as r > 0 .70.

individual study area models.

The initial overall models were “validation” models based on only 60 sites. Model validation may be done by splitting a data set (Neter et al. 1996), so a random sample of 15 observations was removed from the data set prior to the modeling process for validation purposes. The following observations were withheld from the model building process to validate the models: SLM numbers 4, 6,and 14; MLP numbers 1, 2, 4, 6, 21 and 22; HC numbers 8, 11, 16, 17, 21 and 25. Models were then validated by the same methods used for the 3 study areas. After model validation was completed the "validation" models were run with all 75 sites to determine the "full" models.

RESULTS AND DISCUSSION

Relationship of Douglas Fir, Mountain Big Sagebrush and Herbaceous Vegetation

The relationship of Douglas fir variables to mountain big sagebrush and herbaceous variables were similar across the 3 study areas; thus, they are discussed together. Because of the large volume of data, means for all measured variables at the 3 study areas are in Appendix C, while summary statistics for all variables are given in Appendix D.

Mountain Big Sagebrush Canopy Cover

Negative correlation values indicated that as Douglas fir canopy cover, total basal area, and tree density increased mountain big sagebrush canopy cover decreased in each study area (Table 9). Douglas fir canopy cover had the highest negative correlation with sagebrush canopy cover at each of the study areas. For the Sugerloaf Mountain (SLM) study area r = -0.82 (P = 0.0001), for the Medicine Lodge Peak (MLP) study area r = -0.91 (P = 0.0001), and for the Hells Canyon (HC) study area r = -0.92 (P = 0.0001), and for the combined data r = -0.86 (P = 0.0001). Sagebrush canopy cover generally declined curvilinearly as Douglas fir canopy cover increased (Fig. 2). As Douglas fir canopy cover increased to around 20% sagebrush canopy cover dropped below 15%. As Douglas fir canopy cover increased to 30-40%, sagebrush canopy cover generally decreased to about 5% or less.

Douglas fir canopy cover was the primary variable in the "best" models for each of the study areas and overall (Table 10) [standard errors of regression coefficients for all models given in Appendix E]. Although sagebrush canopy cover declined curvilinearly

Table 9. Pearson correlation coefficients between Douglas fir variables[1] and mountain big sagebrush canopy cover.

Area	DFLint	ToBarea	TDFden	DbhDen	ToTrHt	HTG15	DFage
SLM	-0.82	-0.79	-0.65	-0.68	-0.30	----------	-0.58
P-value	0.0001	0.0001	0.0001	0.0001	0.1413	----------	0.0026
MLP	-0.91	-0.85	-0.81	-0.76	-0.25	-0.55	-0.34
	0.0001	0.000	0.000	0.000	0.2295	0.004	0.092
HC	-0.92	-0.77	-0.90	-0.91	-0.48	-0.36	-0.39
	0.0001	0.0001	0.0001	0.0001	0.0152	0.0751	0.0512
Overall	-0.86	-0.80	-0.74	-0.69	-0.27	-0.48	-0.40
	0.0001	0.0001	0.0001	0.0001	0.0183	0.0004	0.0004

1: DFLint = Douglas fir canopy cover, ToBarea = total DF basal area, TDFden = total DF density, DbhDen = density of DF ≥ 1.5 m in height, ToTrHt = average total DF height, HTG15 = average height of DF ≥ 1.5m in height, DFage = average Douglas fir age.

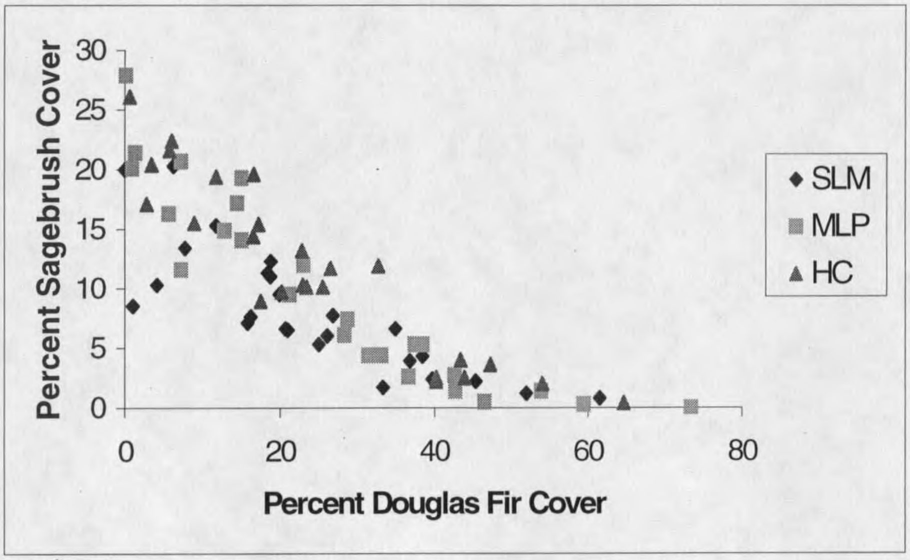

Figure 2. Douglas fir canopy cover versus mountain big sagebrush canopy cover.

overall, as Douglas fir canopy cover increased (Fig. 2, Table 10), this was not the case in all the study areas, as the model for the SLM study area was linear in form. The models involving Douglas fir canopy cover reduced the amount of variation associated with sagebrush canopy cover to a high degree (Table 10). All models yielded high R^2_a values

Table 10. "Best" regression models for mountain big sagebrush canopy cover.

Area	Model	R^2a	MSE
SLM	17.4 - 0.238DFLINT - 0.170DFAGE	0.71	8.3
MLP	23.2 - 0.711DFLINT + 0.005DFLINT^2	0.89	7.0
HC	23.8 - 0.636DFLINT + 0.004DFLINT^2	0.86	7.4
Overall[1]	22.2 - 0.669DFLINT + 0.005DFLINT^2	0.83	8.7

1: SLM site number 21 not included.
Model abbreviations: DFLINT = Douglas fir canopy cover, DFAGE = average Douglas fir age, MSE = error mean square (estimate of variance associated with the model).

ranging from 0.71 (SLM) to 0.89 (MLP).

The overall model did not include SLM site number 21. The regression influential-observation diagnostic techniques used (Neter et al. 1996) indicated that this site exerted undue influence on the regression relationship. Douglas fir canopy cover for this site measured 1%, while sagebrush canopy cover measured 8.5% (Appendix C). However, Douglas fir canopy cover on the site as a whole was > 1%, but as a result of where the line intercepts happened to fall, this was not measured. Because of this, and the fact that the normal inference range for this model should be for higher Douglas fir canopy cover amounts, I decided to omit this site to obtain a better overall model.

My finding of Douglas fir's negative impact on mountain big sagebrush canopy cover supports the opinion of Gruell et al. (1986) who stated that big sagebrush (no subspecies given) in southwestern Montana was declining due to competition from Douglas fir. Patten (1969) reported that as density and basal area of lodgepole pine (*Pinus contortus* Dougl.) in Yellowstone National Park increased, big sagebrush (no subspecies given) canopy cover decreased. Burkhardt and Tisdale (1969) reported that as western juniper canopy cover and density increased mountain big sagebrush canopy cover decreased. Arnold et al. (1964) reported that shrub canopy cover decreased as pinyon pine -juniper (*Juniperus deppeana* Steud., *Juniperus osteosperma* (Torr.) Little, *Juniperus monosperma* (Engelm.) Sarg.) canopy cover increased. Mueggler (1965) reported an r = -0.708 between tree canopy cover and sprouting shrub canopy cover in the cedar (*Thuja plicata* Donn)-hemlock (*Tsuga heterophylla* (Raf.) Sarg.) zone of northern Idaho.

Mountain Big Sagebrush Density

Negative correlation values indicated that the density of "large" mountain big sagebrush declined as Douglas fir canopy cover, basal area, and tree density increased in the 3 study areas and overall (Table 11). Correlation values indicated that as the measures of tree height and Douglas fir age increased the number of "large" mountain big sagebrush decreased (Table 11). Douglas fir canopy cover had the strongest negative relationship with the density of "large" mountain big sagebrush at each study area and overall (Table 11). Correlation values ranged from r = -0.92 ($P = 0.0001$) at the MLP study area to r = -0.94 ($P = 0.0001$) at the HC study area. Density of "large" mountain big sagebrush generally declined curvilinearly as Douglas fir canopy cover increased (Fig. 3 and Table 12); however, the HC study area was an exception as it had a linear model.

Two overall models are presented for density of "large" mountain big sagebrush (this will also be true for grass canopy cover and total herbaceous canopy cover). One model is for the "best" overall model and the other is for when only Douglas fir canopy cover is used in the model. Douglas fir canopy cover, total basal area, total tree density, and density of trees ≥ 1.5 m in height were all often highly correlated for the individual study areas (Tables 13-15), and overall (Table 16). In addition, the 2 tree density

Table 11. Pearson correlation coefficients between Douglas fir variables[1] and "large" mountain big sagebrush density.

Area	DFLint	ToBarea	TDFden	DbhDen	ToTrHt	HTG15	DFage
SLM	-0.93	-0.88	-0.82	-0.78	-0.24	----------	-0.35
P-value	0.0001	0.0001	0.0001	0.0001	0.2537	----------	0.0880
MLP	-0.92	-0.87	-0.84	-0.79	-0.202	-0.52	-0.38
	0.0001	0.0001	0.0001	0.0001	0.3341	0.0072	0.0581
HC	-0.94	-0.79	-0.91	-0.91	-0.48	-0.39	-0.42
	0.0001	0.0001	0.0001	0.0001	0.0161	0.0548	0.0359
Overall	-0.93	-0.83	-0.82	-0.77	-0.23	-0.47	-0.30
	0.0001	0.0001	0.0001	0.0001	0.043	0.0005	0.0098

1: DFLint = Douglas fir canopy cover, ToBarea = total DF basal area, TDFden = total DF density, DbhDen = density of DF ≥ 1.5 m in height, ToTrHt = average total DF height, HTG15 = average height of DF ≥ 1.5m in height, DFage = average Douglas fir age.

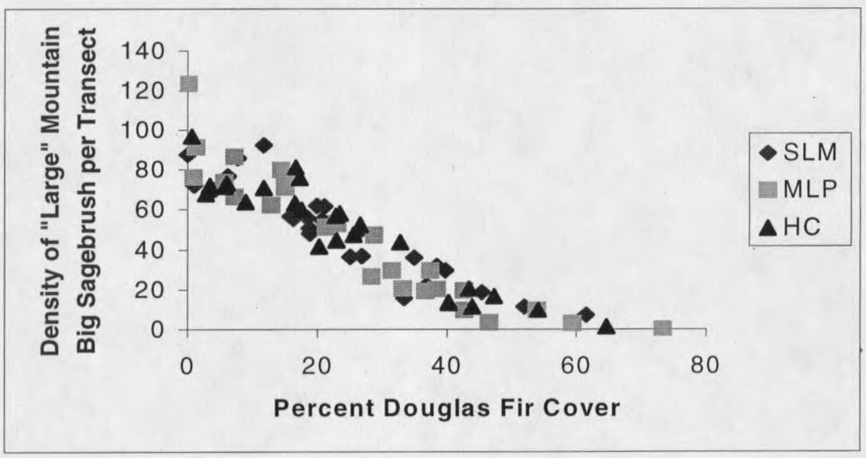

Figure 3. Douglas fir canopy cover versus density of "large" mountain big sagebrush.

Table 12. "Best" regression models for density of "large" mountain big sagebrush.

Area	Model	R^2a	MSE
SLM	$80.1 - 2.238DFLINT + 0.013DFLINT^2 + 3.891ToTrHt$	0.88	70.5
MLP	$99.6 - 2.718DFLINT + 0.018DFLINT^2$	0.90	113.6
HC	$84.3 - 1.435DFLINT$	0.87	92.4
Overall[1]	$77.5 - 2.165DFLINT + 0.011DFLINT^2 + 4.582ToTrHt$	0.90	74.3
Overall[1]	$88.9 - 1.949DFLINT + 0.008DFLINT^2$	0.88	85.7

1: MLP site number 24 not included.
Model abbreviations: DFLINT = Douglas fir canopy cover, ToTrHt = average total tree height, MSE = error mean square (estimate of variance associated with the model).

Table 13. Correlation matrix for the Sugerloaf Mountain study area Douglas fir variables[1].

	DFLint	ToBarea	TDFdens	DbhDens	ToTrHt	DFage
DFLint	1	0.94	0.85	0.90	0.38	0.46
P - value	0	0.0001	0.0001	0.0001	0.0604	0.0218
ToBarea		1	0.74	0.83	0.44	0.52
		0	0.0001	0.0001	0.0289	0.0082
TDFdens			1	0.76	0.07	0.08
			0	0.0001	0.7346	0.7028
DbhDens				1	0.33	0.42
				0	0.0151	0.0362
ToTrHt					1	0.82
					0	0.0001
DFage						1
						0

1: DFLint = DF cover, ToBarea = total DF basal area, TDFdens = total DF density, DbhDens = density of DF ≥ 1.5 m in height, ToTrHt = average total DF height, DFage = average Douglas fir age.

Table 14. Correlation matrix for the Medicine Lodge Peak study area Douglas fir variables[1].

	DFLint	ToBarea	TDFden	DbhDen	ToTrHt	HTG15	DFage
DFLint	1	0.96	0.95	0.93	0.17	0.39	0.38
P - value	0	0.0001	0.0001	0.0001	0.4110	0.0570	0.0635
ToBarea		1	0.93	0.91	0.23	0.44	0.36
		0	0.0001	0.0001	0.2610	0.0280	0.0760
TDFden			1	0.98	0.02	0.24	0.33
			0	0.0001	0.9350	0.2520	0.1070
DbhDen				1	0.12	0.21	0.45
				0	0.5790	0.3060	0.0240
ToTrHt					1	0.73	0.58
					0	0.0001	0.0023
HTG15						1	0.31
						0	0.1350
DFage							1
							0

1: DFLint = DF cover, ToBarea = total DF basal area, TDFden = total DF density, DbhDen = density of DF ≥ 1.5 m in height, ToTrHt = average total DF height, HTG15 = average height of DF ≥ 1.5 m in height, DFage = average Douglas fir age.

measures and total basal area were usually more highly correlated with Douglas fir canopy cover than with each other. Thus, canopy cover may be the only Douglas fir

Table 15. Correlation matrix for the Hells Canyon study area Douglas fir variables[1].

	DFLint	ToBarea	TDFden	DbhDen	ToTrHt	HTG15	DFage
DFLint	1	0.89	0.95	0.95	0.58	0.41	0.50
P - value	0	0.0001	0.0001	0.0001	0.0025	0.0417	0.0103
ToBarea		1	0.89	0.85	0.59	0.59	0.60
		0	0.0001	0.0001	0.0021	0.0020	0.0016
TDFden			1	0.99	0.47	0.35	0.46
			0	0.0001	0.0173	0.0875	0.0203
DbhDen				1	0.50	0.28	0.46
				0	0.0108	0.1763	00211
ToTrHt					1	0.36	0.86
					0	0.0771	0.0001
HTG15						1	0.36
						0	0.0797
DFage							1
							0

1: DFLint = DF cover, ToBarea = total DF basal area, TDFden = total DF density, DbhDen = density of DF ≥ 1.5 m in height, ToTrHt = average total DF height, HTG15 = average height of DF ≥ 1.5 m in height, DFage = average Douglas fir age.

Table 16. Correlation matrix for Douglas fir variables[1] from combined data.

	DFLint	ToBarea	TDFden	DbhDen	ToTrHt	HTG15	DFage
DFLint	1	0.91	0.88	0.87	0.31	0.38	0.36
P - value	0	0.0001	0.0001	0.0001	0.0077	0.0071	0.0017
ToBarea		1	0.83	0.77	0.36	0.47	0.44
		0	0.0001	0.0001	0.0017	0.0007	0.0001
TDFden			1	0.91	0.07	0.28	0.16
			0	0.0001	0.5640	0.0535	0.1703
DbhDen				1	0.17	0.24	0.25
				0	0.1403	0.0932	0.0341
ToTrHt					1	0.63	0.76
					0	0.0001	0.0001
HTG15						1	0.31
						0	0.0270
DFage							1
							0

1: DFLint = DF cover, ToBarea = total DF basal area, TDFden = total DF density, DbhDen = density of trees ≥ 1.5 m in height, ToTrHt = average total DF height, HTG15 = average height of DF ≥ 1.5 m in height, DFage = average Douglas fir age.

fir variable managers need to determine the effects of Douglas fir establishment on big mountain big sagebrush communities. It would be beneficial if good results could be obtained by only measuring 1 variable. Douglas fir canopy cover would be the ideal pick, as it is quick and easy to measure.

Douglas fir canopy cover was the primary variable in all the "best" models (Table 12), although average total tree height was included in 2 of the models. However, comparing the "best" overall model with the overall model that only included Douglas fir canopy cover revealed that adding average total tree height only increased the R^2_a value by 0.02. The models accounted for a large proportion of the variation associated with "large" mountain big sagebrush density as the R^2_a values for all the models were quite high (Table 12).

Medicine Lodge Peak site number 24 was not included in either overall model. The regression influential-observation diagnostic techniques used (Neter et al. 1996) indicated that this site exerted an undue influence on the regression relationship. This site had a Douglas fir canopy cover of 0.1% and was extremely productive, with an average of 123.5 "large" mountain big sagebrush/belt transect (Appendix C). I decided to omit this outlying observation because the normal range of inference for this model should be for higher levels of Douglas fir canopy cover. Omitting this site should yield a better model for the other sites.

Douglas fir canopy cover, total basal area, and density had strong negative relationships with the density of "little" mountain big sagebrush at the MLP study area (Table 17). Correlation values ranged from r = -0.79 (P = 0.0001) for density of trees ≥ 1.5 m in height to r = -0.92 (P = 0.0001) for Douglas fir canopy cover (Table 17). All Douglas fir variables had a negative correlation ($P < 0.05$) with the number of "little" mountain big sagebrush at the SLM study area. Correlation values ranged from r = -

Table 17. Pearson correlation coefficients between Douglas fir variables[1] and "little" mountain big sagebrush density.

Area	DFLint	ToBarea	TDFden	DbhDen	ToTrHt	HTG15	DFage
SLM	-0.66	-0.61	-0.63	-0.64	-0.50	----------	-0.45
P-value	0.0003	0.0012	0.0007	0.0006	0.0105	----------	0.0239
MLP	-0.92	-0.87	-0.84	-0.79	-0.20	-0.52	-0.38
	0.0001	0.0001	0.0001	0.0001	0.3341	0.0072	0.0581
HC	-0.13	-0.17	-0.04	-0.02	-0.18	-0.41	-0.08
	0.5506	0.4317	0.8424	0.9234	0.3878	0.0432	0.6935
Overall	-0.30	-0.37	-0.39	-0.31	-0.10	-0.16	-0.18
	0.0101	0.0012	0.0006	0.0077	0.4107	0.2749	0.1192

1: DFLint = Douglas fir canopy cover, ToBarea = total DF basal area, TDFden = total DF density, DbhDen = density of DF ≥ 1.5 m in height, ToTrHt = average total DF height, HTG15 = average height of DF ≥ 1.5m in height, DFage = average Douglas fir age.

0.45 ($P = 0.0001$) for Douglas fir age to r = -0.66 ($P = 0.0001$) for Douglas fir canopy cover. The effect of Douglas fir canopy cover on density of "little" mountain big sagebrush is illustrated in Figure 4.

Increases in Douglas fir canopy cover, total basal area, and density measures were positively correlated with the number of dead sagebrush. Correlation values for these 4 variables were highest at the HC and MLP study areas (Table 18). Overall, average total tree height and Douglas fir age were not significantly correlated with the number of dead sagebrush ($P > 0.10$), but the average height of trees ≥ 1.5 m in height was significantly correlated (r = 0. 47, $P = 0.0006$). Overall, the number of trees ≥ 1.5 m in height had the highest correlation with the number of dead sagebrush (r = 0.69, $P = 0.0001$), followed by Douglas fir canopy cover (r = 0.66, $P = 0.0001$). The relationship between Douglas fir canopy cover and the density of dead sagebrush is illustrated in Figure 5.

My findings of Douglas fir's negative impact on live mountain big sagebrush density concur with Gruell's (1983) observation that Douglas fir growth and subsequent canopy closure in south central Montana had resulted in mortality of big sagebrush (no

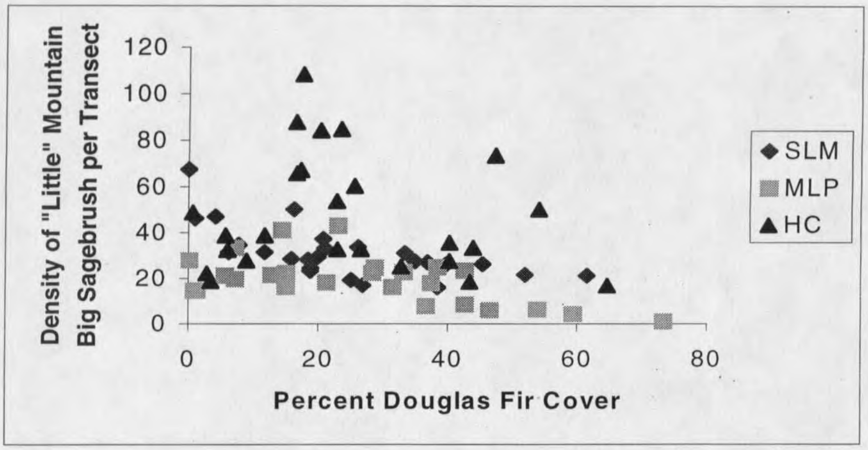

Figure 4. Douglas fir canopy cover versus density of "little" mountain big sagebrush.

Table 18. Pearson correlation coefficients between Douglas fir variables[1] and density of dead sagebrush.

Area	DFLint	ToBarea	TDFden	DbhDen	ToTrHt	HTG15	DFage
SLM	0.39	0.35	0.27	0.50	0.25	----------	0.49
P-value	0.0568	0.087	0.187	0.0106	0.2292	----------	0.0132
MLP	0.81	0.85	0.74	0.69	0.22	0.60	0.20
	0.0001	0.0001	0.0001	0.0001	0.2822	0.0014	0.351
HC	0.77	0.60	0.78	0.79	0.37	0.31	0.26
	0.0001	0.0014	0.0001	0.0001	0.068	0.1364	0.2153
Overall	0.66	0.54	0.58	0.69	0.18	0.47	0.17
	0.0001	0.0001	0.0001	0.0001	0.1228	0.0006	0.1547

1: DFLint = Douglas fir canopy cover, ToBarea = total basal area, TDFden = total DF density, DbhDen = density of DF $\geq$ 1.5 m in height, ToTrHt = average total DF height, HTG15 = average height of DF $\geq$ 1.5m in height, DFage = average Douglas fir age.

subspecies given). In addition to my study, the occurrence of dead sagebrush under Douglas fir has been reported by Arno and Gruell (1983) and by Bushey (1986). The negative impact of other tree species on big sagebrush has been reported elsewhere (Cottam and Stewart 1940, Burkhardt and Tisdale 1969, Patten 1969). Cottam and Stewart (1940) reported that big sagebrush (no subspecies given) declined as Utah

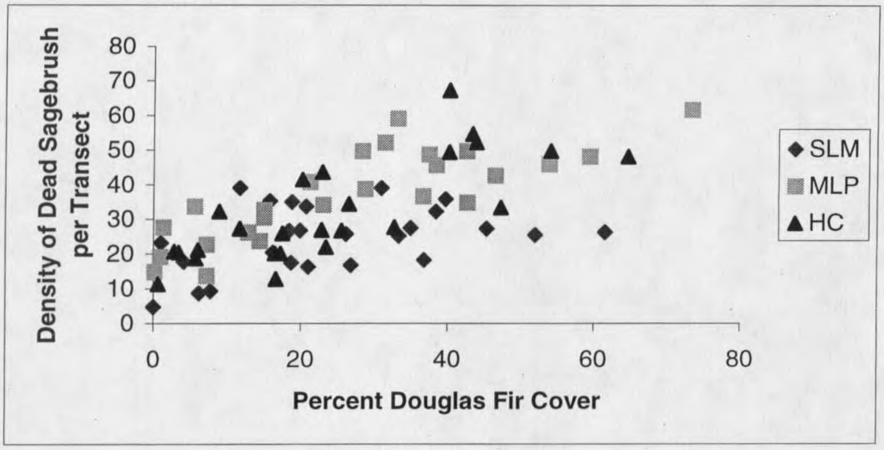

Figure 5. Douglas fir canopy cover versus density of dead sagebrush.

juniper increased, and that more dead sagebrush occurred in stands with higher amounts of juniper. Burkhardt and Tisdale (1969) reported that as western juniper canopy cover and density increased mountain big sagebrush density decreased. Patten (1969) reported that as lodgepole pine matured and became dense, big sagebrush (no subspecies given) was eliminated.

Mountain Big Sagebrush Winter Forage Production

Negative correlation values indicated that mountain big sagebrush winter forage production per plant declined as Douglas fir canopy cover, total basal area, and density increased (Table 19). Overall, mountain big sagebrush production per plant also decreased as tree height and Douglas fir age increased (Table 19). Douglas fir canopy cover, total basal area, and density measures all had a strong negative relationship with individual sagebrush production for the 3 study areas and overall (Table 19). Douglas fir canopy cover generally had the highest negative correlation with individual sagebrush production for each of the study areas and overall. Douglas fir canopy cover had an r = -

Table 19. Pearson correlation coefficients between Douglas fir variables[1] and mountain big sagebrush winter forage production per plant.

Area	DFLint	ToBarea	TDFden	DbhDen	ToTrHt	HTG15	DFage
SLM	-0.81	-0.80	-0.76	-0.65	-0.14	----------	-0.28
P-value	0.0001	0.0001	0.0001	0.0001	0.4991	----------	0.183
MLP	-0.92	-0.88	-0.83	-0.80	-0.32	-0.54	-0.39
	0.0001	0.0001	0.0001	0.0001	0.1183	0.0056	0.0563
HC	-0.93	-0.80	-0.93	-0.92	-0.45	-0.31	-0.41
	0.0001	0.0001	0.0001	0.0001	0.0249	0.1318	0.0438
Overall	-0.87	-0.77	-0.77	-0.75	-0.24	-0.47	-0.25
	0.0001	0.0001	0.0001	0.0001	0.0419	0.0006	0.0001

1: DFLint = Douglas fir canopy cover, ToBarea = total DF basal area, TDFden = total DF density, DbhDen = density of DF ≥ 1.5 m in height, ToTrHt = average total DF height, HTG15 = average height of DF ≥ 1.5m in height, DFage = average Douglas fir age.

0.81 ($P = 0.0001$) for the SLM study area, an r = -0.92 ($P = 0.0001$) for the MLP study area, an r = -0.93 ($P = 0.0001$) for the HC study area, and an r = -0.87 ($P = 0.0001$) overall. Individual mountain big sagebrush plant production declined curvilinearly overall as Douglas fir canopy cover increased (Fig. 6).

I found no studies that have documented the impact of increases in tree-related variables on mountain big sagebrush forage production. Some related work has been done with other species. Short et al. (1977) reported that current annual growth of shrubs in pinyon pine-juniper woodlands decreased as over-story density increased. McConnell and Smith (1970) reported that production of antelope bitterbrush (*Purshia tridentata* (Pursh)) and other shrubs increased as ponderosa pine canopy cover was reduced through thinning.

Increases in Douglas fir canopy cover, total basal area, and tree density decreased total mountain big sagebrush winter forage production per transect as well (Table 20). This was not surprising because total sagebrush production is a function of the density of "large" mountain big sagebrush and individual sagebrush plant production, both of which

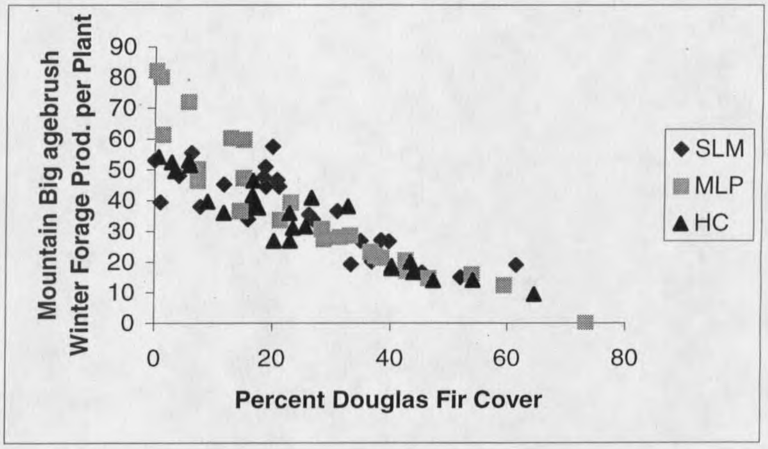

Figure 6. Douglas fir canopy cover versus mountain big sagebrush winter forage production (g) per plant.

Table 20. Pearson correlation coefficients between Douglas fir variables[1] and total mountain big sagebrush production per transect.

Area	DFLint	ToBarea	TDFden	DbhDen	ToTrHt	HTG15	DFage
SLM	-0.88	-0.86	-0.80	-0.73	-0.23	----------	-0.38
P-value	0.0001	0.0001	0.0001	0.0001	0.2722	----------	0.0607
MLP	-0.84	-0.80	-0.72	-0.68	-0.42	-0.70	-0.44
	0.0001	0.0001	0.0001	0.0001	0.0360	0.0001	0.0274
HC	-0.91	-0.74	-0.89	-0.88	-0.46	-0.38	-0.40
	0.0001	0.0001	0.0001	0.0001	0.0197	0.0634	0.0449
Overall	-0.84	-0.74	-0.71	-0.66	-0.31	-0.62	-0.32
	0.0001	0.0001	0.0001	0.0001	0.0071	0.0001	0.0001

1: DFLint = Douglas fir canopy cover, ToBarea = total DF basal area, TDFden = total DF density, DbhDen = density of DF $\geq$ 1.5 m in height, ToTrHt = average total DF height, HTG15 = average height of DF $\geq$ 1.5m in height, DFage = average Douglas fir age.

were reduced as Douglas fir variables increased. Douglas fir canopy cover, total basal area, and density measures all had a strong negative relationship with total mountain big sagebrush winter forage production/transect for the 3 study areas and overall (Table 20). Tree height measures and Douglas fir age were also negatively correlated ($P < 0.05$) with total mountain big sagebrush winter forage production/transect overall (Table 20). Douglas fir canopy cover had the strongest negative relationship with total sagebrush production for the 3 study areas and overall. Correlation values ranged from r = -0.84 (*P*

= 0.0001) for the combined data to r = -0.91 (P = 0.0001) for the HC study area. Total mountain-big sagebrush production declined curvilinearly overall as Douglas fir canopy cover increased (Fig. 7).

The negative impact of Douglas fir on mountain big sagebrush winter forage production is of particular importance to those managing mountain big sagebrush dominated winter ranges for large ungulates. Decreased forage availability may affect the foraging tactics of large ungulates. Collins et al. (1978) reported that elk habitat selection was strongly influenced by forage availability, which in turn influenced consumption rates. Wickstrom et al. (1984) found that elk foraged in conifer understory sites ranging from 339-826 kg/ha total biomass production, while mule deer used sites ranging from 180-669 kg/ha total biomass production. Wickstrom et al. (1984) reported that absolute availability of food did not become important for deer in grass-dominated communities until total biomass fell below 50-100 kg/ha.

Hobbs (1989), using a simulation model, suggested that mortality of mule deer does would increase dramatically during a severe winter if initial shrub biomass was less than 133 kg/ha. Figure 7 shows that production levels did not drop this low until generally about 35-40% canopy cover had been achieved. I believe that these results are valid even though I underestimated winter forage production (see methods). Hobbs (1989) stated that during severe winters deer density did not affect deer mortality until shrub biomass dropped below approximately 267 kg/ha. Mountain big sagebrush winter forage production did not drop to this level until approximately 30% canopy cover had been reached (Figure 7). It should be noted that Hobbs (1989) stressed that the quality of forage available was more important than the quantity.

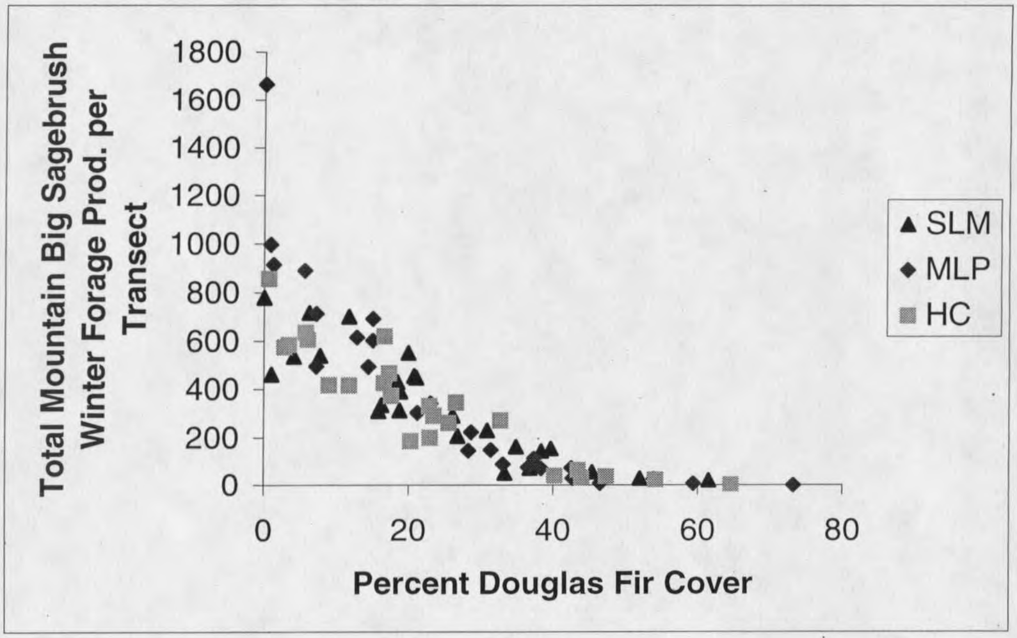

Figure 7. Douglas fir canopy cover versus total mountain big sagebrush winter forage production (kg/ha) per transect.

Mountain Big Sagebrush Age

In 2 of my study areas and overall, mountain big sagebrush age declined as Douglas fir canopy cover, total basal area, and tree density increased, as indicated by negative correlation values (Table 21). Mountain big sagebrush age was negatively correlated ($P < 0.05$) with Douglas fir canopy cover, total basal area, and tree density at the MLP and HC study areas and overall (Table 21). For the MLP study area total Douglas fir density had the strongest negative relationship with sagebrush age ($r = -0.80$, $P = 0.0001$), while for the HC study area total basal area had the strongest negative correlation with sagebrush age ($r = -0.57$, $P = 0.0028$). Overall, total basal area had the strongest negative correlation with sagebrush age ($r = -0.52$, $P = 0.0001$).

Declining mountain big sagebrush age under increasing Douglas fir canopy cover

Table 21. Pearson correlation coefficients between Douglas fir variables[1] and mountain big sagebrush age.

Area	DFLint	ToBarea	TDFden	DbhDen	ToTrHt	HTG15	DFage
SLM	-0.21	-0.01	-0.36	-0.14	0.15	----------	0.25
P-value	0.3035	0.7099	0.0757	0.5034	0.4746	----------	0.2244
MLP	-0.70	-0.71	-0.76	-0.80	-0.00	-0.05	-0.36
	0.0001	0.0001	0.0001	0.0001	0.9931	0.8290	0.0754
HC	-0.51	-0.57	-0.50	-0.51	-0.51	0.00	-0.63
	0.0097	0.0028	0.0113	0.0095	0.0096	0.9926	0.0007
Overall	-0.43	0.52	-0.50	-0.42	-0.07	-0.06	-0.21
	0.0001	0.0001	0.0001	0.0002	0.5697	0.6801	0.0650

1: DFLint = Douglas fir canopy cover, ToBarea = total DF basal area, TDFden = total DF density, DbhDen = density of DF ≥ 1.5 m in height, ToTrHt = average total DF height, HTG15 = average height of DF ≥ 1.5m in height, DFage = average Douglas fir age.

could be part of the reason why I observed that sagebrush plants under higher Douglas fir canopies appeared to be browsed less than plants in the open. Along with declining age, results from the sagebrush production section indicated that individual sagebrush production and total sagebrush production declined as Douglas fir canopy cover increased. Hoffman (1996) reported that mountain big sagebrush winter forage production was related to both mountain big sagebrush age and use levels. Older and more heavily used plants produced more forage. Hoffman (1996) reported that high use mountain big sagebrush sites had significantly older sagebrush plants than low use sites.

Grass Canopy cover

Increases in Douglas fir canopy cover, total basal area, and density had a negative effect on grass canopy cover (Tables 22). Negative correlation values for grass canopy cover were highest at the SLM and HC study areas for the aforementioned Douglas fir variables (Table 22). Correlation values were considerably lower at the MLP study area for Douglas fir canopy cover, total basal area, and density (Table 22).

Table 22. Pearson correlation coefficients between Douglas fir variables[1] and grass canopy cover.

Area	DFLint	ToBarea	TDFden	DbhDen	ToTrHt	HTG15	DFage
SLM	-0.82	-0.79	-0.78	-0.69	-0.23	----------	-0.25
P-value	0.0001	0.0001	0.0001	0.0001	0.2594	----------	0.2327
MLP	-0.49	-0.49	-0.50	-0.50	0.16	0.12	-0.11
	0.0130	0.0120	0.0111	0.0114	0.4474	0.5733	0.6091
HC	-0.80	-0.69	-0.74	-0.73	-0.48	-0.34	-0.38
	0.0001	0.0001	0.0001	0.0001	0.0160	0.0993	0.0578
Overall	-0.60	-0.63	-0.61	-0.54	-0.11	-0.11	-0.17
	0.0001	0.0001	0.0001	0.0001	0.3485	0.4480	0.1441

1: DFLint = Douglas fir canopy cover, ToBarea = total DF basal area, TDFden = total DF density, DbhDen = density of DF ≥ 1.5 m in height, ToTrHt = average total DF height, HTG15 = average height of DF ≥ 1.5m in height, DFage = average Douglas fir age.

Measures of tree height and Douglas fir age were generally not correlated ($P < 0.05$) with grass canopy cover (Table 22). Douglas fir had the strongest negative relationship with grass canopy cover at the SLM (r = -0.82, P = 0.0001) and MLP (r = -0.80, P = 0.0001) study areas, while total Douglas fir density had the strongest negative relationship (r = -0.50, P = *0.0111)* with grass canopy cover at the MLP study area. Overall, total basal area had the highest negative correlation with grass canopy cover (r = -0.63, P = 0.0001). The relationship between Douglas fir total basal area and grass canopy cover is illustrated in Figure 8, while Figure 9 shows the relationship between Douglas fir canopy cover and grass canopy cover. Grass canopy cover declined linearly as Douglas fir canopy cover increased at 2 of the 3 study areas, and declined curvilinearly in the other (Table 23). The R^2_a values wer 0.71 for the SLM study area model, 0.37 for the MLP model, and 0.63 for the HC model.

The MLP regression model was the result of omitting sites number 2 and 24 from a regression model containing the variables Douglas fir canopy cover and average height of trees ≥ 1.5 m in height. The regression influential-observation diagnostic techniques

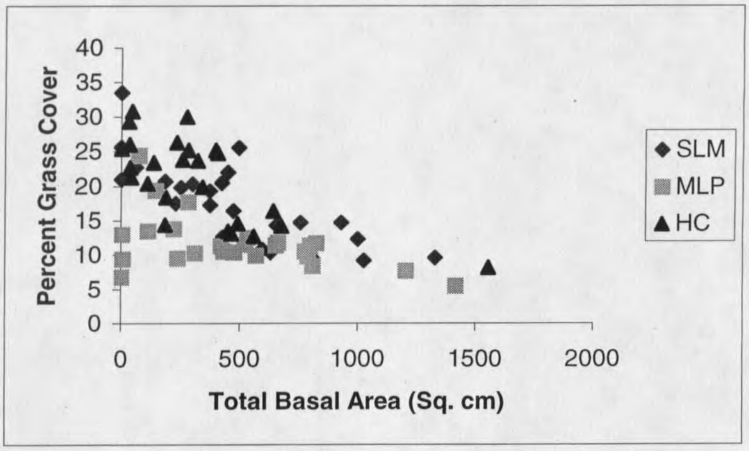

Figure 8. Total Douglas fir basal area versus grass canopy cover.

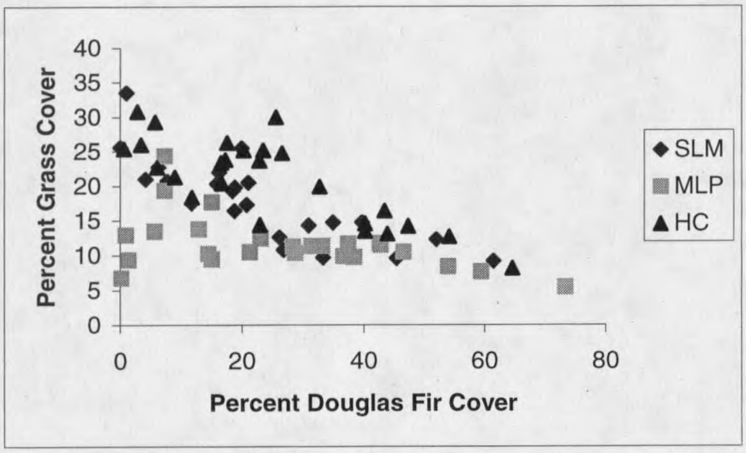

Figure 9. Douglas fir canopy cover versus grass canopy cover.

used (Neter et al. 1996) indicated that these 2 sites exerted undue influence on the regression relationship. The fact that the variable average height of trees ≥ 1.5 m in height was deleted from the model, when these 2 observations were omitted, is an indication of their influence on the model. Site number 2 had a Douglas fir canopy cover of 7.2% and a grass canopy cover of 24.4% (Appendix C) which was considerably higher

Table 23. "Best" regression models for grass canopy cover.

Area	Model	R^2a	MSE
SLM	$27.5 - 0.593DFLINT + 0.005DFLINT^2$	0.71	10.9
MLP[1]	$14.0 - 0.098DFLINT$	0.37	5.5
HC	$28.0 - 0.285DFLINT$	0.63	14.1
Overall[2]	$3.150 - 0.085TDFDENS + 0.001TDFDENS^2$	0.52	0.078
Overall[2]	$3.149 - 0.016DFLINT$	0.46	0.086

1: MLP site numbers 2 and 24 not included.
2: MLP site number 24 not included, natural log transformation done on grass canopy cover.
Model abbreviations: DFLINT = Douglas fir canopy cover, TDFDENS = total DF density, MSE = error mean square (estimate of variance associated with the model).

than the grass canopy cover measured at any other site. Site number 24 had a Douglas fir canopy cover of 0.1% with a grass canopy cover of 6.8% (Appendix C). While Douglas fir canopy cover was very low at this site, sagebrush canopy cover was 27.9% and might have been part of the reason for the low grass canopy cover. The combined effects of Douglas fir and sagebrush canopy cover on grass and total herbaceous canopy cover were not examined because of the potential for multicollinearity due to the strong negative relationship between Douglas fir canopy cover and sagebrush canopy cover. Because both of these sites were outliers, and probably out of the normal inference range of Douglas fir canopy canopy cover, I decided to omit them from the model.

Two overall models are presented for grass canopy cover (Table 23). The first model, the "best" overall model, is a curvilinear model with the variable total Douglas fir density. The second model only uses Douglas fir canopy cover, which was included in the 3 study area models. A natural log transformation was done on grass canopy cover to correct for non-constant variance in both overall models. Medicine Lodge Peak site number 24 (discussed previously) was omitted from both overall models. The regression influential-observation diagnostic techniques used (Neter et al. 1996) indicated that this site exerted undue influence on the regression model. As mentioned previously, because this site was outside of what I felt would probably be the normal inference range of Douglas fir canopy cover values, I decided to omit it from the model. Correlation values (Table 22), and models for the individual study areas (Table 23) indicated that the effects of Douglas fir on grass canopy cover at the MLP study area were not similar to the other study areas. However, I felt that any overall model should incorporate individual study area variation, if inferences were to be made across a wide geographic area.

Total Herbaceous Canopy Cover

Negative correlation values indicated that increases in Douglas fir canopy cover, total basal area and density resulted in a decrease in total herbaceous canopy cover (Table 24). Douglas fir canopy cover, total basal area, and tree density measures had the strongest negative relationships with total herbaceous canopy cover at the SLM and the HC study areas (Table 24). Correlation values at the MLP study area were considerably lower (Table 24). Tree height measures and Douglas fir age were only correlated ($P <$ 0.05) with total herbaceous canopy cover at the HC study area. Douglas fir canopy cover had the strongest negative relationship with total herbaceous canopy cover at the SLM (r = -0.77, P = 0.0001) and HC (r = -0.72, P = 0.0001) study areas. Density of trees ≥ 1.5 m in height had the strongest negative relationship with total herbaceous canopy cover at the MLP study area (r = -0.52, P = 0.0072), while total basal area had the highest correlation value overall (r = -0.61, P = 0.0001).

Individual regression models for the 3 study areas and overall regression models describe the impact that Douglas fir had on total herbaceous canopy cover (Table 25).

Table 24. Pearson correlation coefficients between Douglas fir variables[1] and total herbaceous canopy cover.

Area	DFLint	ToBarea	TDFden	DbhDen	ToTrHt	HTG15	DFage
SLM	-0.77	-0.75	-0.57	-0.60	-0.24	----------	-0.32
P-value	0.0001	0.0001	0.0001	0.0001	0.2452	----------	0.1147
MLP	-0.44	-0.46	-0.48	-0.52	0.16	0.24	-0.06
	0.0299	0.0208	0.0144	0.0072	0.4581	0.2435	0.7949
HC	-0.72	-0.66	-0.65	-0.64	-0.47	-0.41	-0.41
	0.0001	0.0004	0.0005	0.0006	0.0180	0.03998	0.0448
Overall	-0.56	-0.61	-0.45	-0.39	-0.16	0.02	-0.30
	0.0001	0.0001	0.0001	0.0001	0.1749	0.8683	0.0093

1: DFLint = Douglas fir canopy cover, ToBarea = total DF basal area, TDFden = total DF density, DbhDen = density of DF ≥ 1.5 m in height, ToTrHt = average total DF height, HTG15 = average height of DF ≥ 1.5m in height, DFage = average Douglas fir age.

Table 25. "Best" regression models for total herbaceous canopy cover.

Area	Model	R^2a	MSE
SLM	$37.9 - 0.363DFLINT$	0.57	24.3
MLP	$28.0 - 0.015TOBAREA + 3.642HTG15$	0.407	35.9
HC	$40.4 - 0.160DFLINT - 0.009DFLINT^2$	0.58	31.9
Overall	$40.2 - 0.015TOBAREA$	0.358	47.1
Overall	$37.6 + 0.052DFLINT - 0.005DFLINT^2$	0.35	47.9

Model abbreviations: DFLINT = Douglas fir canopy cover, TOBAREA = total DF basal area, HTG15 = average height of DF ≥ 1.5 m in height, MSE = error mean square (estimate of variance associated with the model).

Individual study area models were quite variable. Models for the SLM (linear) and HC (curvilinear) study areas included the variable Douglas fir canopy cover, while the linear model for the MLP study area included the variables total basal area and average height of trees ≥ 1.5 m in height (Table 25). The R^2_a values were not particularly high for any of the study areas, as for the SLM study area $R^2_a = 0.57$, for MLP $R^2_a = 0.41$, and for the HC study area $R^2_a = 0.58$.

Two overall models are presented. The first is the "best" overall model and uses total basal area in a linear model. The second overall model only uses Douglas fir canopy cover. Similar to grass canopy cover, the effect of Douglas fir on total herbaceous canopy cover at the MLP study area was not similar to the other 2 study areas (Tables 24 and 25). However, as explained for grass canopy cover, any overall model should incorporate individual study area variation, if inferences want to be made across a wide geographic area. The relationship between Douglas fir canopy cover and total herbaceous canopy cover is in Figure 10, while the relationship between total basal area and total herbaceous canopy cover is in Figure 11.

The negative effect that increases in tree canopy cover, basal area and density has on grass and total herbaceous canopy cover has been documented in the literature (Arnold 1950, Pase 1958, Clary 1971). Clary (1971) found r = -0.37 between total understory production and increases in Utah juniper. Schott and Pieper (1985) reported that canopy shading by one-seeded juniper negatively influenced the basal area of most grasses studied.

It was not surprising that some of the grass and total herbaceous canopy cover models were linear in form, while others were curvilinear. Previous research involving the effects of increasing tree canopy cover or basal area on herbaceous canopy cover and production has shown both linear and curvilinear declines (Arnold 1950, Pase 1958, McConnell and Smith 1970). Arnold (1950) reported that both herbaceous density and grass yield had a negative linear relationship with ponderosa pine canopy cover. Pase (1958) stated that herbage production declined curvilinearly with increases in both tree basal area and canopy cover of ponderosa pine. McConnell and Smith (1970) found a highly significant negative linear trend between ponderosa pine canopy cover and average increase in total yield of herbaceous species. McConnell and Smith (1970)

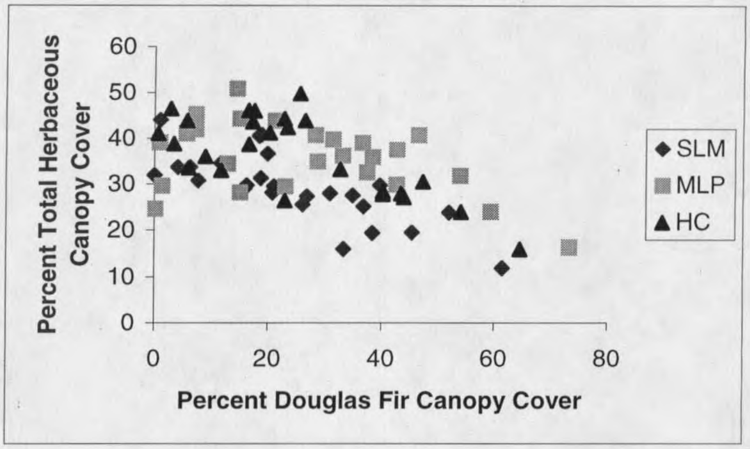

Figure 10. Douglas fir canopy cover versus total herbaceous canopy cover.

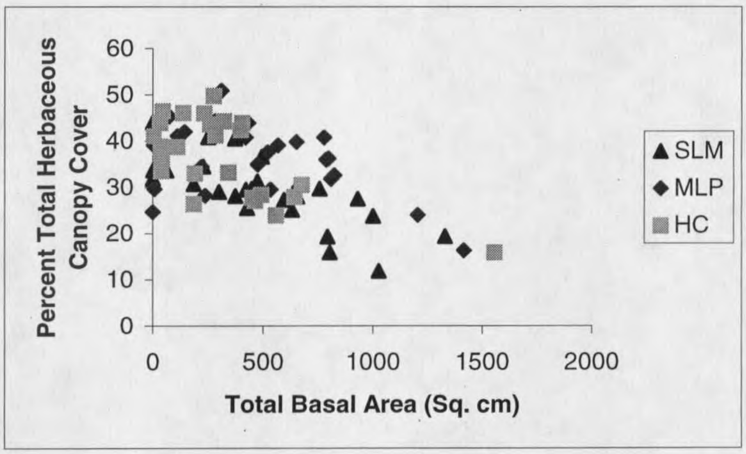

Figure 11. Total Douglas fir basal area versus total herbaceous canopy cover.

reported that grass production decreased faster than forb production. When tree canopy cover exceeded 45%, forb production was greater than grass production. Arnold (1964) reported that both grass basal intercept and herbage yields declined curvilinearly as canopy in pinyon-juniper woodlands increased. Negative impacts to herbaceous species from increases in tree species have also been reported by Cooper (1960), Kranz and Linder (1973), Froeming (1974), and by McPherson and Wright (1990).

Model Validation Results

Sugerloaf Mountain

The models developed for mountain big sagebrush canopy cover, density of "large" mountain big sagebrush, grass canopy cover and total herbaceous canopy cover for the SLM study area are in Table 26. The approximate width of the 80% prediction intervals, the percentage of observed values from the other 2 study areas falling within the prediction intervals, and the correlation between predicted and observed values for each study area are in Table 27 [predicted values, prediction intervals, and observed values for all models are given in Appendix F].

The percentage of MLP and HC observed values that fell within the 80% prediction intervals was variable between models and study areas (Table 27). The model for density of "large" mountain big sagebrush had the highest percentages of observations falling within prediction intervals (84% for MLP, 84% for HC), while the model for total herbaceous canopy cover had the lowest (32% for MLP, 48% for HC). The SLM models for mountain big sagebrush canopy cover, density of "large" mountain big sagebrush, and grass canopy cover would appear to be validated, while the model for total herbaceous canopy cover would appear not to be validated. However, the 80% prediction intervals for the validated models are fairly wide (Table 27), indicating that the precision of the estimates is not high. For example, with a predicted value of 10% mountain big sagebrush canopy cover, the true value of mountain big sagebrush canopy cover could lie anywhere between 6% and 14% canopy cover with a prediction interval width of 8%. The wide prediction intervals reflect the variation in observed values within the study area.

Table 26. "Best" regression models for the Sugerloaf Mountain study area.

Variable	Model	R^2a	MSE
SageLint	17.4 – 0.238DFLINT – 0.170DFAGE	0.71	8.3
ArtrG15	80.1 – 2.234DFLINT + 0.013DFLINT^2 + 3.891ToTrHt	0.88	70.5
GrassCov	27.5 – 0.593DFLINT + 0.005DFLINT^2	0.71	10.9
HerbCov	37.9 – 0.363DFLINT	0.57	24.3

Model abbreviations: SageLint = mountain big sagebrush canopy cover, ArtrG15 = density of "large" mountain big sagebrush, GrassCov = grass canopy cover, HerbCov = total herbaceous canopy cover, DFLINT = Douglas fir canopy cover, ToTrHt = average total DF height, DFAGE = average DF age.

Table 27. Sugerloaf Mountain validation results.

		Medicine Lodge Peak		Hells Canyon	
Model	Width of P.I. ≅	% Obs. in 80% P.I.	r	%Obs. in 80% P.I.	r
SageLint	8%	76	0.93	64	0.92
ArtrG15	23 plants/tran	84	0.95	84	0.93
GrassCov	9%	72	0.40	56	0.73
HerbCov	13%	32	0.43	48	0.72

Observed values may fall within a given prediction interval due to good model performance, or because the intervals or so wide that only extreme values fall outside their range. Because of this, graphs of predicted versus observed values plotted with a line representing perfect prediction were also used to validate the models. This technique provides a better indication of model acurracy than the prediction interval information.

Correlation values often indicated a strong linear relationship between the predicted values from one study area and the observed values from the other study areas (Table 27). Correlation values were especially high between predicted and observed values for mountain big sagebrush canopy cover (r = 0.93 for MLP, r = 0.92 for HC), and density of "large" mountain big sagebrush (r = 0.95 for MLP, r = 0.93 for HC). However, even though the correlation values indicated a strong linear relationship between predicted and observed values, this in itself does not indicate good predictive capability, as any linear relationship will yield a high correlation value. For this reason, predicted versus observed values were graphed with a line representing perfect prediction.

Graphs of predicted versus observed values, with a line representing perfect prediction, showed that the SLM mountain big sagebrush canopy cover model generally did not predict well (Fig. 12, 13). The SLM model's predicted values were generally greater than the MLP observed values when sagebrush canopy cover was < 10%, and the predicted values were generally less than the MLP observed values when sagebrush canopy cover was > 10% (Fig. 12). The SLM model's predicted sagebrush canopy cover values were generally less than the HC observed values (Fig. 13). The model for density of "large" mountain big sagebrush appeared to perform the best (Fig. 14, 15). The SLM models for grass and total herbaceous canopy cover did not accurately predict the MLP and HC study area observed values (Fig. 16-19).

Medicine Lodge Peak

Medicine Lodge Peak study area's "best" models and validation results are presented in Tables 28 and 29 respectively. The mountain big sagebrush canopy cover, density of "large" mountain big sagebrush, and total herbaceous canopy cover models appeared to be validated, as most of the observed values for the SLM and HC study areas fell within the 80% prediction intervals (Table 29). The model for "large" mountain big sagebrush density had the highest percentage of observation falling within the prediction intervals (88% for SLM, 84% for HC), while the model for grass canopy cover had the least (36% for SLM, 16% for HC).

Correlation values indicated a strong linear relationship between predicted and

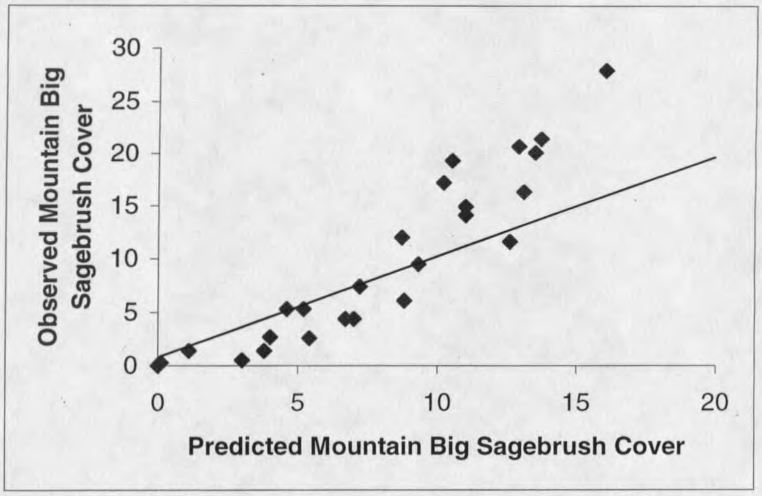

Figure 12. Sugerloaf Mountain validation results: predicted versus observed for Medicine Lodge Peak mountain big sagebrush canopy cover. (Line represents perfect prediction)

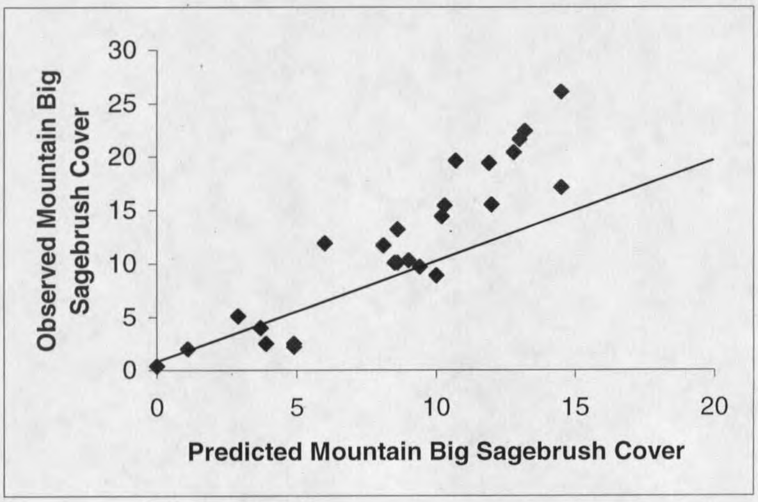

Figure 13. Sugerloaf Mountain validation results: predicted versus observed for Hells Canyon mountain big sagebrush canopy cover. (Line represents perfect prediction)

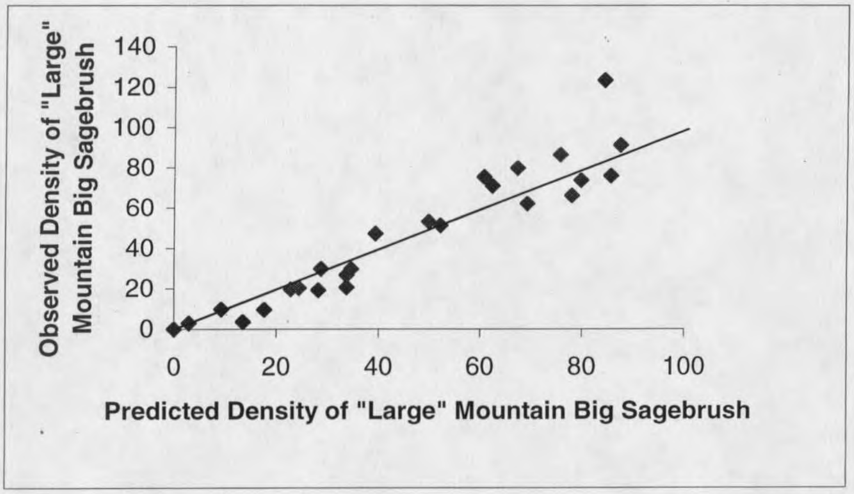

Figure 14. Sugerloaf Mountain validation results: predicted versus observed for Medicine Lodge Peak density of "large" mountain big sagebrush. (Line represents perfect prediction)

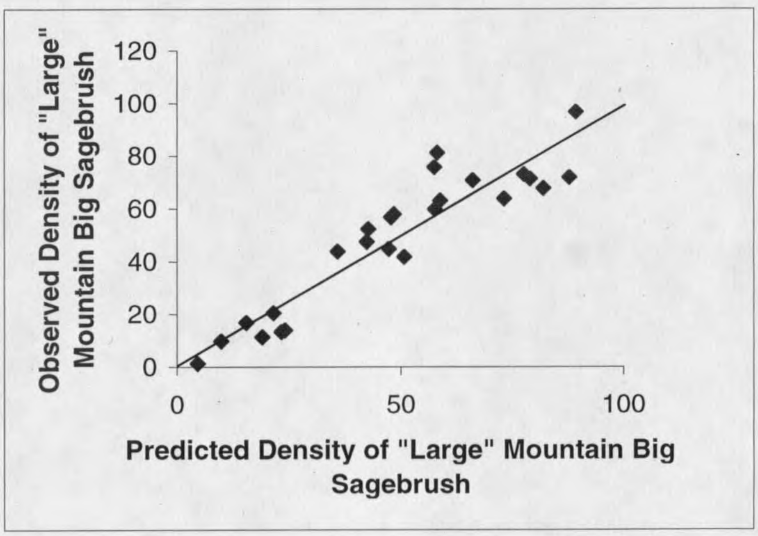

Figure 15. Sugerloaf Mountain validation results: predicted versus observed for Hells Canyon density of "large" mountain big sagebrush. (Line represents perfect prediction)

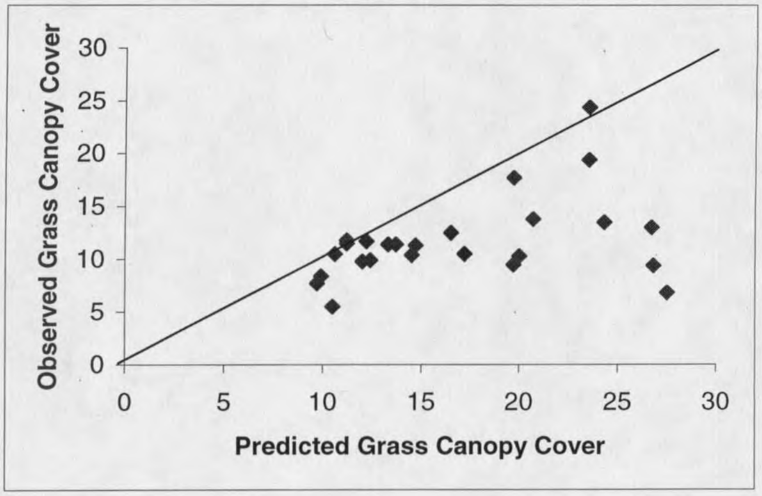

Figure 16. Sugerloaf Mountain validation results: predicted versus observed for Medicine Lodge Peak grass canopy cover. (Line represents perfect prediction)

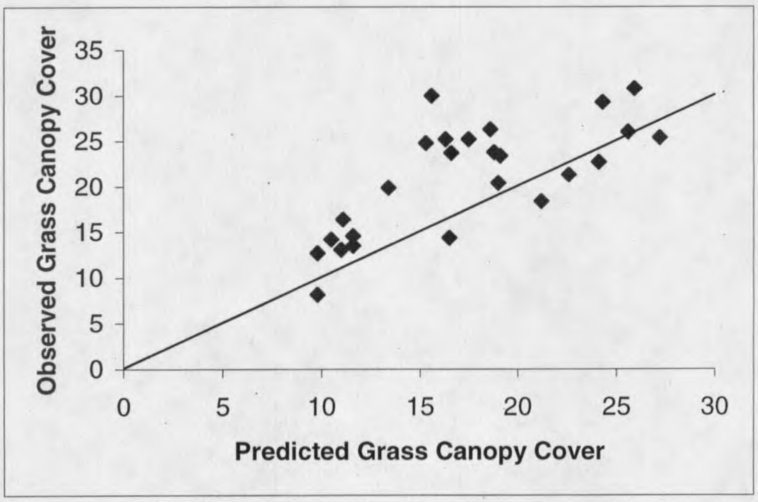

Figure 17. Sugerloaf Mountain validation results: predicted versus observed for Hells Canyon grass canopy cover. (Line represents perfect prediction)

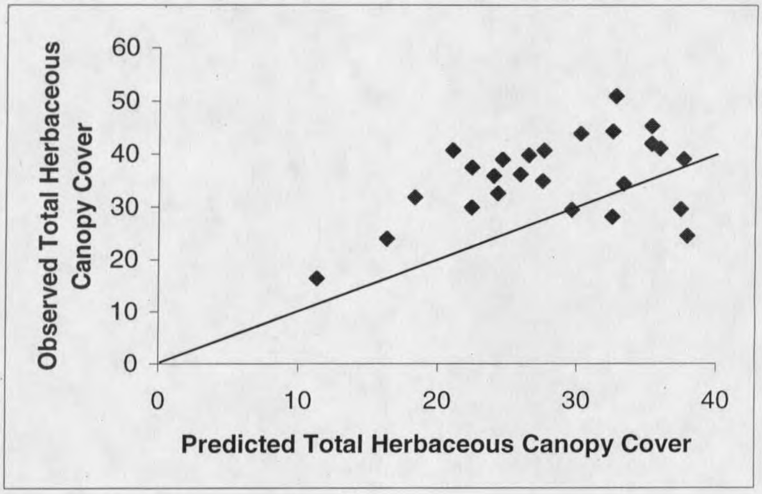

Figure 18. Sugerloaf Mountain validation results: predicted versus observed for Medicine Lodge Peak total herbaceous canopy cover. (Line represents perfect prediction)

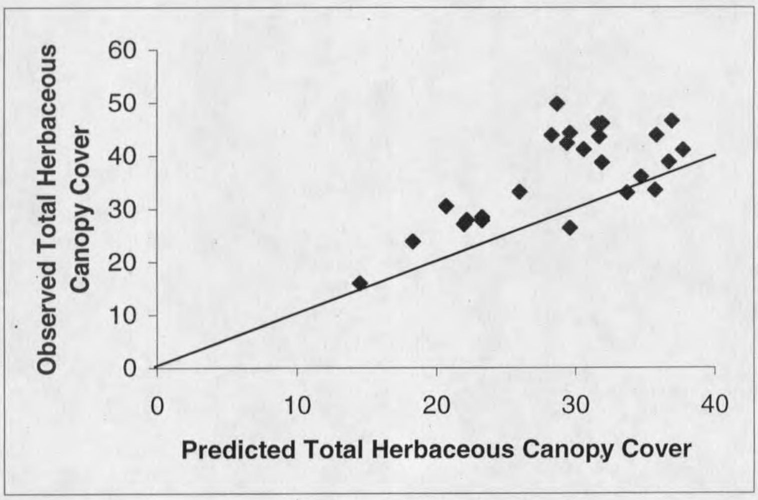

Figure 19. Sugerloaf Mountain validation results: predicted versus observed for Hells Canyon total herbaceous canopy cover. (Line represents perfect prediction)

Table 28. "Best" regression models for the Medicine Lodge Peak study area.

Variable	Model	R^2a	MSE
SageLint	$23.2 - 0.711DFLINT + 0.005DFLINT^2$	0.89	7.0
ArtrG15	$99.6 - 2.718DFLINT + 0.018DFLINT^2$	0.90	113.6
GrassCov[1]	14.0 – 0.098DFLINT	0.37	5.5
HerbCov	28.0 – 0.015TOBAREA + 3.642HTG15	0.41	35.9

1: MLP site number 2 and 24 not included in the model

Model abbreviations: SageLint = mountain big sagebrush canopy cover, ArtrG15 = density of "large" mountain big sagebrush, GrassCov = grass canopy cover, HerbCov = total herbaceous canopy cover, DFLINT = Douglas fir canopy cover, TOBAREA = total DF basal area, HTG15 = average height of DF ≥ 1.5 m in height.

Table 29. Medicine Lodge Peak validation results.

		Sugerloaf Mountain		Hells Canyon	
Model	Width of P.I. ≅	% Obs. In 80% P.I.	r	%Obs. in 80% P.I.	r
SageLint	7%	68	0.84	84	0.93
ArtrG15	29 plants/tran	88	0.93	84	0.92
GrassCov	6.5%	36	0.82	16	0.80
HerbCov	16%	*[1]	-	84	0.60

1: HTG15 not measured at SLM study area.

observed values for density of "large" mountain big sagebrush (0.93 for SLM; 0.92for HC) (Table 29). The correlation between predicted and observed values of mountain big sagebrush canopy cover for the HC study area was also high (r = 0.93). The MLP mountain big sagebrush canopy cover model often did not predict SLM or HC observed values accurately (Fig. 20, 21). The MLP model for density of "large" mountain big sagebrush generally did an adequate job of predicting SLM and HC observed values (Fig. 22, 23). Grass canopy cover was under predicted at both validation study areas (Fig. 24, 25). Total herbaceous canopy cover at the HC study area was not predicted well by the MLP model (Fig. 26). The model used for total herbaceous canopy cover could not predict values for the SLM study area because the average height of trees (≥ 1.5 m in height) was not measured.

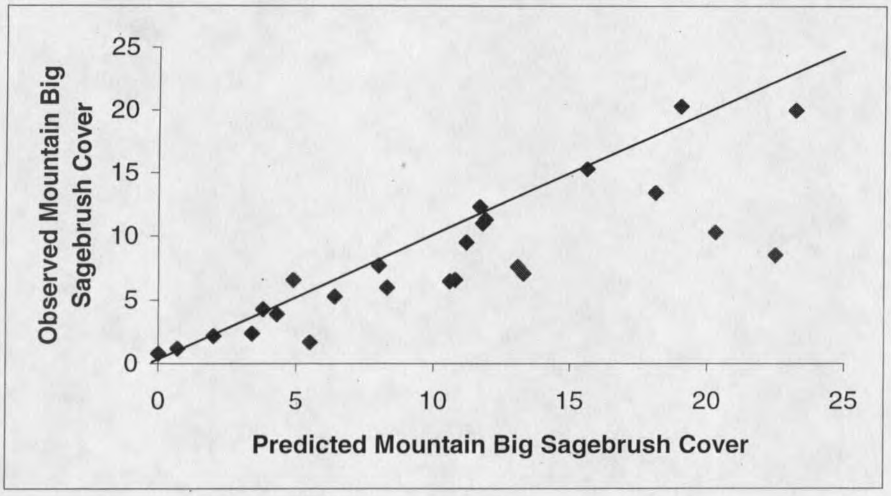

Figure 20. Medicine Lodge Peak model validation results: predicted versus observed for Sugerloaf Mountain mountain big sagebrush canopy cover. (Line represents perfect prediction)

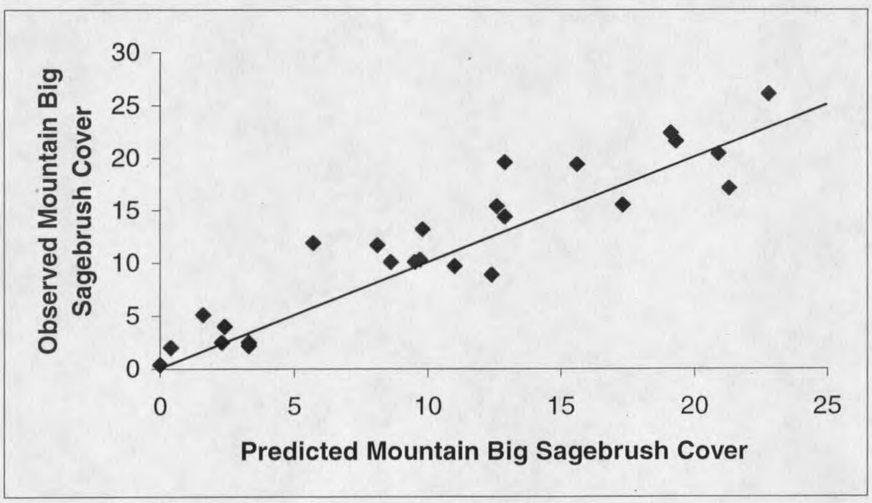

Figure 21. Medicine Lodge Peak model validation results: predicted versus observed for Hells Canyon mountain big sagebrush canopy cover. (Line represents perfect prediction)

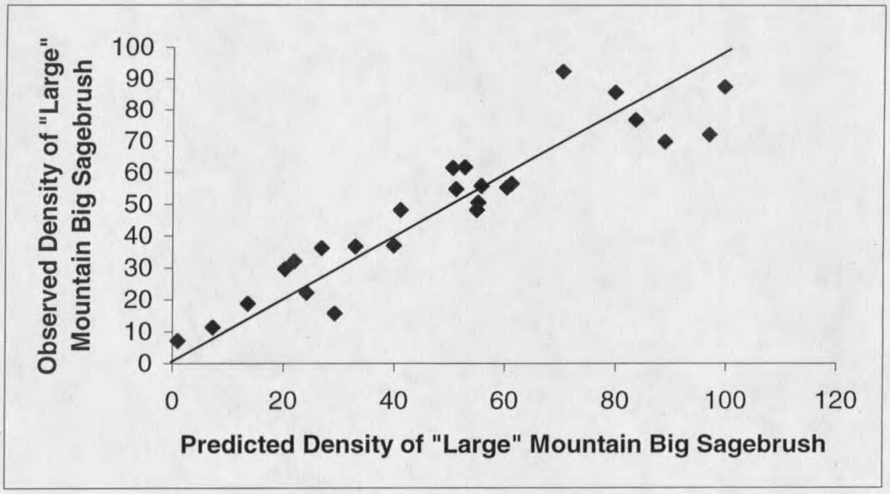

Figure 22. Medicine Lodge Peak model validation results: predicted versus observed for Sugerloaf Mountain density of "large" mountain big sagebrush. (Line represents perfect prediction)

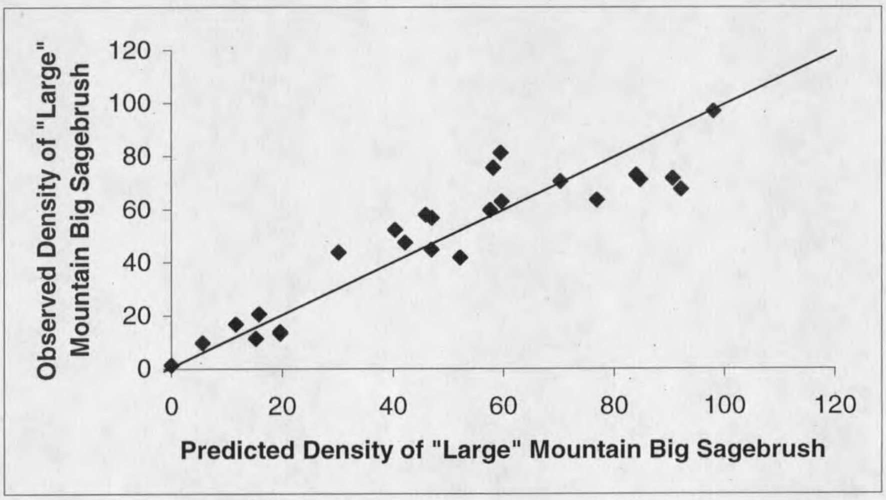

Figure 23. Medicine Lodge Peak model validation results: predicted versus observed for Hells Canyon density of "large" mountain big sagebrush. (Line represents perfect prediction)

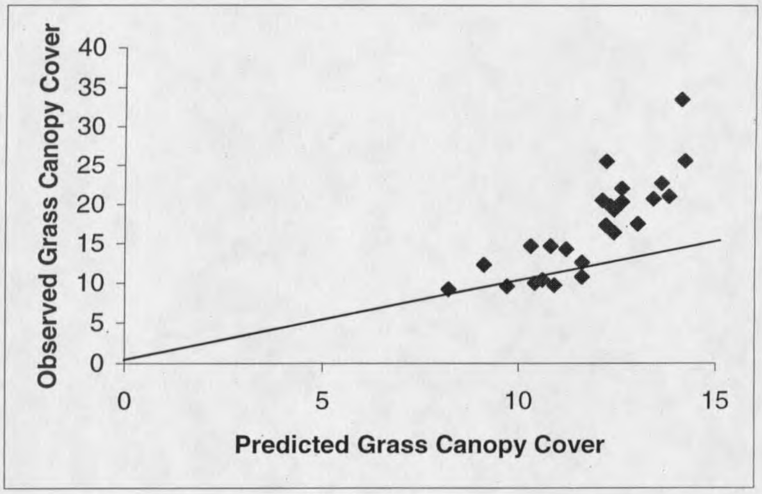

Figure 24. Medicine Lodge Peak model validation results: predicted versus observed for Sugerloaf Mountain grass canopy cover. (Line represents perfect prediction)

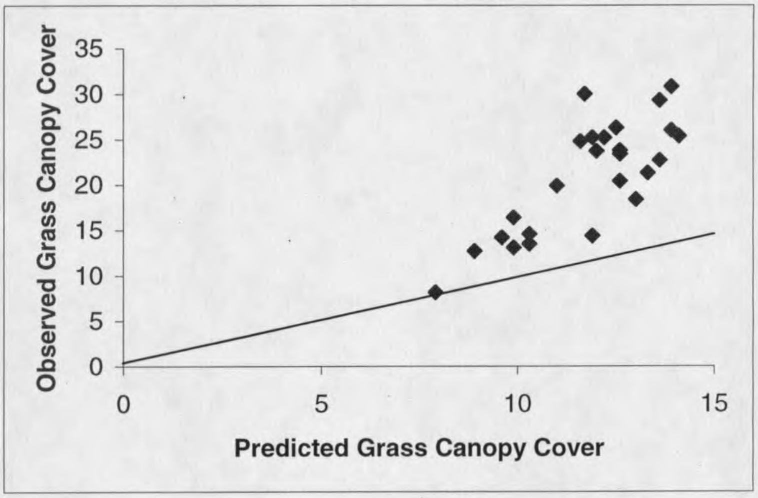

Figure 25. Medicine Lodge Peak model validation results: predicted versus observed for Hells Canyon grass canopy cover. (Line represents perfect prediction)

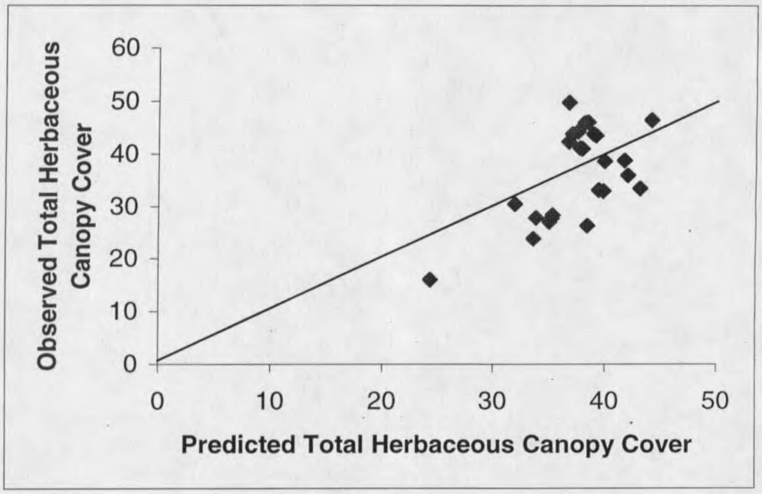

Figure 26. Medicine Lodge Peak model validation results: predicted versus observed for Hells Canyon total herbaceous canopy cover. (Line represents perfect prediction)

Hells Canyon

The "best" regression models for the HC study area and model validation results are in Tables 30 and 31 respectively. The percentage of SLM and MLP observed values falling with in the 80% prediction intervals varied by model and by study area (Table 31). The models for mountain big sagebrush cover and density of "large" mountain big sagebrush were validated the best based on the percentage of observations falling inside of prediction intervals. Density of "large" mountain big sagebrush had the highest percentage of observations falling inside prediction intervals (92% for SLM, 76% for MLP), while mountain big sagebrush cover had 64% (SLM) and 84% (MLP) of observations falling with in the 80% prediction intervals. Prediction intervals were fairly wide for all models, as was the case with the other 2 study areas.

Similar to the other study areas, a strong linear relationship was indicated between the predicted and observed values for density of "large" mountain big (r = 0.93 for

Table 30. "Best" regression models for the Hells Canyon study area.

Variable	Model	R^2a	MSE
SageLint	$23.8 - 0.636DFLINT + 0.004DFLINT^2$	0.86	7.4
ArtrG15	$84.3 - 1.435DFLINT$	0.87	92.4
GrassCov	$28.0 - 0.285DFLINT$	0.63	14.1
HerbCov	$40.4 - 0.160DFLINT - 0.009DFLINT^2$	0.58	31.9

Model abbreviations: SageLint = mountain big sagebrush canopy cover, ArtrG15 = density of "large" mountain big sagebrush, GrassCov = grass canopy cover, HerbCov = total herbaceous canopy cover, DFLINT = Douglas fir canopy cover, TOBAREA = total DF basal area, HTG15 = average height of DF ≥ 1.5 m in height.

Table 31. Hells Canyon validation results.

		Sugerloaf Mountain		Medicine Lodge Peak	
Model	Width of P.I. ≅	% Obs. in 80% P.I.	r	%Obs. in 80% P.I.	r
SageLint	7.5%	64	0.84	84	0.95
ArtrG15	26 plants/tran	92	0.93	76	0.94
GrassCov	10%	60	0.82	28	0.49
HerbCov	15%	52	0.72	68	0.61

SLM, r = 0.94 for MLP). The correlation between predicted and observed values for mountain big sagebrush canopy cover at the MLP study area was also strong (r = 0.95).

The HC model for mountain big sagebrush canopy cover generally over predicted the SLM and MLP observed values (Fig. 27, 28). The HC model for density of "large" mountain big sagebrush did an adequate job of predicting both SLM and MLP observed values (Fig. 29, 30). Although, it did a better job of predicting the MLP observed values. There was not a strong linear relationship between the MLP predicted and observed values for either grass canopy cover (r = 0.49) or total herbaceous canopy cover (r = 0.61). Grass canopy cover was greatly overestimated for both the SLM and MLP study areas (Fig. 31, 32). Total herbaceous canopy cover was generally not predicted well (Fig. 33, 34).

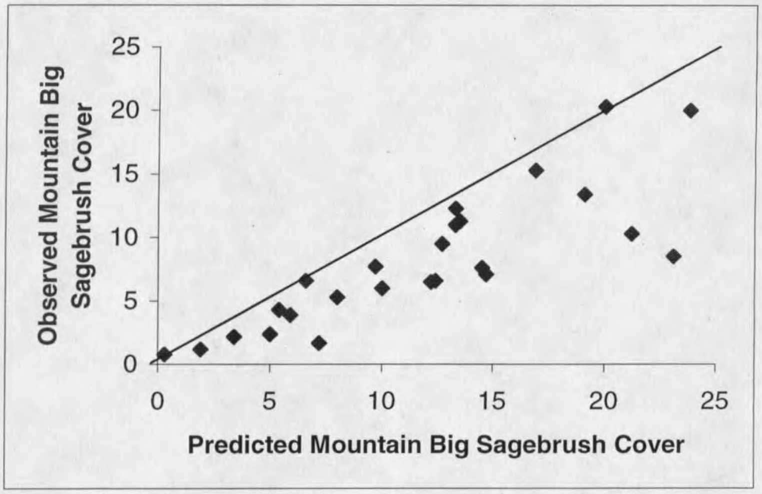

Figure 27. Hells Canyon model validation results: predicted versus observed for Sugerloaf Mountain mountain big sagebrush canopy cover. (Line represents perfect prediction)

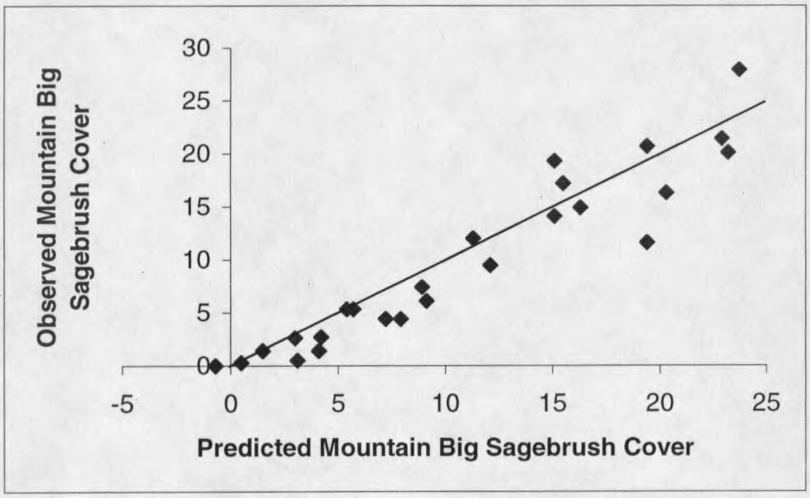

Figure 28. Hells Canyon model validation results: predicted versus observed for Medicine Lodge Peak mountain big sagebrush canopy cover. (Line represents perfect prediction)

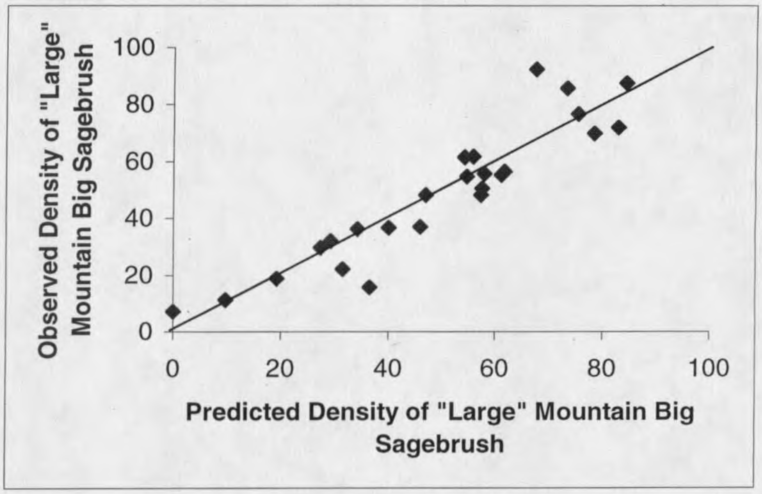

Figure 29. Hells Canyon model validation results: predicted versus observed for Sugerloaf Mountain density of “large” mountain big sagebrush. (Line represents perfect prediction)

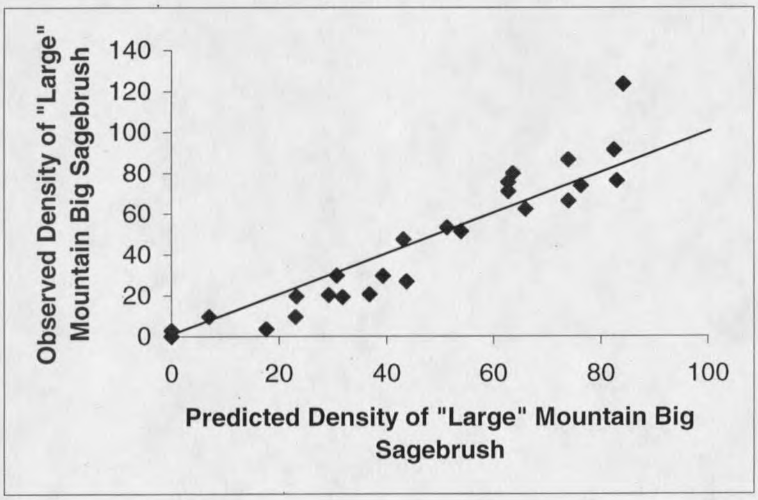

Figure 30. Hells Canyon model validation results: predicted versus observed for Medicine Lodge Peak density of “large” mountain big sagebrush. (Line represents perfect prediction)

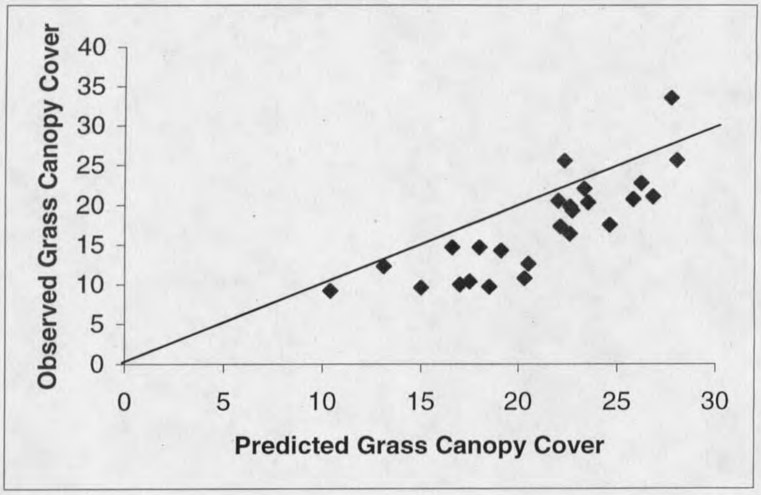

Figure 31. Hells Canyon Model validation results: predicted versus observed for Sugerloaf Mountain grass canopy cover. (Line represents perfect prediction)

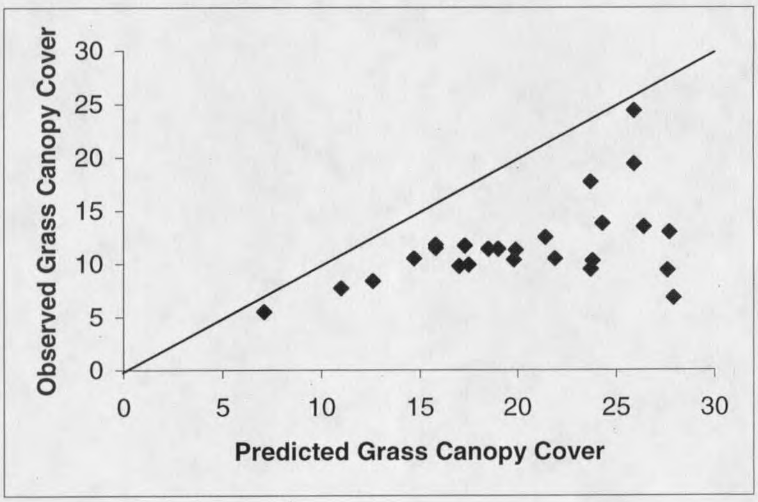

Figure 32. Hells Canyon model validation results: predicted versus observed for Medicine Lodge Peak grass canopy cover. (Line represents perfect prediction)

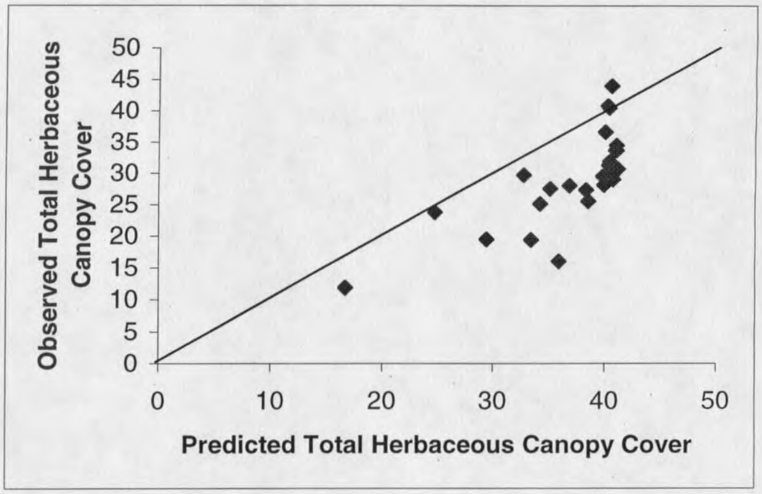

Figure 33. Hells Canyon model validation results: predicted versus observed for Sugerloaf Mountain total herbaceous canopy cover. (Line represents perfect prediction)

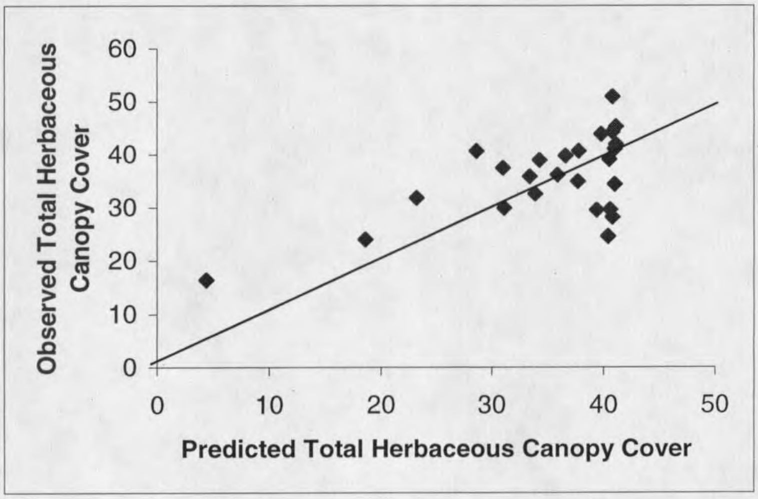

Figure 34. Hells Canyon model validation results: predicted versus observed for Medicine Lodge Peak total herbaceous canopy cover. (Line represents perfect prediction)

Overall Regression Models

The overall "validation" regression models for southwestern Montana (3 study areas combined), for mountain big sagebrush canopy cover, density of "large" mountain big sagebrush, grass canopy cover and total herbaceous canopy cover are in Table 32. The models in Table 32 are based on fewer sites than the "full" overall models presented earlier in the results section, as 15 sites were withheld in order to validate the model (refer to methods). Sites omitted from the "full" models because of undue influence on the regression relationship were also not included in the "validation" models. A natural log transformation was also done on the "validation" models for grass canopy cover.

Most of the validation sites (withheld sites) were within the 80% prediction intervals for the different models (Table 33). The mountain big sagebrush canopy cover model had the lowest percentage of observations falling within the 80% prediction intervals (73%). Models only using Douglas fir canopy cover as a predictor performed as well as the "best" models (Table 33). Prediction intervals were fairly wide (Table 33), as they were with the individual study areas. The prediction interval for density of "large" mountain big sagebrush using only Douglas fir as a predictor was 2 plants wider than the prediction interval for the "best" model. Prediction intervals for grass and total herbaceous canopy cover were similar between the "best" models and Douglas fir canopy cover only models.

Correlation values between predicted and observed values for mountain big sagebrush canopy cover ($r = 0.91$) and for density of "large" mountain big sagebrush ($r = 0.94$ for "best", $r = 0.94$ for DF only) indicated a strong linear relationship between predicted and observed values. The mountain big sagebrush canopy cover "validation"

Table 32. "Best" overall "validation" regression models.

Variable	Model	R^2a	MSE
SageLint[1] n = 59	$21.8 - 0.661DFLINT + 0.005DFLINT^2$	0.83	8.7
ArtrG15[2] n = 59	$75.6 - 2.111DFLINT + 0.011DFLINT^2 + 4.375ToTrHt$	0.90	69.3
ArtrG15[2] n = 59	$86.9 - 1.866DFLINT + 0.008DFLINT^2$	0.88	83.5
GrassCov[3] n = 59	$3.160 - 0.088TDFDENS + 0.001TDFDENS^2$	0.56	0.076
GrassCov[3] n = 59	$3.161 - 0.016DFLINT$	0.50	0.860
HerbCov n = 60	$40.3 - 0.015TOBAREA$	0.41	46.8
HerbCov n = 60	$37.7 - 0.054DFLINT - 0.006DFLINT^2$	0.41	46.8

1: SLM number 21 not included in model.
2: MLP number 24 not included in model.
3. MLP number 24 not included in model, natural log transformation done on GrassCov.
Model abbreviations: SageLint = mountain big sagebrush canopy cover, ArtrG15 = density of "large" mountain big sagebrush, GrassCov = grass canopy cover, HerbCov = total herbaceous canopy cover, DFLINT = Douglas fir canopy cover, TDFDENS = total DF density, TOBAREA = total DF basal area, ToTrHt = average total DF height.

Table 33. "Best" overall regression model validation results.

Model	Width of P.I. ≅	% Obs. in 80% P.I.	r
SageLint	8%	73	0.91
ArtrG15	22 plants/tran	93	0.94
ArtrG15[1]	24 plants	87	0.95
GrassCov	min. – 6%, max. – 17%	80	0.48
GrassCov[1]	min. - 9%, max. - 16%	80	0.43
HerbCov	18%	80	0.21
HerbCov[1]	18%	80	0.11

1: Douglas fir canopy cover only models.

model generally predicted observed values of mountain big sagebrush canopy cover < 15% well, but not for values above that (Fig. 35). The 2 models for density of "large" mountain big sagebrush generally predicted observed values fairly well (Fig. 36, 37).

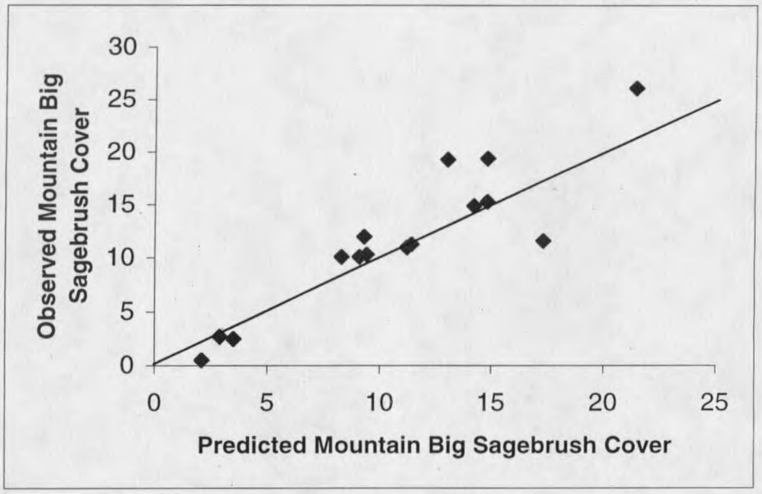

Figure 35. Overall model validation results: predicted versus observed for mountain big sagebrush canopy cover. (Line represents perfect prediction)

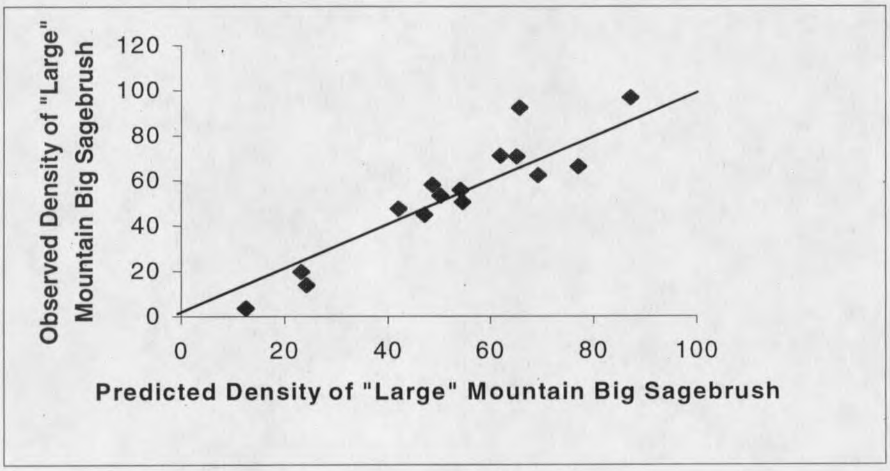

Figure 36. Overall model validation results: predicted versus observed density of "large" mountain big sagebrush. (Line represents perfect prediction)

There was not a strong linear relationship between predicted and observed values for grass and total herbaceous canopy cover (Table 33). However, the different models for grass and total herbaceous canopy cover were still occasionally fairly accurate (Fig. 38-41).

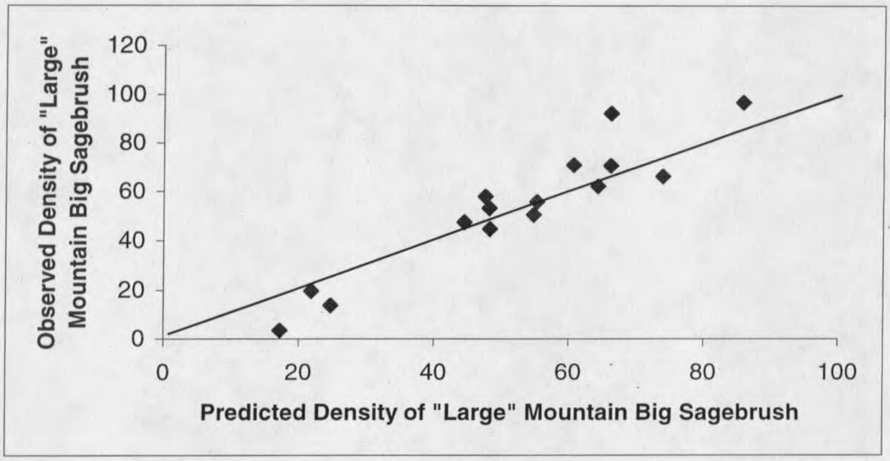

Figure 37. Overall model validation results: predicted versus observed density of "large" mountain big sagebrush using Douglas fir canopy cover in the model only. (Line represents perfect prediction)

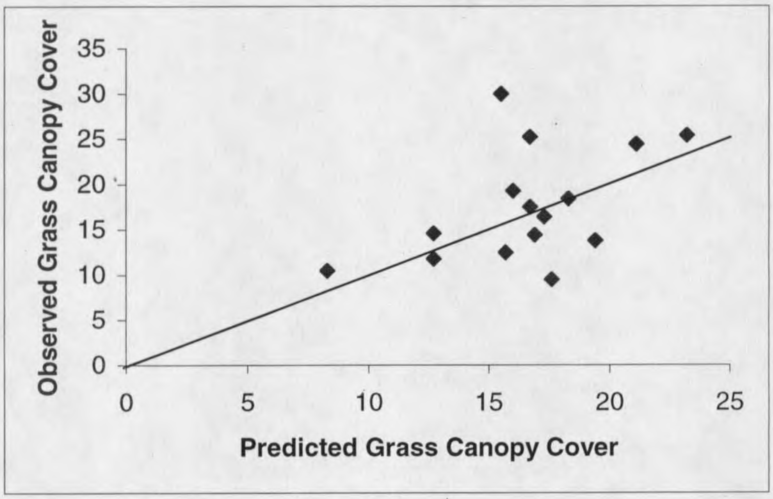

Figure 38. Overall model validation results: predicted versus observed for grass canopy cover. (Line represents perfect prediction)

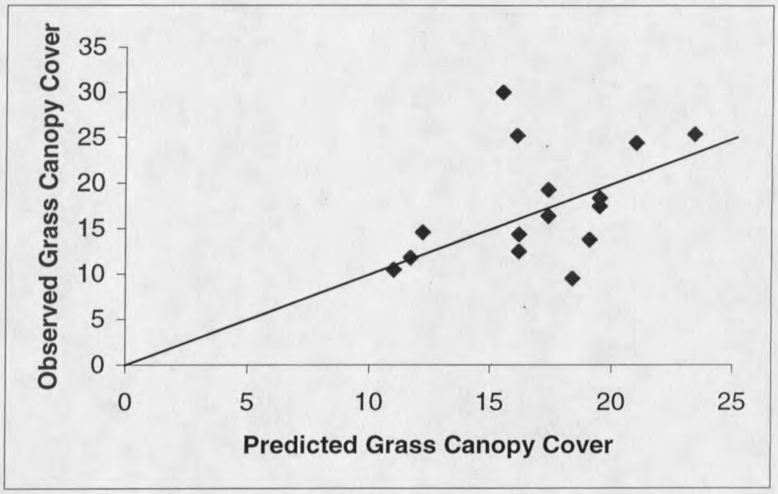

Figure 39. Overall model validation results: predicted versus observed for grass canopy cover using Douglas fir canopy cover in the model only. (Line represents perfect prediction)

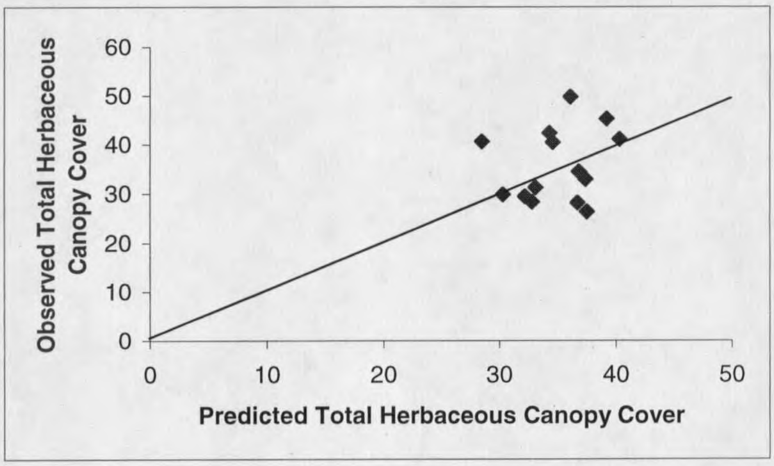

Figure 40. Overall model validation results: predicted versus observed for total herbaceous canopy cover. (Line represents perfect prediction)

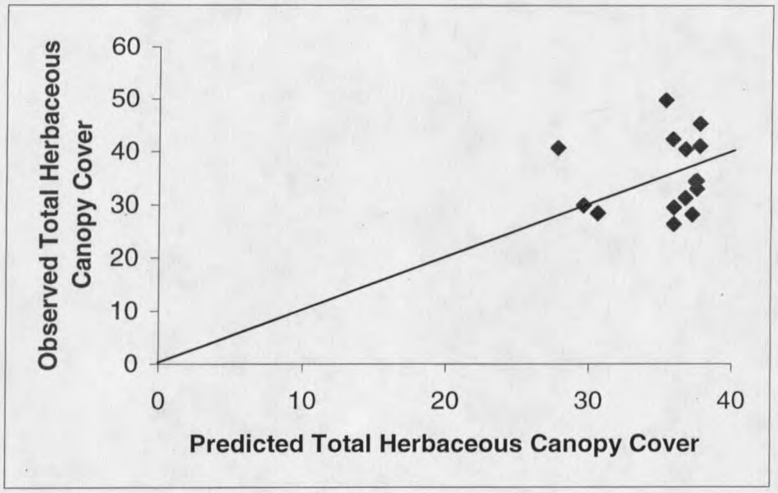

Figure 41. Overall model validation results: predicted versus observed for total herbaceous canopy cover using Douglas fir canopy cover in the model only. (Line represents perfect prediction)

MANAGEMENT IMPLICATIONS AND CONCLUSIONS

Douglas fir establishment in mountain big sagebrush communities had an effect on those communities in my study. Mountain big sagebrush canopy cover, density, and production all declined with increasing Douglas fir canopy cover, total basal area, and density. The specific relationships, as indicated by the models developed for the different response variables, were quite variable between study areas. This variation between study areas was reflected in the validation results for the individual study area models. Except for density of "large" mountain big sagebrush, comparisons of predicted versus observed values, with a line representing perfect prediction, indicated that the models generally did not predict accurately from 1 study area to another. However, when variation was incorporated into the predictive process by comparing observed values with 80% prediction intervals, models for mountain big sagebrush canopy cover, and grass and total herbaceous canopy cover were often validated.

While individual study area models were often not accurate, overall models derived by combining the variation from the 3 study areas often were accurate. Both overall "validation" models for density of "large" sagebrush performed reasonably well (Fig. 36, 37). The overall "validation" model for sagebrush cover also performed well when sagebrush cover was < 15% (Fig. 35). "Validation" models for grass and total herbaceous canopy cover were occasionally accurate as well (Fig. 38-41). The model validation results indicated that the overall "full" models for mountain big sagebrush canopy cover (Table 10), and density of "large" mountain big sagebrush (Table 12) would generally provide reasonably accurate estimates of the effects of Douglas fir establishment on mountain big sagebrush. The overall "full" models for grass canopy cover (Table 23) and total herbaceous canopy cover (Table 25) may also be useful; however, they appear to be less precise.

The effects of Douglas fir establishment on grass and total herbaceous canopy varied more than did the effects of Douglas fir establishment on mountain big sagebrush variables. Obviously, besides Douglas fir establishment, other factors such as past grazing history were influencing grass and total herbaceous canopy cover. The Medicine Lodge Peak study area had a large amount of hair-cap moss (*Polytrichum juniperinum* Hedw.) present which may have influenced grass and forb production at that study area.

I found that Douglas fir canopy cover was the most important tree-related variable affecting mountain big sagebrush communities. Model results indicated that the effects of Douglas fir establishment in mountain big sagebrush communities could be determined by measuring Douglas fir canopy cover alone. Sagebrush cover declined to less than 15% canopy cover (Fig. 2), while total sagebrush production generally declined to around 300 kg/ha (Fig. 7) as Douglas fir cover increased beyond 20%. As Douglas fir cover increased to 35-40%, sagebrush cover generally declined to less than 5% canopy cover (Fig. 2), and total sagebrush production declined to less than 200 kg/ha (Fig. 7).

The ability to predict the amount of Douglas fir canopy cover present at a given future point in time would be beneficial. Unfortunately, I do not have that capability with my data. In addition, I do not think any vegetative measurement will provide that information because of the effects such factors as climate, grazing practices, and wildlife browsing have on the growth and spread of Douglas fir. The level of Douglas fir canopy cover that will be tolerated before some form of control is desired will depend on what species are being managed for and the overall desired management goals. Any form of control will have to take into consideration that a given level of Douglas fir canopy cover will rarely occur at a landscape level, but rather different patches will have different levels of canopy cover.

If prescribed fire is considered as a tool to control establishing Douglas fir, it should be remembered that fire has a long-term negative impact on mountain big sagebrush (Harniss and Murray 1973, Walhof 1997). Douglas fir stand characteristics that affect fire's ability to spread and to be controlled such as canopy cover and density will need to be considered also. In addition, factors that affect fire's ability to kill Douglas fir such as Douglas fir age and canopy height will need to be considered.

Future research should attempt to focus on use levels of mountain big sagebrush communities by large ungulates and other wildlife species at different levels of Douglas fir establishment. However, I recognize that it will be extremely complicated to monitor use at any specific location due to fluctuating ungulate population levels, and seasonal and annual variations in vegetative production and use. I found that sagebrush growth was severely affected under higher canopy covers, and plant growth form was often altered. Future research may want to focus on the effects to forage quality or secondary compound production in big sagebrush as canopy cover increases.

LITERATURE CITED

Antos, J.A., B. McCune, and C. Bara. 1983. The effect of fire on an ungrazed western Montana grassland. Amer. Midl. Natur. 110:354-364.

Arno, S.F. 1976. The historical role of fire in the Bitterroot National Forest. USDA For. Serv. Res. Pap. INT-187. Intermountain Forest and Range Experiment Station. Odgen, Utah. 29p.

Arno, S.F. and G.E. Gruell. 1983. Fire history at the forest-grassland ecotone Southwestern Montana. J. Range Manage. 36:332-336.

Arno, S.F. and G.E. Gruell. 1986. Douglas-fir encroachment into mountain grasslands in Southwestern Montana. J. Range Manage. 39:272-275.

Arnold, J.F. 1950. Changes in ponderosa pine bunchgrass ranges in Northern Arizona resulting from pine regeneration and grazing. J. For. 48:118-126.

Arnold, J.F., D.A. Jameson, and E.H. Reid. 1964. The pinyon-juniper type of Arizona: effects of grazing, fire and tree control. USDA Prod. Res. Rep. No. 84. 28p.

Blackburn, W.H. and P.T. Tueller. 1970. Pinyon and juniper invasion in black sagebrush communities in East-Central Nevada. Ecol. 51:841-848.

Blaisdell, J.P. 1953. Ecological effects of planned burning of sagebrush-grass range on the Upper Snake River Plains. USDA Technical Bull. No. 1075. 39p.

BLM. 1997. Environmental Assessment: Toll Mountain habitat project. Headwaters Resource Area, Bureau of Land Management. Butte, Mont. 46p.

Bradley, A.F., W.C. Fischer, and N.V. Noste. 1992. Fire ecology of the forest habitat types of Idaho and Western Wyoming. USDA For. Serv. Gen. Tech. Rep. INT-290. Intermountain Research Station. Ogden, Utah. 92p.

Bunting, S.C., B.M. Kilgore, and C.L. Bushey . 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the Northern Great Basin. USDA For. Serv. Gen. Tech. Rep. INT-231. Intermountain Research Station. Ogden, Utah. 33p.

Burkhardt, J.W. 1969. Western juniper invasion in Southwestern Idaho and analysis of cause. PH.D. Thesis. University of Idaho. Moscow, Idaho. 61p.

Burkhardt, J.W. and E.W. Tisdale. 1969. Nature and successional status of western juniper vegetation in Idaho. J. Range Manage. 22:264-270.

Bushey, C.L. 1986. Final report for the Galena Gulch prescribed fire demonstration project: fire effects and postburn evaluation of results in east-side shrub/grass communities of the Douglas fir habitat types. Report from Systems for

Environmental Management, Inc. to USDA For. Serv. Intermountain Fire Sciences Lab. Missoula, Mont. 31p.

Campbell, D.L. and J. Evans. 1975. Improving wildlife habitat in young Douglas-fir plantations. Trans. N. Amer. Wild. Nat. Res. Conf. 40:202-208.

Canfield, J.E., J.L. Lyon, and J.M. Hillis. 1986. The influence of viewing angle on elk hiding cover in young timber stands. USDA For. Serv. Res. Pap. INT-371. Intermountain Research Station. Ogden, Utah. 5p.

Canfield, R.H. 1941. Application of the line intercept method in sampling range vegetation. J. For. 39:388-394.

Caprio, J.M., D.I. Cooksey, J.S. Jacobsen, G.A. Nielsen, and R.R. Roche. 1994. MAPS Atlas - A Land and Climate Information System. Extension Bulletin 125, Montana State University, Bozeman, Mont.

Clary, W.P. 1971. Effects of Utah juniper removal on herbage yields from Springerville soils. J. Range Manage. 24:373-378.

Clements, F.E. 1916. Plant succession: an analysis of the development of vegetation. Carnegie Institution of Washington. Washington D.C. 512p.

Collins, W.B., P.J. Urness, and D.D. Austin. 1978. Elk diets and activities on different lodgepole pine habitat segments. J. Wildl. Manage. 42:799-810.

Conrad, C.E. and C.E. Poulton. 1966. Effect of wildfire on Idaho fescue and bluebunch wheatgrass. J. Range Manage. 19:138-141.

Cooper, C.F. 1960. Changes in vegetation structure, and growth of southwestern pine forests since white settlement. Ecol. Monogr. 30:129-164.

Cottam, W.P. and G. Stewart. 1940. Plant succession as a result of grazing and meadow dessication by erosion since settlement in 1862. J. For. 30: 613-626.

Countrymen, C.M. and D.R. Cornelius. 1957. Some effects of fire on a perennial range type. J. Range Manage. 10:39-41.

Creamer, W.H. 1991. Prediction of available forage production of big sagebrush. M.S. Thesis: Montana State University. Bozeman, Montana. 73p.

Daubenmire, R. 1959. A canopy cover method of vegetational analysis. Northwest Science 33:43-64.

Davis, K.M., B.D. Clayton, and W.C. Fisher. 1980. Fire ecology of Lolo National Forest habitat types. USDA. For. Ser. Gen. Tech. Rep. INT-79. 77p. Intermountain Forest and Range Experiment Station. Odgen, Utah.

Dawson, R.J., H.M. Armleder, and M.J. Waterhouse. 1990. Preferences of mule deer for Douglas-fir foliage from different sized trees. J. Wildl. Manage. 54:378-382.

Etchberger, R.C., P.R. Krausman, and R. Mazaika. 1989. Mountain sheep habitat characteristics in Pusch Ridge Wilderness, Arizona. J. Wildl. Manage. 53:902-907.

Fischer, W.C. and B.D. Clayton. 1983. Fire ecology of Montana forest habitat types east of the continental divide. USDA For. Serv. Gen. Tech. Rep. INT-141. Intermountain Forest and Range Experiment Station. Ogden, Utah. 83p.

Fischer, W.C. and A.F. Bradley. 1987. Fire ecology of Western Montana forest habitat types. USDA For. Serv. Gen. Tech. Rep. INT-223. Intermountain Research Station. Ogden, Utah. 95p.

Flint, R. 1925. Fire resistance of Northern Rocky Mountain conifers. Idaho Forester 7:7-10,41-43.

Foster, J.H. 1917. The spread of timbered areas in Central Texas. J. For. 15:442-445.

Fraas, W.W., C.L. Wambolt, and M.R. Frisina. 1992. Prescribed fire effects on a bitterbrush-mountain big sagebrush-bluebunch wheatgrass community. In: Bedunah, D., Wambolt, C.L., McArthur, E.D., Compilers. Proceedings-Symposium on ecology and management of riparian shrub communities. USDA For. Serv. Gen. Tech. Rep. INT-289. Intermountain Forest and Range Experiment Station. Odgen, Utah.

Froeming, D.K. 1974. Herbage production and forest cover in *Pseudotsuga menziesii-Symphoricarpos* habitat types of northern Idaho. M.S. Thesis. University of Idaho, Moscow. Idaho. 39p.

Goldblum, D. and T.T. Veblen. 1992. Fire history of the ponderosa pine/Douglas fir forest in the Colorado front range. Physical Geography 13:133-148.

Gruell, G.E. 1980. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Volume 1- photographic record and analysis. USDA. For. Serv. Res. Pap. INT-235. Intermountain Forest and Range Experiment Station. Odgen, Utah. 207p.

Gruell, G.E., C.S. Wyman, S.F. Arno, and W.J. Reich. 1982. Seventy years of vegetative change in a managed ponderosa pine forest in Western Montana. USDA For.

Serv. Gen. Tech. Rep. INT-130. Intermountain Forest and Range Experiment Station. Ogden, Utah. 42p.

Gruell, G.E. 1983. Fire and vegetative trends in the Northern Rockies: Interpretations from 1871-1982. photographs. USDA. For. Ser. Gen. Tech. Rep. INT-158. Intermountain Forest and Range Experiment Station. Ogden, Utah. 117p

Gruell, G.E., Brown, J.K., and C.L. Bushey. 1986. Prescribed fire opportunities in grasslands invaded by douglas-fir: state of the art guidelines. Gen. Tech. Rep. INT-198. Intermountain Research Station. Ogden, Utah. 19p.

Harniss, R.D. and R.B. Murray. 1973. 30 years of vegetal change following burning of sagebrush-grass range. J. Range Manage. 26:322-325.

Hobbs, N.T. 1989. Linking energy balance to survival in mule deer: Development and test of a simulation model. Wildlife Monographs No. 101. 39p.

Hoffman, J.V. 1924. Natural regeneration of Douglas fir in the Pacific Northwest. USDA Dept. Bull. No. 1200. 62p.

Hoffman, T.L. 1996. An ecological investigation of mountain big sagebrush in the Gardiner Basin. M.S. Thesis. Montana State University. Bozeman, Mont. 84p.

Isaac, L.A. 1938. Factors affecting establishment of Douglas fir seedlings. USDA Circular No. 46. 45p.

Johnsen, T.N. 1962. One-seed juniper invasion of Northern Arizona grasslands. Ecol. Monogr. 32:167-207.

Johnson, J.R. and G.F. Payne. 1968. Sagebrush reinvasion as affected by some environmental influences. J. Range Manage. 21:209-213.

Kalabokidis, K.D. and R.H. Wakimoto. 1992. Prescribed burning in uneven-aged stand management of ponderosa pine/Douglas fir forests. J. Environ. Manage. 34:221-235.

Klebenow, D.H. 1969. Sage grouse nesting and brood habitat in Idaho. J. Wildl. Manage. 33:649-662.

Kranz, J.J. and R.L. Linder. 1973. Value of Black Hills forest communities to deer and cattle. J. Range Manage. 26:263-265.

Kufeld, R.C. 1973. Foods eaten by Rocky Mountain elk. J. Range Manage. 26:106-113.

Kufeld, R.C., O.C. Wallmo, and C. Feddema. 1973. Foods of the Rocky Mountain mule deer. USDA For. Serv. Res. Pap. RM-111. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado. 31p.

Laycock, W.A. 1991. Stable states and thresholds of range condition on North American rangelands: A viewpoint. J. Range Manage. 44:427-433.

Lehman, K.S. 1995. Disturbance regimes of the Southern Elkhorn Mountain landscape. M.S. Thesis. University of Idaho. Moscow, Idaho. 63p.

Loft, E.R. and J.W. Menke. 1984. Deer use and habitat characteristics of transmission-line corridors in a Douglas-fir forest. J. Wildl. Manage. 48:1311-1316.

Loope, L.L. and G.E. Gruell. 1973. The ecological role of fire in the Jackson Hole area, Northwestern Wyoming. Quaternary Research 3:425-443.

Lotan, J. E. and J. K. Brown. 1985. Fire's effects on wildlife habitat - symposium proceedings. USDA For. Serv. Gen. Tech. Rep. INT-186. Intermountain Research Station. Ogden, Utah. 96p.

Lovaas, A.L. 1958. Mule deer food habits and range use Little Belt Mountains, Montana. J. Wildl. Manage. 22:275-283.

Lyon, J. 1971. Vegetal development following prescribed burning of Douglas-fir in south central Idaho. USDA For. Serv. Res. Pap. INT-105. Intermountain Forest and Range Experiment Station. Ogden, Utah. 30p.

Lyon, J. 1979. Habitat effectiveness for elk as influenced by roads and cover. J. For. 77:658-660.

Lyon, J.L., and C.E. Jensen. 1980. Management implications of elk and deer use of clearcuts in Montana. J. Wildl. Manage. 44:352-362.

Marcum, L.C. 1975. Summer-fall habitat selection and use by a Western Montana elk herd. Ph.D. Thesis. University of Montana. Missoula, Mont.

Marcum, C.L., W.D. Edge, M.D. Scott, J.F. Lehmkul, and S.L. Olson. 1984. Final report of the Chamberlain Creek elk study. School of Forestry, University of Montana. 257p.

McConnell, B.R. and J.G. Smith. 1970. Response of understory vegetation to ponderosa pine thinning in Eastern Washington. J. Range Manage. 23:208-212.

McPherson, G.R. and H.A. Wright. 1990. Effects of cattle grazing and *Juniperus pinchotii* on herb cover and production in Western Texas. Amer. Midl. Natur. 123:144-151.

Miller, F.H. 1921. Reclamation of grasslands by Utah juniper. J. For. 19:647-651.

MINITAB, INC. 1996. User's Guide, Release 11. MINITAB, INC.

Montagne, C., L.C. Munn, G.A. Nielsen, J.W. Rogers, and H.E. Hunter. 1982. Soils of Montana. Montana Agricultural Experiment Station Bulletin no. 744. Montana State University. Bozeman, Mont. 95p.

Mueggler, W.F. and J.P. Blaisdell. 1958. Effects on associated species of burning, rotobeating, spraying and railing sagebrush. J. Range Manage. 11:61-66.

Mueggler, W.F. 1965. Ecology of seral shrub communities in the cedar-hemlock zone of Northern Idaho. Ecol. Monogr. 35:165-185.

Mueggler, W.F. and W.L. Stewart. 1980. Grassland and shrubland habitat types of Western Montana. USDA For. Serv. Gen. Tech. Rep. INT-66. Intermountain Forest and Range Experiment Station. Ogden, Utah. 154p.

Neter, J., M.H. Kutner, C.J. Nachtsheim, and W. Wasserman. 1996. Applied linear statistical models. Times Mirror Higher Education Group, Inc. USA. 1408p.

Noy-Meir, I. and B.H. Walker. 1986. Stability and resilience in rangelands. p. 21-25. *In* P.J. Joss, P.W. Lynch, and O.B. Williams (eds.), Rangelands a Resource Under Siege.

Patten, D.T. 1963. Vegetational pattern in relation to environments in the Madison Range, Montana. Ecol. Monogr. 33:375-406.

Patten, D.T. 1969. Succession from sagebrush to mixed conifer forest in the Northern Rocky Mountains. Amer. Midl. Natur. 82:229-240.

Pase, C.P. 1958. Herbage production and composition under immature ponderosa pine stands in Black Hills. J. Range. Manage. 11:238-243.

Peek, J.M., M.D. Scott, L.S. Nelson, D.J. Pierce, and L.L. Irwin. 1982. Role of cover in habitat management for big game in Northwestern United States. Trans. 47th N. Amer. Wildl. and Nat. Res. Conf. 47:363-373.

Personius, T.L., C.L. Wambolt, J.R. Stephens, and R.G. Kelsey. 1987. Crude terpenoid influence on mule deer preferences for sagebrush. J. Range Manage. 40:84-88.

Peterson, J.G. 1995. Ecological implications of sagebrush manipulation. Montana Fish, Wildlife and Parks. Federal Aid in Wildife Restoration Project W-101-R-2. 49p.

Pfister, R.D., Kovalchik, B.L., Arno, S.F., and R.C. Presby. 1977. Forest habitat types of Montana. USDA. For. Ser. Gen. Tech. Rep. INT-34. 174p. Intermountain Forest and Range Experiment Station. Ogden, Utah.

Reynolds, H.G. 1964. Elk and deer habitat use of pinyon-juniper woodlands in Southern New Mexico. Trans. North. Am. Wildl. and Nat. Res. Conf. 29:438-444.

Risenhoover, K.L. and J.A. Bailey. 1980. Visibility: an important factor for an indigenous, low-elevation bighorn herd in Colorado. p. 18-28. *In*: Northern Wild Sheep and Goat Council: Proceedings Biennial Symposium.

Risenhoover, K.L. and J.A. Bailey. 1985. Foraging ecology of mountain sheep: implications for habitat management. J. Wildl. Manage. 49:797-804.

Roberson, J.A. 1984. Sage grouse-sagebrush relationships: a review. p. 157-175. *In*: M.E. Durant and B.L. Welch (eds.), Proc.-Symposium on the biology of *Artemisia* and *Chrysothamnus*. USDA For. Serv. Gen. Tech. Rep. INT-200. Intermountain Forest and Range Experiment Station. Ogden, Utah. 398p.

Rummel, R.S. 1951. Some effects of livestock grazing on ponderosa pine forest and range in central Washington. Ecol. 32:594-607.

Sampson, A.W. 1917. Succession as a factor in range management. J. For. 15:593.

SAS Institute Inc. 1988. SAS/STAT™ User's Guide, Release 6.03 Edition. Cary, NC. 1028p.

Schott, M.R. and R.D. Pieper. 1985. Influence of canopy characteristics of one-seed juniper on understory grasses. J. Range Manage. 38:328-331.

Schwarzkoph, W.F. 1973. Range use and relationships of mule deer on the east slope of the Bridger Mountains, Montana. M.S. Thesis. Montana State University. Bozeman, Mont. 64p.

Shearer, R.G. 1974. Early establishment of conifers following prescribed broadcast burning in western larch/douglas-fir forests. in Proceeding of Tall Timbers Fire Ecology Conference and Intermountain Fire Research Council Fire and Land Management Symposium 14:481-500.

Short, H.H., W. Evans, and E.L. Boeker. 1977. The use of natural and modified pinyon pine-juniper woodlands by deer and elk. J. Wildl. Manage. 41:543-559.

Sindelar, B.W. 1971. Douglas-fir invasion of Western Montana grasslands. PH.D. Thesis. University of Montana. Missoula, Montana. 130pp.

Skovlin, J. M. 1982. Habitat requirements and evaluations. p. 369-413. *In*: J.W. Thomas and D.E. Toweill (eds.), Elk of North America: Ecology and management. Wildlife Management Institute. 698p.

Smith, R. L. 1986. Elements of ecology. 2nd edition. Harper & Row, Publishers, Inc. New York, New York. 465p.

Soil Survey Staff. 1994. Keys to soil taxonomy. USDA-SCS. Pocahontas Press, Inc. Blacksburg, Virginia. 524p.

Springfield, H.W. 1976. Characteristics and management of southwestern pinyon-juniper ranges: the status of our knowledge. USDA. For. Ser. Res. Pap. RM-160. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado. 32p.

Starker, T.J. 1934. Fire resistance in the forest. J. For. 32:462-467.

Steerey, W.F. 1979. Distribution, range use and population characteristics of mule deer associated with the Schafer Creek Winter Range, Bridger Mountains, Montana. M.S. Thesis. Montana State University. Bozeman, Montana. 119p.

Stickney, P.F. 1980. Database for post-fire succession, first 6 to 9 years, in Montana larch-fir forests. USDA For. Serv. Gen. Tech. Rep. INT-62. Intermountain Forest and Range Experiment Station. Ogden, Utah. 133p.

Strang, R.M. and J.V. Parminter. 1980. Conifer encroachment on the Chilcotin Grasslands of British Columbia. For. Chron. 56:13-18.

Striby, K.C. 1985. The in vitro digestibility and utilization of big sagebrush and black sagebrush. M.S. Thesis. Montana State University. Bozeman, Mont. 111p.

Suring, L.H., and P.A. Vohs, Jr. 1979. Habitat use by Columbian white-tailed deer. J. Wildl. Manage. 43:610-619.

Tande, G.F. 1979. Fire history and vegetation pattern of coniferous forests in Jasper National Park, Alberta. Can. J. Botany. 57:1912-1931.

Thomas, J.W., H. Black Jr., R.J. Scherzinger, and R.J. Pedersen. 1979. Deer and elk. p.104-127. *In*: J.W. Thomas (ed.), Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA For. Serv. Agriculture Handbook. No. 553.

Tucker, R.E., W. Majak, P.D. Parkinson, and A. McLean. 1976. Palatability of Douglas fir foliage to mule deer in relation to chemical and spatial factors. J. Range Manage. 29:486-489.

USDA. 1986. Beaverhead National Forest Plan. USDA. For. Ser. Beaverhead Nat. For.

USDA. 1987. Deerlodge National Forest Plan. USDA. For. Ser. Deerlodge Nat. For. pg. II-10.

Vale, T.R. 1975. Invasion of big sagebrush (*Artemisia tridentata*) by white fir (*Abies concolor*) on the southeastern slopes of the Warner Mountains, California. Great Basin Naturalist 35:319-324.

Wakelyn, L.A. 1987. Changing habitat conditions on bighorn sheep ranges in Colorado. J. Wildl. Manage. 51:904-912.

Walhof, K.S. 1997. A comparison of burned and unburned big sagebrush communities. M.S. Thesis. Montana State University. Bozeman, Mont. 74p.

Wallestad, R. and D. Pyrah. 1974. Movement and nesting of sage grouse hens in central Montana. J. Wildl. Manage. 38:630-633.

Wallestad, R. and P. Schladweiler. 1974. Breeding season movements and habitat selection of male sage grouse. J. Wildl. Manage. 38:634-637.

Wallestad, R., J.G. Peterson, and R.L. Eng. 1975. Foods of adult sage grouse in central Montana. J. Wildl. Manage. 39:628-638.

Wambolt, C.L. and G.F. Payne. 1986. An 18 year comparison of control methods for Wyoming big sagebrush in Southwestern Montana. J. Range Manage. 39:314-319.

Wambolt, C.L., W.H. Creamer, and R.J. Rossi. 1994. Predicting big sagebrush winter forage by subspecies and browse form class. J. Range Manage. 47:231-234.

Wambolt, C.L. 1996. Mule deer and elk foraging preference for 4 sagebrush taxa. J. Range Manage. 49:499-503

Waugh, W.J. and H.G. Fisser. 1986. Demography of juniper encroachment of a Bighorn Basin, Wyoming site. Wyoming Shrublands 15:35-41.

Welch, B.L., and F.J. Wagstaff. 1990. Rejuvenation of mountain big sagebrush on mule deer winter ranges using onsite plants as a seed source. in Proceedings-Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management. USDA. For. Ser. Gen. Tech. Rep. INT-276. Intermountain Research Station. Ogden, Utah. pg 171-174.

Westoby, M.B., B. Walker, and I. Noy-Meir. 1989. Opportunistic management for rangelands not at equilibrium. J. Range Manage. 42:266-274.

Wickstrom, M.L., C.T. Robbins, T.A. Hanley. D.E. Spalinger, and S.M. Parish. 1984. Food intake and foraging energetics of elk and mule deer. J. Wildl. Manage. 48:1285-1301.

Wilkins, B.T. 1957. Range use, food habits, and agricultural relationships of the mule deer, Bridger Mountains, Montana. J. Wildl. Manage. 21:159-169.

Winward, A.H. 1970. Taxonomic and ecological relationships of the big sagebrush complex in Idaho. PH.D. Thesis. University of Idaho. Moscow, Idaho.

Winward, A.H. and E.H. Tisdale. 1977. Taxonomy of the *Artemisia tridentata* complex in Idaho. Idaho For., Wildl. and Range Exp. Sta. Bull. No. 19. University of Idaho. 15p.

Wright, H.A. and A.W. Bailey. 1982. Fire ecology: United States and Southern Canada. John Wiley & Sons Inc., New York, N.Y.

Young, R.P. 1982. Fire as vegetation management tool in rangelands of the intermountain region. in Managing intermountain rangelands-improvement of range and wildlife habitats: Proceedings of a symposium. USDA For. Ser. Gen. Tech. Rep. INT-157. p18-31. Intermountain Forest and Range Experiment Station. Odgen, Utah.

Zimmerman, G.T. 1979. Livestock grazing, fire and their interactions within the Douglas-fir/ninebark habitat types of northern Idaho. M.S. Thesis. University of Idaho. Moscow, Idaho.

Zimmerman, G.T. and L.F. Neuenschwander. 1984. Livestock grazing influences on community structure, fire intensity, and fire frequency within the Douglas fir/ninebark habitat type. J. Range Manage. 37:104-110.

APPENDICES

APPENDIX A

PLANT SPECIES LISTS

Table 34. Plant species occurring in the Sugerloaf Mountain study area.

Scientific Name	Common Name
Pseudotsuga menziesii	Douglas fir
Pinus flexilis	limber pine
Juniperus scopulorum	Rocky Mountain juniper
Artemisia tridentata vaseyana	mountain big sagebrush
Purshia tridentata	antelope bitterbrush
Juniperus communis	common juniper
Tetradymia canescens	gray horsebrush
Chrysothamnus nauseosus	rubber rabbitbrush
Crysothamnus viscidiflorus	green rabbitbrush
Festuca idahoensis	Idaho fescue
Agropyron spicatum	bluebunch wheatgrass
Poa pratensis	Kentucky bluegrass
Poa sp.	bluegrass
Koeleria macrantha	prairie junegrass
Stipa comata	needleandthread
Stipa viridula	green needlegrass
Juncus balticus	Baltic rush
Bromus tectorum	cheatgrass
Taraxacum officinale	common dandelion
Artemisia frigida	fringed sagewort
Sedum sp.	stonecrop
Crepis acuminata	hawksbeard
Tragopon dubius	salsify
Castilleja pallescens.	paintbrush
Lupinus spp.	lupine
Allium textile	nodding onion
Phlox hoodi	Hood's phlox
Lewisia rediviva	bitterroot
Linaria dalmatica	Dalmation toadflax
Commandra umbellata	bastard toadflax
Oxtropis spp.	stemless locoweed
Gaura coccinea	gaura
Vicia sp.	vetch
Eriogonum umbellatum	buckwheat
Eriogonum sp.	buckwheat
Thlapsi arvense	penny cress
Collinsia parviflora	blue-eyed Mary
Potentilla argentia	cinquefoil
Chrysopsis villosa	hairy goldenaster
Geum triflorum	prairie smoke avens

Table 34. cont.

Frageria vesca	wild strawberry
Arenaria congesta	ballhead sandwort
Antennaria parvifolia	Nuttall's pussy-toes
Penstemon laricifolius	beardtongue
Arnica sororia	arnica
Phlox longifolia	phlox
Hieracium albiflorum	hawkweed
Arabis drummondi	Drummond's rockcress
Collomia grandiflora	collomia
Viola sp.	violet
Chenopodium album	lamb's quarters
Lithospermum sp.	stoneseed
Astragalus adsurgens	milk-vetch
Astragalus tenellus	milk-vetch
Senecio sp.	groundsel
Polytrichum juniperum	hair-cap moss
Selaginella densa	spike moss

Table 35. Plant species occurring in the Medicine Lodge Peak study area.

Scientific Name	Common Name
Pseudotsuga menziesii	Douglas fir
Pinus flexilis	limber pine
Juniperus scopulorum	Rocky Mountain juniper
Artemisia tridentata vaseyana	mountain big sagebrush
Juniperus communis	common juniper
Tetradymia canescens	gray horsebrush
Chrysothamnus nauseosus	rubber rabbitbrush
Chrysothamnus viscidiflorus	green rabbitbrush
Rosa woodsii	Wood's rose
Ribes cereum	currant
Ribes sp.	gooseberry
Festuca idahoensis	Idaho fescue
Agropyron spicatum	bluebunch wheatgrass
Agropyron trachycaulum	slender wheatgrass
Bromus carinatus	mountain brome
Poa arida	plains bluegrass
Carex sp.	sedge
Juncus sp.	rush
Zigadenus sp.	death camas
Lupinus sp.	lupine
Delphinium nelsoni	low larkspur
Achillea millefolium	western yarrow
Castilleja spp.	paintbrush
Dodecathon spp.	shooting star
Crepis accuminata	hawksbeard
Taraxacum officinale	common dandelion
Sedum sp.	stonecrop
Antennaria sp.	pussy-toes
Heuchera parvifolia	alum root
Phlox longifolia	phlox
Phlox sp.	phlox
Vicia sp.	vetch
Potentilla spp.	cinquefoil
Saxifraga sp.	saxifrage
Eriogonum spp.	buckwheat
Arnica sororia	arnica
Arabis sp.	rock cress

Table 35. cont.

Senecio sp.	groundsel
Viola sp.	violet
Agoseris glauca	mountain-dandelion
Frageria virginiana	wild strawberry
Frageria vesca	wild strawberry
Arenaria congesta	ballhead sandwort
Lomatium sp.	biscuit-root
Geranium richardsoni	Richardson's geranium
Stellaria longipea	chickweed
Erysium asperum	wallflower
Phacelia heterophylla	phacelia
Lithospermum sp.	stoneseed
Collomia grandiflora	collomia
Geum triflorum	praire smoke avens
Tragapogon sp.	salsify
Perideridia sp.	yampah
Polytrichum juniperum	hair-cap moss
Selaginella densa	spike moss

Table 36. Plant species occurring in the Hells Canyon study area.

Scientific Name	Common Name
Pseudotsuga menziesii	Douglas fir
Pinus flexilis	limber pine
Pinus contorta	lodgepole pine
Juniperus scopulorum	Rocky Mountain juniper
Artemisia tridentata vaseyana	mountain big sagebrush
Juniperus communis	common juniper
Tetradymia canescens	gray horsebrush
Chrysothamnus viscidiflorus	green rabbitbrush
Ribes cereum	currant
Ribes sp.	gooseberry
Festuca idahoensis	Idaho fescue
Agropyron spicatum	bluebunch wheatgrass
Agropyron trachycaulum	slender wheatgrass
Bromus carinatus	mountain brome
Stipa comata	needleandthread
Stipa nelsonii	Nelson's needlegrass
Stipa richardsonii	Richardson's needlegrass
Poa pratensis	Kentucky bluegrass
Poa secunda	Sandberg's needlegrass
Koeleria macrantha	prairie junegrass
Danthonia intermedia	timber danthonia
Agrostis scabra	winter bentgrass
Carex sp.	sedge
Juncus sp.	rush
Artemisia ludoviciana	cudweed sagewort
Artemisia frigida	fringed sagewort
Lupinus sp.	lupine
Delphinium sp.	larkspur
Achillea millefolium	western yarrow
Castilleja spp.	paintbrush
Dodecathon spp.	shooting star
Taraxacum officinale	common dandelion
Sedum sp.	stonecrop
Antennaria parvifolia	Nuttall's pussytoes
Vicia sp.	vetch
Potentilla spp.	cinquefoil
Eriogonum spp.	buckwheat
Arnica sororia	arnica
Arabis sp.	rock cress

Table 36. cont.

Viola sp.	violet
Agoseris glauca	mountain-dandelion
Frageria virginiana	wild strawberry
Frageria vesca	wild strawberry
Arenaria congesta	ballhead sandwort
Geranium richardsoni	Richardson's geranium
Geum triflorum	praire smoke avens
Tragapogon sp.	salsify
Penstemon sp.	beardtongue
Pedicularis sp.	lousewort
Townsendia parryi	Parry's townsendia
Oxytropis sp.	stemless-locoweed
Iris missouriensis	Rocky Mountain flag
Chrysopsis villosa	hairy goldenaster
Lewisia rediviva	bitterroot
Erigeron spp.	fleabane
Allium cernuum	nodding onion
Frasera speciosa	frasera
Haplopappus acaulis	goldenweed
Cynoglossum officinale	Hound's tongue
Galium boreale	bedstraw
Anemone patens	anemone
Synthyris pinnatifida	synthyris
Polytrichum juniperum	hair-cap moss
Selaginella densa	spike moss

APPENDIX B

SAGEBRUSH WINTER FORAGE PRODUCTION MODELS

Table 37. Models used to estimate big sagebrush winter forage production.

Low use mountain big sagebrush

$$\ln(F) = 0.647 + 0.034\,(MJ) + 0.031\,(AC) - 0.0002\,(C1)$$

High use mountain big sagebrush

$$\ln(F) = 0.489 + 0.037\,(MJ) + 0.050\,(AC) - 0.0003\,(C1)$$

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

APPENDIX C

SITE MEANS

Table 38. Sugerloaf Mountain study area means[1] for Douglas fir, sagebrush age and cover, grass cover, and total herbaceous cover.

Site	DFLint	ToBarea	TDFdens	DbhDens	ToTreeHt	DFAGE	SageAge	SageLint	GrassCov	HerbCov
	(%)	(cm^2/tran)	(#/61m^2)	(#/61m^2)	(m)	(years)	(years)	(%)	(%)	(%)
1	26.8	595.3	9.7	2.5	2.4	12.1	11.0	7.7	10.8	27.3
2	52.0	1000.4	14.5	5.8	4.0	20.7	13.2	1.2	12.3	23.8
3	18.8	250.4	6.8	3.0	2.3	14.5	15.3	12.3	19.8	40.8
4	18.7	473.9	3.7	2.0	3.1	19.4	18.3	11.0	16.4	31.3
5	34.9	929.8	6.2	3.0	4.8	22.8	18.3	6.6	14.7	27.5
6	18.4	372.9	4.7	2.5	2.9	17.1	17.9	11.3	19.3	40.5
7	36.8	631.1	14.7	2.0	2.3	14.4	14.3	3.9	10.4	25.1
8	38.4	793.2	9.5	3.5	2.6	20.4	19.0	4.3	10.0	19.4
9	0.0	0.0	0.0	0.0	0.0	0.0	11.2	20.0	25.6	31.9
10	7.7	184.5	1.0	0.8	4.6	26.8	12.9	13.4	20.7	30.7
11	19.9	495.1	1.8	1.8	5.3	37.2	18.1	9.5	25.5	36.6
12	15.8	299.7	1.8	1.5	3.6	25.7	19.3	7.1	20.3	29.0
13	26.1	428.2	6.2	2.8	3.1	20.5	19.3	6.0	12.6	25.5
14	11.7	228.9	4.2	2.2	2.8	18.9	19.7	15.3	17.5	34.5
15	39.7	757.1	6.3	3.5	3.8	28.1	15.8	2.4	14.7	29.7
16	20.7	374.3	2.3	2.0	4.5	27.4	16.2	6.6	17.3	28.1
17	61.5	1026.3	11.5	7.2	3.6	26.8	12.4	0.8	9.2	11.9
18	6.2	61.5	0.5	0.5	4.1	10.8	20.2	20.3	22.7	33.7
19	4.1	1.7	0.8	0.3	1.2	10.8	20.2	10.3	21.0	33.7
20	21.0	422.7	2.3	2.0	4.2	27.5	21.4	6.5	20.5	29.5
21	1.0	0.1	0.3	0.2	1.3	15.0	20.8	8.5	33.5	44.0
22	33.3	803.3	4.5	2.0	3.4	27.3	17.8	1.7	9.7	16.0
23	16.2	448.8	4.2	2.2	2.8	19.3	18.4	7.6	22.0	29.7
24	45.4	1329.0	8.5	5.0	3.8	28.4	21.4	2.2	9.6	19.5
25	30.9	655.3	7.2	5.3	3.4	25.6	20.4	5.3	14.3	28.0

1: DFLint = DF canopy cover, ToBarea = total DF basal area, TDFdens = total DF density, DbhDens = density of DF ≥ 1.5 m in height, ToTreeHt = average total DF height, DFAGE = average DF age, SageAge = average sagebrush age, SageLint = sagebrush canopy cover, GrassCov = grass canopy cover, HerbCov = total herbaceous canopy cover.

Table 39. Sugerloaf Mountain study area means[1] for Douglas fir, sagebrush density and production.

Site	DFLint	ToBarea	TDFdens	DbhDens	ToTreeHt	DFAGE	ArtrG15	ArtrL15	Dead	ProdAve	Tsagepro
	(%)	(cm^2/tran)	(#/61m^2)	(#/61m^2)	(m)	(years)	(#/61m^2)	(#/61m^2)	(#/61m^2)	(g/plant)	(Kg/Ha)
1	26.8	595.3	9.7	2.5	2.4	12.1	37.0	17.0	16.7	33.9	208.4
2	52.0	1000.4	14.5	5.8	4.0	20.7	11.3	21.7	25.5	15.0	28.7
3	18.8	250.4	6.8	3.0	2.3	14.5	48.2	24.5	35.0	44.5	391.8
4	18.7	473.9	3.7	2.0	3.1	19.4	50.5	23.3	17.5	50.9	313.9
5	34.9	929.8	6.2	3.0	4.8	22.8	36.2	27.5	27.5	26.9	163.3
6	18.4	372.9	4.7	2.5	2.9	17.1	55.8	28.2	26.7	47.6	430.9
7	36.8	631.1	14.7	2.0	2.3	14.4	22.2	27.2	18.3	20.2	72.4
8	38.4	793.2	9.5	3.5	2.6	20.4	32.0	16.0	32.3	27.2	145.6
9	0.0	0.0	0.0	0.0	0.0	0.0	87.5	67.5	4.8	53.1	780.5
10	7.7	184.5	1.0	0.8	4.6	26.8	85.7	34.7	9.3	38.1	539.8
11	19.9	495.1	1.8	1.8	5.3	37.2	61.7	29.5	26.8	57.5	551.6
12	15.8	299.7	1.8	1.5	3.6	25.7	56.5	28.5	35.3	33.9	311.5
13	26.1	428.2	6.2	2.8	3.1	20.5	48.2	33.8	25.8	35.5	292.9
14	11.7	228.9	4.2	2.2	2.8	18.9	92.3	31.5	39.0	45.3	701.2
15	39.7	757.1	6.3	3.5	3.8	28.1	29.7	26.2	35.8	26.7	155.3
16	20.7	374.3	2.3	2.0	4.5	27.4	54.8	37.3	33.7	46.7	455.5
17	61.5	1026.3	11.5	7.2	3.6	26.8	7.2	21.3	26.3	19.0	21.2
18	6.2	61.5	0.5	0.5	4.1	10.8	76.7	31.5	8.7	55.4	717.6
19	4.1	1.7	0.8	0.3	1.2	10.8	69.8	47.0	17.7	48.0	534.9
20	21.0	422.7	2.3	2.0	4.2	27.5	61.5	33.2	16.3	44.5	448.5
21	1.0	0.1	0.3	0.2	1.3	15.0	72.0	46.2	23.2	39.5	462.6
22	33.3	803.3	4.5	2.0	3.4	27.3	15.7	31.2	25.2	19.2	51.1
23	16.2	448.8	4.2	2.2	2.8	19.3	55.3	50.2	20.5	36.9	336.8
24	45.4	1329.0	8.5	5.0	3.8	28.4	18.8	26.3	27.3	16.6	56.1
25	30.9	655.3	7.2	5.3	3.4	25.6	36.7	19.3	39.0	36.6	231.6

1: DFLint = DF canopy cover, ToBarea = total DF basal area, TDFdens = total DF density, DbhDens = density of DF ≥ 1.5 m in height, ArtrG15 = sagebrush with an average crown cover ≥ 15 cm, ArtrL15 = sagebrush with an average crown cover < 15 cm, Dead = number of dead sagebrush, ProdAve = average sagebrush production per plant, Tsagepro = total sagebrush production per transect.

Table 40. Medicine Lodge Peak study area means[1] for Douglas fir, sagebrush age and cover, grass cover, and herbaceous cover.

Site	DFLint	ToBarea	TDFdens	DbhDens	ToTreeHt	HTG15M	DFAGE	SageAge	SageLint	GrassDau	HerbDau
	(%)	(cm2/tran)	(#/61m2)	(#/61m2)	(m)	(m)	(years)	(years)	(%)	(%)	(%)
1	23.0	533.5	5.0	3.7	3.7	4.8	18.8	20.2	12.0	12.5	29.5
2	7.2	73.7	1.3	1.2	3.4	3.8	17.9	25.9	11.6	24.4	45.3
3	33.1	798.2	7.8	4.3	3.5	6.0	16.2	23.2	4.4	11.4	36.2
4	42.6	661.6	8.0	5.8	3.8	5.0	19.0	20.5	2.7	11.8	29.9
5	28.3	420.9	8.5	2.7	1.7	4.7	10.6	20.9	6.1	11.3	40.7
6	46.5	776.6	15.7	10.0	2.5	3.6	19.2	15.7	0.5	10.5	40.7
7	42.7	521.6	11.5	7.3	2.5	3.6	20.3	20.5	1.4	11.5	37.5
8	21.2	431.9	3.8	2.5	3.5	5.2	17.9	19.4	9.5	10.5	43.9
9	38.4	788.0	8.3	5.5	2.9	4.3	21.2	20.0	5.3	9.8	35.9
10	37.4	824.2	7.8	5.5	3.7	5.0	19.4	20.2	5.3	11.7	32.6
11	73.3	1416.9	26.0	19.8	3.2	4.1	23.6	0.0	0.0	5.5	16.4
12	53.9	808.6	12.2	8.5	3.2	4.4	20.5	18.4	1.4	8.4	31.8
13	28.7	476.3	6.8	5.0	3.3	4.3	19.6	20.8	7.4	10.4	34.9
14	31.4	652.8	8.7	5.7	3.1	4.4	16.8	26.2	4.4	11.4	39.8
15	36.6	568.2	9.0	6.5	3.3	4.3	19.2	21.5	2.6	9.9	39.0
16	14.4	311.0	3.0	2.7	4.3	4.7	22.0	16.3	17.2	10.3	50.9
17	5.6	112.5	2.0	1.2	3.0	4.9	17.2	25.0	16.3	13.5	41.1
18	15.0	282.4	3.7	2.3	2.9	4.3	16.3	29.2	14.1	17.7	44.3
19	7.2	143.6	2.0	1.3	2.8	3.8	16.1	27.3	20.7	19.4	42.0
20	0.9	3.7	0.7	0.7	1.9	1.9	21.3	22.8	20.1	13.0	39.1
21	12.8	221.6	2.3	2.2	4.0	4.3	19.5	31.7	14.9	13.8	34.4
22	15.0	237.0	3.5	2.7	3.3	4.2	19.1	27.8	19.3	9.5	28.2
23	1.3	7.1	0.7	0.7	2.6	2.6	19.5	24.9	21.4	9.4	29.6
24	0.1	0.0	0.2	0.0	1.1	0.0	8.0	21.8	27.9	6.8	24.6
25	59.4	1203.4	20.5	12.3	2.7	4.2	18.2	17.6	0.3	7.7	24.0

1: DFLint = DF canopy cover, ToBarea = total DF basal area, TDFdens = total DF density, DbhDens = density of DF ≥ 1.5 m in height, ToTreeHt = average total DF height, DFAGE = average DF age, SageAge = average sagebrush age, SageLint = sagebrush canopy cover, GrassCov = grass canopy cover, HerbCov = total herbaceous canopy cover.

Table 41. Medicine Lodge Peak study area means[1] for Douglas fir, sagebrush density and production.

Site	DFLint	ToBarea	TDFdens	DbhDens	ToTreeHt	HTG15M	DFAGE	ArtrG15	ArtrL15	Dead	ProdAve	Tsagepro
	(%)	(cm2/tran)	(#/61m2)	(#/61m2)	(m)	(m)	(years)	(#/61m2)	(#/61m2)	(#/61m2)	(g/plant)	(Kg/Ha)
1	23.0	533.5	5.0	3.7	3.7	4.8	18.8	53.2	43.0	34.2	39.4	342.9
2	7.2	73.7	1.3	1.2	3.4	3.8	17.9	66.2	33.5	22.8	46.4	494.2
3	33.1	798.2	7.8	4.3	3.5	6.0	16.2	20.7	22.8	59.2	28.7	89.2
4	42.6	661.6	8.0	5.8	3.8	5.0	19.0	19.7	23.5	49.7	20.6	73.8
5	28.3	420.9	8.5	2.7	1.7	4.7	10.6	26.8	22.5	49.7	30.9	146.9
6	46.5	776.6	15.7	10.0	2.5	3.6	19.2	3.5	6.0	42.7	14.7	8.4
7	42.7	521.6	11.5	7.3	2.5	3.6	20.3	9.7	8.5	34.8	17.1	28.9
8	21.2	431.9	3.8	2.5	3.5	5.2	17.9	51.3	18.3	40.8	33.7	303.5
9	38.4	788.0	8.3	5.5	2.9	4.3	21.2	20.3	25.0	45.7	21.4	71.3
10	37.4	824.2	7.8	5.5	3.7	5.0	19.4	29.8	18.0	48.7	22.0	114.0
11	73.3	1416.9	26.0	19.8	3.2	4.1	23.6	0.0	1.0	61.7	0.0	0.0
12	53.9	808.6	12.2	8.5	3.2	4.4	20.5	9.8	6.3	46.0	15.9	25.8
13	28.7	476.3	6.8	5.0	3.3	4.3	19.6	47.3	24.8	38.8	27.5	224.2
14	31.4	652.8	8.7	5.7	3.1	4.4	16.8	29.7	16.2	52.2	28.2	149.1
15	36.6	568.2	9.0	6.5	3.3	4.3	19.2	19.3	7.8	36.7	23.3	76.4
16	14.4	311.0	3.0	2.7	4.3	4.7	22.0	79.8	41.2	23.8	36.7	493.3
17	5.6	112.5	2.0	1.2	3.0	4.9	17.2	73.8	21.2	33.7	72.1	889.7
18	15.0	282.4	3.7	2.3	2.9	4.3	16.3	75.5	16.2	30.5	47.3	602.8
19	7.2	143.6	2.0	1.3	2.8	3.8	16.1	86.5	19.7	13.7	50.3	713.7
20	0.9	3.7	0.7	0.7	1.9	1.9	21.3	76.2	14.5	19.2	80.2	998.0
21	12.8	221.6	2.3	2.2	4.0	4.3	19.5	62.2	21.5	26.2	60.3	615.2
22	15.0	237.0	3.5	2.7	3.3	4.2	19.1	71.0	22.3	32.7	59.8	692.2
23	1.3	7.1	0.7	0.7	2.6	2.6	19.5	91.3	14.7	27.7	61.4	915.7
24	0.1	0.0	0.2	0.0	1.1	0.0	8.0	123.5	28.0	14.8	82.4	1665.3
25	59.4	1203.4	20.5	12.3	2.7	4.2	18.2	3.0	4.3	48.2	12.4	6.1

1: DFLint = DF canopy cover, ToBarea = total DF basal area, TDFdens = total DF density, DbhDens = density of DF ≥ 1.5 m in height, ArtrG15 = sagebrush with an average crown cover ≥ 15 cm, ArtrL15 = sagebrush with an average crown cover < 15 cm, Dead = number of dead sagebrush, ProdAve = average sagebrush production per plant, Tsagepro = total sagebrush production per transect.

Table 42. Hells Canyon study area means[1] for Douglas fir, sagebrush age and cover, grass cover and total herbaceous cover.

Site #	DFLint	ToBarea	TDFdens	DbhDens	ToTreeHt	HTG15M	DFAGE	SageAge	SageLint	GrassDau	HerbDau
	(%)	(cm2/tran)	(#/61m2)	(#/61m2)	(m)	(m)	(years)	(years)	(%)	(%)	(%)
1	16.5	136.3	3.5	3.2	3.1	3.4	18.8	21.9	14.4	23.4	46.1
2	17.2	258.4	3.0	2.2	3.1	4.1	17.2	29.7	15.4	23.8	43.6
3	8.9	41.3	1.2	0.8	3.1	4.0	18.9	25.6	15.5	21.3	36.0
4	3.4	34.3	0.5	0.5	3.9	3.9	22.0	20.3	20.4	26.0	38.8
5	5.7	31.6	2.0	1.8	2.9	3.1	17.5	27.4	21.6	29.3	43.9
6	16.6	109.4	2.5	2.0	3.0	3.7	15.9	31.5	19.6	20.4	38.7
7	32.7	342.2	2.5	2.0	3.9	4.5	21.3	29.0	11.9	19.9	33.2
8	25.5	275.2	5.2	3.8	2.8	3.5	16.5	29.3	10.1	30.0	49.8
9	26.5	405.1	3.8	2.8	3.3	4.1	17.1	31.6	11.7	24.8	43.9
10	17.5	233.4	3.5	3.0	3.3	3.7	18.8	25.4	8.9	26.3	46.0
11	23.4	398.0	4.2	3.5	3.5	4.0	18.7	27.7	10.1	25.2	42.4
12	22.8	321.2	5.3	4.0	3.1	3.9	19.8	30.8	13.2	23.7	44.3
13	2.8	44.1	0.8	0.3	2.1	4.6	13.0	38.0	17.1	30.8	46.5
14	64.6	1556.7	11.8	8.5	4.0	5.3	24.2	7.0	0.4	8.2	16.0
15	40.2	450.8	6.3	5.2	3.2	3.8	16.8	23.7	2.2	13.5	27.8
16	40.2	490.7	8.0	6.7	3.4	4.0	17.1	28.2	2.5	14.6	28.4
17	22.9	184.5	4.0	3.0	3.0	3.6	17.1	26.5	10.3	14.4	26.4
18	20.2	282.9	4.7	3.2	2.7	3.8	18.4	31.9	9.7	25.2	41.2
19	47.3	675.1	7.5	6.0	3.2	3.8	18.9	14.3	5.1	14.2	30.5
20	43.9	463.4	6.8	5.5	3.2	3.8	17.5	28.9	2.5	13.1	27.1
21	11.7	188.6	3.0	1.8	2.7	4.0	15.7	30.6	19.4	18.4	33.0
22	43.4	641.8	7.8	6.8	3.7	4.2	19.8	27.4	4.0	16.4	27.9
23	54.1	559.1	9.2	8.0	3.4	3.8	20.1	12.2	2.0	12.7	23.9
24	6.0	37.3	0.8	0.5	2.7	4.3	16.2	31.1	22.4	22.7	33.5
25	0.6	0.8	0.2	0.2	2.7	2.7	16.0	16.8	26.1	25.4	41.1

1: DFLint = DF canopy cover, ToBarea = total DF basal area, TDFdens = total DF density, DbhDens = density of DF ≥ 1.5 m in height, ToTreeHt = average total DF height, DFAGE = average DF age, SageAge = average sagebrush age, SageLint = sagebrush canopy cover, GrassCov = grass canopy cover, HerbCov = total herbaceous canopy cover.

Table 43. Hells Canyon study area means[1] for Douglas fir, sagebrush density and production.

Site #	DFLint	ToBarea	TDFdens	DbhDens	ToTreeHt	HTG15M	DFAGE	ArtrG15	ArtrL15	Dead	ProdAve	Tsagepro
	(%)	(cm2/tran)	(#/61m2)	(#/61m2)	(m)	(m)	(years)	(#/61m2)	(#/61m2)	(#/61m2)	(g/plant)	(Kg/Ha)
1	16.5	136.3	3.5	3.2	3.1	3.4	18.8	63.0	87.8	20.2	41.8	426.6
2	17.2	258.4	3.0	2.2	3.1	4.1	17.2	75.7	67.2	20.2	38.2	467.7
3	8.9	41.3	1.2	0.8	3.1	4.0	18.9	63.7	27.8	32.3	39.7	419.4
4	3.4	34.3	0.5	0.5	3.9	3.9	22.0	71.8	18.8	20.5	49.6	584.8
5	5.7	31.6	2.0	1.8	2.9	3.1	17.5	71.3	38.8	18.7	53.0	636.1
6	16.6	109.4	2.5	2.0	3.0	3.7	15.9	81.2	65.8	12.8	46.5	619.9
7	32.7	342.2	2.5	2.0	3.9	4.5	21.3	43.8	25.3	27.8	38.2	273.3
8	25.5	275.2	5.2	3.8	2.8	3.5	16.5	47.5	60.3	26.8	31.6	263.1
9	26.5	405.1	3.8	2.8	3.3	4.1	17.1	52.3	32.8	34.5	40.9	346.8
10	17.5	233.4	3.5	3.0	3.3	3.7	18.8	59.8	108.3	26.0	37.8	374.5
11	23.4	398.0	4.2	3.5	3.5	4.0	18.7	58.0	84.8	22.0	31.2	293.6
12	22.8	321.2	5.3	4.0	3.1	3.9	19.8	56.8	53.8	27.0	36.0	332.2
13	2.8	44.1	0.8	0.3	2.1	4.6	13.0	67.7	22.2	20.8	52.5	575.7
14	64.6	1556.7	11.8	8.5	4.0	5.3	24.2	1.3	16.8	48.2	9.5	2.1
15	40.2	450.8	6.3	5.2	3.2	3.8	16.8	13.2	27.7	49.5	18.7	40.3
16	40.2	490.7	8.0	6.7	3.4	4.0	17.1	13.8	35.7	67.3	17.9	41.2
17	22.9	184.5	4.0	3.0	3.0	3.6	17.1	44.8	32.8	43.7	26.9	201.0
18	20.2	282.9	4.7	3.2	2.7	3.8	18.4	41.8	84.2	41.5	27.0	186.7
19	47.3	675.1	7.5	6.0	3.2	3.8	18.9	16.7	73.5	33.5	14.0	38.1
20	43.9	463.4	6.8	5.5	3.2	3.8	17.5	11.3	33.5	52.3	16.7	32.1
21	11.7	188.6	3.0	1.8	2.7	4.0	15.7	70.7	38.8	27.3	36.1	418.0
22	43.4	641.8	7.8	6.8	3.7	4.2	19.8	20.5	18.5	54.7	20.1	64.9
23	54.1	559.1	9.2	8.0	3.4	3.8	20.1	9.7	50.2	49.8	14.1	23.6
24	6.0	37.3	0.8	0.5	2.7	4.3	16.2	73.0	32.5	21.2	51.4	608.0
25	0.6	0.8	0.2	0.2	2.7	2.7	16.0	96.8	48.8	11.3	54.2	857.7

1: DFLint = DF canopy cover, ToBarea = total DF basal area, TDFdens = total DF density, DbhDens = density of Df ≥ 1.5 m in height, ArtrG15 = sagebrush with an average crown cover ≥ 15 cm, ArtrL15 = sagebrush with an average crown cover < 15 cm, Dead = number of dead sagebrush, ProdAve = average sagebrush production per plant, Tsagepro = total sagebrush production per transect.

APPENDIX D

SUMMARY STATISTICS FOR STUDY AREA SITES

Table 44. Sugerloaf Mountain study area summary statistics for Douglas fir canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	26.8	14.5	11.5	53.6	5.9
2	6	52.0	11.0	34.4	66.6	4.5
3	6	18.8	5.0	13.0	26.5	2.1
4	6	18.7	9.5	7.8	29.8	3.9
5	6	34.9	13.2	24.2	59.9	5.4
6	6	18.4	8.8	9.6	32.4	3.6
7	6	36.8	16.9	17.0	61.9	6.9
8	6	38.4	8.9	29.7	50.7	3.6
9	6	0.0	0.0	0.0	0.0	0.0
10	6	7.7	7.9	0.0	19.0	3.2
11	6	19.9	15.8	6.3	41.0	6.4
12	6	15.8	8.8	4.2	28.1	3.6
13	6	26.1	8.5	14.9	40.5	3.5
14	6	11.7	7.2	2.0	19.9	2.9
15	6	39.7	18.7	16.2	62.8	7.6
16	6	20.7	11.1	8.8	35.4	4.5
17	6	61.5	15.4	40.9	80.4	6.3
18	6	6.2	6.0	0.0	13.7	2.4
19	6	4.1	5.6	0.0	11.3	2.3
20	6	21.0	7.3	11.0	31.8	3.0
21	6	1.0	2.0	0.0	5.0	0.8
22	6	33.3	12.2	14.6	50.1	5.0
23	6	16.2	8.0	5.6	29.2	3.3
24	6	45.4	13.5	28.5	64.9	5.5
25	6	30.9	12.6	17.7	52.8	5.1

Table 45. Sugerloaf Mountain study area summary statistics for total basal area.

Site	N	Mean (cm^2)	Std. Dev.	Min. (cm^2)	Max. (cm^2)	Std. Error
1	6	595.3	523.5	0.0	1234.6	213.7
2	6	1000.4	290.2	594.5	1285.0	118.5
3	6	250.4	151.0	1.6	443.1	61.7
4	6	473.9	516.9	25.1	1420.0	211.0
5	6	929.8	450.6	516.0	1715.0	184.0
6	6	372.9	239.4	0.0	640.8	97.6
7	6	631.1	631.4	63.6	1555.8	257.8
8	6	793.2	357.9	105.2	1128.4	146.1
9	6	0.0	0.0	0.0	0.0	0.0
10	6	184.5	223.5	0.0	581.2	91.2
11	6	495.1	466.4	0.0	1145.0	190.3
12	6	299.7	296.4	3.1	821.1	121.0
13	6	428.2	388.0	0.0	1045.8	158.4
14	6	228.9	232.3	0.0	588.0	94.8
15	6	757.1	564.1	0.0	1514.0	230.3
16	6	374.3	268.4	0.0	793.2	109.6
17	6	1026.3	869.6	293.7	2727.2	355.0
18	6	61.5	139.8	0.0	346.4	57.1
19	6	1.7	2.9	0.0	7.1	1.2
20	6	422.7	114.1	283.5	564.6	46.6
21	6	0.1	0.3	0.0	0.8	0.1
22	6	803.3	397.5	0.0	1038.3	162.3
23	6	448.8	247.3	0.0	706.9	101.0
24	6	1329.0	336.5	784.5	1753.8	137.4
25	6	655.3	268.3	330.6	1103.2	109.5

Table 46. Sugerloaf Mountain study area Summary statistics for total Douglas fir density.

Site	N	Mean (#)	Std. Dev.	Min. (#)	Max. (#)	Std. Error
1	6	9.7	1.4	8.0	12.0	0.6
2	6	14.5	7.5	9.0	27.0	3.1
3	6	6.8	3.5	3.0	12.0	1.4
4	6	3.7	2.3	2.0	8.0	0.9
5	6	6.2	3.4	2.0	11.0	1.4
6	6	4.7	4.6	1.0	13.0	1.9
7	6	14.7	7.4	4.0	25.0	3.0
8	6	9.5	5.9	4.0	20.0	2.4
9	6	0.0	0.0	0.0	0.0	0.0
10	6	1.0	0.9	0.0	2.0	0.4
11	6	1.8	1.5	0.0	4.0	0.6
12	6	1.8	1.2	1.0	4.0	0.5
13	6	6.2	4.6	1.0	14.0	1.9
14	6	4.2	4.6	0.0	13.0	1.9
15	6	6.3	5.6	0.0	16.0	2.3
16	6	2.3	1.4	0.0	4.0	0.6
17	6	11.5	5.0	6.0	19.0	2.0
18	6	0.5	0.5	0.0	1.0	0.2
19	6	0.8	0.8	0.0	2.0	0.3
20	6	2.3	1.5	1.0	5.0	0.6
21	6	0.3	0.5	0.0	1.0	0.2
22	6	4.5	3.7	0.0	9.0	1.5
23	6	4.3	1.0	3.0	6.0	0.4
24	6	8.5	2.6	6.0	13.0	1.1
25	6	7.2	5.0	4.0	17.0	2.1

Table 47. Sugerloaf Mountain study area summary statistics for density of Douglas fir ≥ 1.5 m in height.

Site	N	Mean (#)	Std. Dev.	Min. (#)	Max. (#)	Std. Error
1	6	2.5	2.1	0.0	5.0	0.8
2	6	5.8	1.7	4.0	9.0	0.7
3	6	3.0	2.0	2.0	7.0	0.8
4	6	2.0	0.6	1.0	3.0	0.3
5	6	3.0	1.3	2.0	5.0	0.5
6	6	2.5	3.3	0.0	9.0	1.4
7	6	2.0	1.3	1.0	4.0	0.5
8	6	3.5	1.2	2.0	5.0	0.5
9	6	0.0	0.0	0.0	0.0	0.0
10	6	0.8	0.8	0.0	2.0	0.3
11	6	1.8	1.5	0.0	4.0	0.6
12	6	1.5	0.8	1.0	3.0	0.3
13	6	2.8	2.6	0.0	7.0	1.1
14	6	2.0	1.5	0.0	4.0	0.6
15	6	3.5	2.4	0.0	6.0	1.0
16	6	2.0	1.1	0.0	3.0	0.4
17	6	7.2	3.8	4.0	14.0	1.6
18	6	0.5	0.5	0.0	1.0	0.2
19	6	0.3	0.5	0.0	0.0	0.2
20	6	2.0	0.9	1.0	3.0	0.4
21	6	0.2	0.4	0.0	1.0	0.2
22	6	2.0	1.3	0.0	3.0	0.5
23	6	2.3	1.5	0.0	4.0	0.6
24	6	5.0	1.3	3.0	7.0	0.5
25	6	5.3	4.4	2.0	14.0	1.8

Table 48. Sugerloaf Mountain study area summary statistics for total Douglas fir height.

Site	N	Mean (m)	Std. Dev.	Min. (m)	Max. (m)	Std. Error
1	29	2.6	2.9	0.20	9.1	0.5
2	35	3.8	3.0	0.15	9.7	0.5
3	26	2.3	2.0	0.30	6.5	0.4
4	18	3.1	2.9	0.30	8.8	0.7
5	22	4.6	3.0	0.30	9.1	0.6
6	24	2.7	2.6	0.05	7.9	0.5
7	30	2.2	2.9	0.05	10.4	0.5
8	32	2.6	2.1	0.20	6.7	0.4
9	1	0.0	0.0	0.00	0.0	0.0
10	6	4.6	2.3	1.20	7.3	1.0
11	11	5.3	0.5	4.60	6.1	0.1
12	12	3.6	2.6	0.20	8.7	0.7
13	25	3.1	2.7	0.20	8.5	0.5
14	17	2.8	2.2	0.10	6.9	0.5
15	22	3.9	2.8	0.15	9.5	0.6
16	14	4.6	2.2	0.80	7.0	0.6
17	32	3.6	2.3	0.15	7.3	0.4
18	3	4.1	2.9	1.80	7.3	1.6
19	5	1.2	0.9	0.30	2.5	0.4
20	14	4.2	1.9	0.30	6.2	0.5
21	2	1.3	0.5	0.95	1.6	0.3
22	20	3.4	3.4	0.10	9.8	0.8
23	20	2.9	2.4	0.40	9.1	0.5
24	30	3.8	2.7	0.20	8.7	0.5
25	27	3.4	1.9	0.30	7.5	0.4

Table 49. Sugerloaf Mountain study area summary statistics for Douglas fir Age.

Site	N	Mean (years)	Std. Dev.	Min. (years)	Max. (years)	Std. Error
1	31	12.1	13.8	1.0	42.0	2.5
2	33	21.9	18.2	1.0	52.0	3.2
3	26	14.5	11.8	3.0	43.0	2.3
4	19	19.9	16.3	2.0	56.0	3.7
5	25	22.8	18.3	1.0	53.0	3.7
6	19	17.1	13.2	3.0	42.0	3.0
7	29	14.4	18.7	1.0	60.0	3.5
8	30	19.8	16.4	2.0	55.0	3.0
9	1	0.0	0.0	0.0	0.0	0.0
10	5	26.8	7.2	18.0	35.0	3.2
11	10	36.9	8.9	23.0	55.0	2.8
12	10	25.7	15.7	3.0	51.0	5.0
13	24	21.1	14.0	3.0	43.0	2.9
14	17	18.9	12.9	1.0	44.0	3.1
15	23	27.8	18.8	1.0	62.0	3.9
16	14	27.4	12.7	6.0	44.0	3.4
17	32	26.6	17.9	1.0	66.0	3.2
18	3	19.7	11.9	10.0	33.0	6.9
19	4	10.8	6.7	5.0	17.0	3.3
20	14	27.5	13.0	2.0	46.0	3.5
21	1	15.0	0.0	15.0	15.0	0.0
22	19	27.3	20.7	1.0	63.0	4.7
23	25	17.1	15.1	1.0	55.0	3.0
24	31	28.3	18.0	3.0	60.0	3.2
25	28	25.6	13.3	3.0	47.0	2.5

Table 50. Sugerloaf Mountain study area summary statistics for mountain big sagebrush canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	7.7	4.4	3.2	14.5	1.8
2	6	1.2	1.2	0.0	2.7	0.5
3	6	12.3	4.6	6.6	18.7	1.9
4	6	11.0	4.0	7.0	17.4	1.6
5	6	6.6	3.7	3.3	13.1	1.5
6	6	11.3	2.9	8.0	14.9	1.2
7	6	3.9	2.9	2.0	9.8	1.2
8	6	4.3	2.8	1.3	9.6	1.1
9	6	20.0	6.7	10.8	28.6	2.8
10	6	13.4	3.4	10.5	20.0	1.4
11	6	9.5	0.8	8.8	10.5	0.3
12	6	7.1	1.7	4.8	9.2	0.7
13	6	6.0	2.3	2.4	9.5	0.9
14	6	15.3	3.3	12.1	21.2	1.3
15	6	2.4	2.7	0.0	6.4	1.1
16	6	6.6	3.6	3.0	11.8	1.5
17	6	0.8	0.8	0.0	2.2	0.3
18	6	20.3	7.9	10.5	30.7	3.2
19	6	10.3	3.0	5.6	13.8	1.2
20	6	6.5	2.3	3.1	9.8	1.0
21	6	8.5	3.3	5.5	15.0	1.4
22	6	1.7	2.0	0.1	4.3	0.8
23	6	7.6	1.5	5.3	9.4	0.6
24	6	2.2	1.2	0.2	3.6	0.5
25	6	5.3	1.3	3.8	7.2	0.5

Table 51. Sugerloaf Mountain study area summary statistics for density of "large" mountain big sagebrush.

Site	N	Mean (#)	Std. Dev.	Min. (#)	Max. (#)	Std. Error
1	6	37.0	4.3	30.0	42.0	1.8
2	6	11.3	7.9	4.0	26.0	3.2
3	6	48.2	12.7	29.0	65.0	5.2
4	6	50.5	8.0	41.0	63.0	3.3
5	6	36.2	6.6	30.0	48.0	2.7
6	6	55.8	9.8	41.0	68.0	4.0
7	6	22.2	6.6	14.0	32.0	2.7
8	6	32.0	5.3	26.0	39.0	2.2
9	6	87.5	15.5	68.0	110.0	6.3
10	6	85.7	8.6	72.0	94.0	3.5
11	6	61.7	7.8	52.0	73.0	3.2
12	6	56.5	10.5	40.0	68.0	4.3
13	6	48.2	12.2	27.0	60.0	5.0
14	6	92.3	11.0	80.0	107.0	4.5
15	6	29.7	30.1	0.0	77.0	12.3
16	6	54.8	21.3	28.0	86.0	8.7
17	6	7.2	3.9	2.0	12.0	1.6
18	6	76.7	10.6	59.0	88.0	4.3
19	6	69.8	6.9	61.0	78.0	2.8
20	6	61.5	6.6	55.0	71.0	2.7
21	6	72.0	13.5	48.0	85.0	5.5
22	6	15.7	10.7	6.0	31.0	4.4
23	6	55.3	14.6	36.0	80.0	5.9
24	6	18.8	12.5	7.0	42.0	5.1
25	6	36.7	6.4	29.0	45.0	2.6

Table 52. Sugerloaf Mountain Study area summary statistics for density of "little" mountain big sagebrush.

Site	N	Mean (#)	Std. Dev.	Min. (#)	Max. (#)	Std. Error
1	6	17.0	5.1	9.0	23.0	2.1
2	6	21.7	15.4	3.0	41.0	6.3
3	6	24.5	10.6	12.0	41.0	4.3
4	6	23.3	5.0	17.0	32.0	2.1
5	6	27.5	6.0	20.0	36.0	2.4
6	6	28.2	6.9	22.0	41.0	2.8
7	6	27.2	15.4	16.0	57.0	6.3
8	6	16.0	7.9	8.0	31.0	3.2
9	6	67.5	23.4	37.0	100.0	9.6
10	6	34.7	9.8	19.0	46.0	4.0
11	6	29.5	10.2	20.0	43.0	4.2
12	6	28.5	5.5	23.0	35.0	2.2
13	6	33.8	7.1	27.0	47.0	2.9
14	6	31.5	20.3	15.0	70.0	8.3
15	6	26.2	14.1	8.0	49.0	5.7
16	6	37.3	21.2	21.0	76.0	8.6
17	6	21.3	8.8	12.0	32.0	3.6
18	6	31.5	9.3	22.0	44.0	3.8
19	6	47.0	10.7	35.0	64.0	4.4
20	6	33.2	12.0	21.0	55.0	4.9
21	6	46.2	12.6	26.0	60.0	5.1
22	6	31.2	3.2	27.0	36.0	1.3
23	6	50.2	22.6	25.0	87.0	9.2
24	6	26.3	15.3	5.0	41.0	6.2
25	6	19.3	13.9	9.0	47.0	5.7

Table 53. Sugerloaf Mountain study area summary statistics for density of dead sagebrush.

Site	N	Mean (#)	Std. Dev.	Min. (#)	Max. (#)	Std. Error
1	6	16.7	3.4	11.0	22.0	1.6
2	6	25.5	6.4	15.0	35.0	2.6
3	6	35.0	10.9	19.0	46.0	4.4
4	6	17.5	4.6	13.0	26.0	1.9
5	6	27.5	9.6	15.0	42.0	3.9
6	6	26.7	9.1	13.0	39.0	3.7
7	6	18.3	8.7	4.0	24.0	3.5
8	6	32.3	4.5	25.0	37.0	1.8
9	6	4.8	2.2	3.0	9.0	0.9
10	6	9.3	3.9	3.0	13.0	1.6
11	6	26.8	4.6	23.0	34.0	1.9
12	6	35.3	4.2	29.0	41.0	1.7
13	6	25.8	6.6	22.0	39.0	2.7
14	6	39.0	4.5	33.0	46.0	1.8
15	6	35.8	8.6	22.0	44.0	3.5
16	6	33.7	2.8	30.0	37.0	1.1
17	6	26.3	7.2	17.0	35.0	3.0
18	6	8.7	3.6	3.0	13.0	1.5
19	6	17.7	5.4	11.0	24.0	2.2
20	6	16.3	2.5	13.0	19.0	1.0
21	6	23.2	4.9	16.0	30.0	2.0
22	6	25.2	5.3	20.0	32.0	2.2
23	6	20.5	5.1	15.0	27.0	2.1
24	6	27.3	10.3	16.0	40.0	4.2
25	6	39.0	5.5	31.0	48.0	2.3

Table 54. Sugerloaf Mountain study area summary statistics for mountain big sagebrush age.

Site	N	Mean (years)	Std. Dev.	Min. (years)	Max. (years)	Std. Error
1	30	10.6	4.5	5.0	22.0	0.8
2	29	12.2	6.8	4.0	27.0	1.3
3	30	15.3	6.6	5.0	37.0	1.2
4	30	18.3	8.0	7.0	42.0	1.5
5	30	17.0	7.7	5.0	41.0	1.4
6	30	17.9	8.3	5.0	42.0	1.5
7	30	14.3	5.7	5.0	29.0	1.0
8	30	18.4	7.0	2.0	32.0	1.3
9	30	11.2	4.7	4.0	21.0	0.9
10	30	12.9	7.7	5.0	39.0	1.4
11	30	18.4	8.2	7.0	43.0	1.5
12	31	19.2	8.9	8.0	42.0	1.6
13	30	19.0	8.9	7.0	39.0	1.6
14	30	19.7	8.9	6.0	44.0	1.6
15	24	15.8	6.3	4.0	31.0	1.3
16	30	16.2	7.2	6.0	37.0	1.3
17	25	12.4	6.4	6.0	38.0	1.3
18	30	13.8	7.3	3.0	29.0	1.3
19	30	19.9	9.2	7.0	44.0	1.7
20	30	21.7	12.0	5.0	52.0	2.2
21	30	20.8	12.2	6.0	45.0	2.2
22	30	17.8	9.5	5.0	39.0	1.7
23	30	21.9	13.4	5.0	55.0	2.4
24	30	21.4	14.5	7.0	52.0	2.7
25	30	20.4	8.0	9.0	39.0	1.5

Table 55. Sugerloaf Mountain study area summary statistics for individual mountain big sagebrush plant production.

Site	N	Mean (g/plant)	Std. Dev.	Min. (g/plant)	Max. (g/plant)	Std. Error
1	60	33.9	46.2	5.6	243.6	6.0
2	44	15.0	12.3	5.9	61.2	1.9
3	60	44.5	94.0	6.2	680.6	12.1
4	60	50.9	55.2	4.7	297.1	7.1
5	60	26.9	20.9	5.7	98.4	2.7
6	60	47.5	63.2	5.0	409.0	8.2
7	60	20.2	22.7	5.4	133.7	2.9
8	60	27.2	27.9	7.1	178.5	3.6
9	60	53.1	54.8	6.9	236.0	7.1
10	60	38.0	36.3	6.3	174.3	4.7
11	60	57.4	158.1	6.3	1203.0	20.4
12	60	33.9	50.6	5.8	357.4	6.5
13	60	35.5	30.9	7.8	131.5	4.0
14	60	45.3	55.2	6.4	296.1	7.1
15	45	26.7	25.2	5.6	128.6	3.8
16	60	46.7	47.7	6.7	209.6	6.2
17	33	21.0	27.9	5.8	152.6	4.9
18	60	55.0	88.4	5.7	582.7	11.4
19	60	47.5	84.2	6.4	636.6	10.9
20	60	44.7	54.7	6.4	285.6	7.1
21	60	39.5	66.2	6.0	492.9	8.5
22	48	19.6	19.4	5.8	126.1	2.8
23	60	36.9	38.5	7.1	198.1	5.0
24	48	16.6	12.6	5.6	78.3	1.8
25	59	37.0	38.6	6.2	202.6	5.0

Table 56. Sugerloaf Mountain study area summary statistics for total mountain big sagebrush production/transect.

Site	N	Mean (g/61m^2)	Std. Dev.	Min. (g/61m^2)	Max. (g/61m^2)	Std. Error
1	6	1271	773	417	2367	315
2	6	175	155	44	463	63
3	6	2389	2418	803	7053	987
4	6	2600	852	1914	4265	348
5	6	996	383	493	1541	156
6	6	2627	1032	1502	4076	421
7	6	442	147	196	630	60
8	6	887	373	473	1373	152
9	6	4758	2167	1624	7755	885
10	6	3290	970	2182	4557	396
11	6	3363	2319	1523	7561	947
12	6	1898	757	904	2952	309
13	6	1785	794	572	2813	324
14	6	4275	1560	2266	5732	637
15	6	947	1154	0	2672	471
16	6	2777	1853	1018	5857	757
17	6	129	125	23	315	51
18	6	4375	2346	2112	8712	958
19	6	3261	1337	2110	5838	546
20	6	2734	604	1837	3522	246
21	6	2820	1484	1536	5108	606
22	6	312	262	59	769	107
23	6	2053	856	1102	3432	349
24	6	342	334	102	1000	136
25	6	1412	773	566	2583	316

Table 57. Sugerloaf Mountain study area summary statistics for grass canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	10.8	2.0	8.3	13.8	0.8
2	6	12.3	3.3	7.5	17.5	1.4
3	6	19.8	4.4	13.5	25.0	1.8
4	6	16.4	2.1	14.5	19.5	0.9
5	6	14.7	3.4	8.8	19.3	1.4
6	6	19.3	2.6	16.8	24.0	1.0
7	6	10.4	2.8	6.8	13.5	1.1
8	6	10.0	1.4	8.5	12.0	0.6
9	6	25.6	8.3	19.3	40.8	3.4
10	6	20.7	4.2	14.5	27.5	1.7
11	6	25.5	6.8	18.3	36.8	2.8
12	6	20.3	4.1	14.8	26.5	1.7
13	6	12.6	1.8	11.0	16.0	0.7
14	6	17.5	4.6	12.0	23.3	1.9
15	6	14.7	6.1	7.3	20.5	2.5
16	6	17.3	3.2	12.8	20.5	1.3
17	6	9.2	3.2	6.5	13.8	1.3
18	6	22.7	3.9	18.0	26.5	1.6
19	6	21.0	3.9	16.0	26.5	1.6
20	6	20.5	6.2	13.3	27.5	2.5
21	6	33.5	6.4	21.8	39.0	2.6
22	6	9.7	3.1	6.3	13.8	1.3
23	6	22.0	5.3	17.0	29.0	2.2
24	6	9.6	4.2	4.3	14.8	1.7
25	6	14.3	2.7	10.8	18.3	1.1

Table 58. Sugerloaf Mountain study area summary statistics for forb canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	16.1	9.5	6.0	31.3	3.9
2	6	11.7	5.7	4.0	19.3	2.3
3	6	16.7	6.7	9.5	24.3	2.7
4	6	14.0	3.9	8.3	20.0	1.6
5	6	11.3	5.7	4.0	21.5	2.3
6	6	17.2	8.4	9.8	33.8	3.4
7	6	14.9	4.3	7.3	20.5	1.8
8	6	9.9	1.8	7.5	13.0	0.7
9	6	5.5	3.0	2.3	9.0	1.2
10	6	7.5	2.9	4.0	11.0	1.2
11	6	10.5	7.1	4.3	24.5	2.9
12	6	9.0	2.8	4.5	12.0	1.2
13	6	12.6	4.6	8.3	21.3	1.9
14	6	16.0	8.3	8.5	31.3	3.4
15	6	13.7	6.8	5.0	22.8	2.8
16	6	10.3	7.8	3.5	21.8	3.2
17	6	3.8	2.2	1.8	7.3	0.9
18	6	7.8	3.8	4.0	14.5	1.5
19	6	10.8	7.6	4.5	23.5	3.1
20	6	8.7	3.4	3.8	13.3	1.4
21	6	8.0	6.0	4.5	20.0	2.4
22	6	6.1	1.6	3.5	8.3	0.7
23	6	9.2	3.8	3.6	14.5	1.5
24	6	10.3	7.4	0.8	18.8	3.0
25	6	13.2	3.5	8.3	18.5	1.4

Table 59. Sugerloaf Mountain study area summary statistics for total herbaceous canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	27.3	12.5	13.5	47.5	5.1
2	6	23.8	7.7	13.3	34.5	3.1
3	6	40.8	9.3	25.3	52.5	3.8
4	6	31.7	5.7	22.3	37.3	2.3
5	6	27.5	4.5	22.3	34.8	1.8
6	6	40.5	7.8	31.0	54.8	3.2
7	6	25.1	6.7	12.0	30.0	2.7
8	6	19.4	4.2	13.3	25.0	1.7
9	6	31.9	9.2	21.3	45.3	3.7
10	6	30.7	8.1	23.8	43.0	3.3
11	6	36.6	8.0	27.5	48.8	3.3
12	6	29.0	3.7	24.3	33.3	1.5
13	6	25.5	5.4	20.0	34.8	2.2
14	6	34.5	7.8	23.8	47.8	3.2
15	6	29.7	11.9	13.8	42.5	4.8
16	6	28.1	8.9	17.8	42.8	3.6
17	6	11.9	3.3	7.8	14.8	1.3
18	6	33.7	5.9	26.3	40.8	2.4
19	6	33.7	12.5	24.0	57.3	5.1
20	6	29.5	5.0	24.0	38.0	2.1
21	6	44.0	8.4	28.8	54.5	3.4
22	6	16.0	2.7	12.0	19.5	1.1
23	6	29.7	5.7	22.7	38.0	2.3
24	6	19.5	10.8	4.3	31.8	4.4
25	6	28.0	7.7	19.0	40.3	3.1

Table 60. Medicine Lodge Peak study area summary statistics for Douglas fir canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	23.0	12.7	6.0	43.9	5.2
2	6	7.2	4.4	0.0	13.1	1.8
3	6	33.1	11.1	17.5	47.2	4.5
4	6	42.6	16.5	14.5	59.3	6.7
5	6	28.3	4.3	24.2	35.4	1.7
6	6	46.5	11.0	37.8	64.6	4.5
7	6	42.7	14.4	21.6	63.3	5.9
8	6	21.2	14.3	8.2	43.5	5.8
9	6	38.4	13.9	20.0	61.7	5.7
10	6	37.4	8.5	25.4	50.1	3.5
11	6	73.3	12.0	52.6	87.3	4.9
12	6	53.9	12.7	33.5	71.1	5.2
13	6	28.7	9.2	18.0	42.6	3.8
14	6	31.4	12.5	14.2	48.7	5.1
15	6	36.6	17.1	19.6	67.6	7.0
16	6	14.4	9.8	2.0	23.2	4.0
17	6	5.6	2.9	0.0	8.1	1.2
18	6	15.0	6.5	7.5	26.1	2.6
19	6	7.2	4.5	0.0	13.2	1.8
20	6	0.9	1.6	0.0	4.2	0.7
21	6	12.8	8.4	5.1	25.6	3.4
22	6	15.0	5.7	6.1	22.1	2.3
23	6	1.3	1.5	0.0	3.2	0.6
24	6	0.1	0.2	0.0	0.5	0.1
25	6	59.4	20.1	29.0	83.8	8.2

Table 61. Medicine Lodge Peak study area summary statistics for total basal area.

Site	N	Mean (cm^2)	Std. Dev.	Min. (cm^2)	Max. (cm^2)	Std. Error
1	6	533.5	294.8	183.0	855.5	120.3
2	6	73.7	53.2	0.0	132.9	21.7
3	6	798.2	403.8	333.8	1519.2	164.8
4	6	661.6	290.3	98.2	890.7	118.5
5	6	420.9	123.3	205.0	544.3	50.3
6	6	776.6	369.1	435.1	1456.0	150.7
7	6	521.6	219.8	292.2	920.1	89.7
8	6	431.9	422.9	69.3	1081.9	172.7
9	6	788.0	567.2	277.3	1669.4	231.6
10	6	824.2	318.9	478.3	1398.0	130.2
11	6	1416.9	292.9	1047.5	1677.1	119.6
12	6	808.6	309.1	398.6	1134.1	126.2
13	6	476.3	214.8	265.0	762.7	87.7
14	6	652.8	482.0	6.7	1182.2	196.8
15	6	568.2	246.0	282.8	1027.1	100.4
16	6	311.0	245.0	28.3	624.4	100.0
17	6	112.5	106.8	0.0	270.4	43.6
18	6	282.4	136.7	153.9	534.3	55.8
19	6	143.6	73.1	0.0	201.9	29.8
20	6	3.7	7.0	0.0	17.5	2.9
21	6	221.6	148.3	33.2	476.9	60.5
22	6	237.0	74.8	146.3	348.9	30.6
23	6	7.1	11.5	0.0	28.3	4.7
24	6	0.0	0.0	0.0	0.0	0.0
25	6	1203.4	645.6	448.6	2057.5	263.6

Table 62. Medicine Lodge Peak study area summary statistics for total Douglas fir density.

Site	N	Mean	Std. Dev.	Min.	Max.	Std. Error
		(#)		(#)	(#)	
1	6	5.0	1.9	2.0	7.0	0.8
2	6	1.3	0.8	0.0	2.0	0.3
3	6	7.8	2.6	4.0	11.0	1.0
4	6	8.0	3.3	3.0	11.0	1.4
5	6	8.5	2.1	7.0	12.0	0.8
6	6	15.7	6.2	8.0	25.0	2.5
7	6	11.5	5.2	6.0	21.0	2.1
8	6	3.8	2.2	1.0	7.0	0.9
9	6	8.3	3.4	5.0	14.0	1.4
10	6	7.8	2.3	5.0	12.0	0.9
11	6	26.0	6.8	18.0	34.0	2.8
12	6	12.2	3.3	7.0	17.0	1.3
13	6	6.8	1.7	5.0	9.0	0.7
14	6	8.7	3.9	4.0	13.0	1.6
15	6	9.0	4.4	5.0	15.0	1.8
16	6	3.0	1.1	1.0	4.0	0.4
17	6	2.0	1.3	1.0	4.0	0.5
18	6	3.7	2.8	1.0	9.0	1.1
19	6	2.0	0.6	1.0	3.0	0.3
20	6	0.7	1.2	0.0	3.0	0.5
21	6	2.3	1.8	1.0	5.0	0.7
22	6	3.5	1.4	1.0	5.0	0.6
23	6	0.7	0.8	0.0	2.0	0.3
24	6	0.2	0.4	0.0	1.0	0.2
25	6	20.5	4.1	16.0	28.0	1.7

Table 63. Medicine Lodge Peak study area summary statistics for total density of Douglas fir ≥ 1.5 m in Height.

Site	N	Mean	Std. Dev.	Min.	Max.	Std. Error
		(#)		(#)	(#)	
1	6	3.7	1.6	1.0	6.0	0.7
2	6	1.2	0.8	0.0	2.0	0.3
3	6	4.3	2.1	2.0	8.0	0.8
4	6	5.8	2.6	2.0	9.0	1.0
5	6	2.7	0.8	2.0	4.0	0.3
6	6	10.0	4.6	6.0	19.0	1.9
7	6	7.3	2.8	3.0	12.0	1.2
8	6	2.5	2.1	1.0	6.0	0.8
9	6	5.5	2.2	3.0	9.0	0.9
10	6	5.5	1.9	4.0	9.0	0.8
11	6	19.8	5.4	14.0	28.0	2.2
12	6	8.5	2.9	5.0	13.0	1.2
13	6	5.0	0.6	4.0	6.0	0.3
14	6	5.7	2.9	2.0	8.0	1.2
15	6	6.5	3.7	3.0	12.0	1.5
16	6	2.7	1.4	1.0	4.0	0.6
17	6	1.2	0.8	0.0	2.0	0.3
18	6	2.3	2.0	1.0	6.0	0.8
19	6	1.3	0.8	0.0	2.0	0.3
20	6	0.7	1.2	0.0	3.0	0.5
21	6	2.2	1.8	1.0	5.0	0.7
22	6	2.7	0.8	1.0	3.0	0.3
23	6	0.7	0.8	0.0	2.0	0.3
24	6	0.0	0.0	0.0	0.0	0.0
25	6	12.3	5.1	6.0	21.0	2.1

Table 64. Medicine Lodge Peak study area summary statistics for total Douglas fir height.

Site	N	Mean (m)	Std. Dev.	Min. (m)	Max. (m)	Std. Error
1	30	3.6	2.6	0.20	7.6	0.5
2	8	3.4	1.3	0.30	4.3	0.5
3	47	3.5	3.1	0.10	8.8	0.4
4	48	3.8	2.6	0.20	8.2	0.4
5	52	1.7	2.2	0.10	6.4	0.3
6	94	2.5	1.7	0.15	6.1	0.2
7	69	2.6	1.8	0.15	6.1	0.2
8	23	3.5	2.6	0.20	6.7	0.5
9	50	2.9	2.2	0.10	6.4	0.3
10	47	3.7	2.3	0.15	7.0	0.3
11	156	3.2	2.1	0.15	7.9	0.2
12	73	3.2	2.0	0.15	6.4	0.2
13	42	3.3	2.1	0.10	6.1	0.3
14	54	3.0	2.2	0.15	6.2	0.3
15	54	3.3	2.0	0.10	5.9	0.3
16	18	4.3	1.5	0.45	6.2	0.4
17	12	2.6	2.1	0.10	5.5	0.6
18	22	2.9	2.0	0.20	5.8	0.4
19	12	2.8	2.1	0.10	5.2	0.6
20	4	2.0	0.6	1.50	2.9	0.3
21	14	4.0	1.2	0.50	5.2	0.3
22	21	3.4	1.7	0.25	6.6	0.4
23	4	2.6	0.8	1.80	3.7	0.4
24	1	1.1	0.0	1.10	1.1	0.0
25	123	2.7	2.1	0.15	8.2	0.2

Table 65. Medicine Lodge Peak study area summary statistics for Douglas fir height ≥ 1.5 m in height.

Site	N	Mean (m)	Std. Dev.	Min. (m)	Max. (m)	Std. Error
1	22	4.8	1.9	1.8	7.6	0.4
2	7	3.8	0.3	3.5	4.3	0.1
3	26	3.0	1.8	1.8	8.8	0.4
4	35	5.1	1.8	1.6	8.2	0.3
5	17	4.5	1.7	2.0	6.4	0.4
6	60	3.6	1.2	1.5	6.1	0.2
7	44	3.7	1.3	1.6	6.1	0.2
8	15	5.2	1.4	1.5	6.7	0.4
9	33	4.3	1.3	1.5	6.4	0.2
10	33	5.0	1.4	1.7	7.0	0.2
11	119	4.1	1.5	1.5	7.9	0.1
12	51	4.3	1.3	1.5	6.4	0.2
13	31	4.2	1.6	1.5	6.1	0.3
14	35	4.3	1.5	1.6	6.2	0.3
15	39	4.3	1.2	1.6	5.9	0.2
16	16	4.7	1.0	2.3	6.2	0.2
17	7	4.1	1.1	2.4	5.5	0.4
18	14	4.2	1.2	1.8	5.8	0.3
19	8	4.0	1.1	1.6	5.2	0.4
20	4	2.0	0.6	1.5	2.9	0.3
21	13	4.3	0.8	2.7	5.2	0.2
22	16	4.2	0.9	3.0	6.6	0.2
23	3	2.8	0.8	2.3	3.7	0.4
24	0	0.0	0.0	0.0	0.0	0.0
25	74	4.2	1.5	1.6	8.2	0.2

Table 66. Medicine Lodge Peak study area summary statistics for Douglas fir age.

Site	N	Mean (years)	Std. Dev.	Min. (years)	Max. (years)	Std. Error
1	26	18.8	9.5	2.0	33.0	1.9
2	8	17.9	6.9	3.0	23.0	2.4
3	31	16.2	11.0	1.0	33.0	2.0
4	29	19.0	10.5	2.0	35.0	1.9
5	29	10.6	10.6	2.0	34.0	2.0
6	30	18.9	10.3	2.0	31.0	1.9
7	31	20.2	9.7	4.0	34.0	1.7
8	21	17.9	9.3	4.0	31.0	2.0
9	31	20.3	11.2	2.0	38.0	2.0
10	31	19.4	8.8	3.0	33.0	1.6
11	30	23.7	9.1	3.0	35.0	1.7
12	31	20.5	8.8	2.0	38.0	1.6
13	31	19.7	8.0	8.0	33.0	1.4
14	28	16.6	8.6	2.0	28.0	1.6
15	32	19.2	9.4	3.0	30.0	1.7
16	18	22.0	5.0	11.0	27.0	1.2
17	12	17.2	10.4	1.0	29.0	3.0
18	17	16.3	8.5	2.0	26.0	2.1
19	12	15.9	9.1	1.0	29.0	2.6
20	4	21.5	1.9	19.0	23.0	1.0
21	14	19.5	6.3	9.0	29.0	1.7
22	20	19.2	7.5	6.0	30.0	1.7
23	4	19.5	4.1	14.0	24.0	2.1
24	1	8.0	0.0	8.0	8.0	0.0
25	30	18.2	9.2	4.0	34.0	1.7

Table 67. Medicine Lodge Peak study area summary statistics for mountain big sagebrush canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	12.0	3.3	7.3	15.1	1.4
2	6	11.6	1.8	9.6	14.7	0.7
3	6	4.4	2.4	1.6	8.3	1.0
4	6	2.7	3.1	0.1	8.2	1.2
5	6	6.1	4.0	1.7	12.7	1.6
6	6	0.5	0.3	0.0	0.7	0.1
7	6	1.4	2.0	0.0	5.2	0.8
8	6	9.5	5.1	2.9	16.2	2.1
9	6	5.3	2.6	3.9	10.6	1.1
10	6	5.3	4.0	1.4	12.0	1.6
11	6	0.0	0.0	0.0	0.0	0.0
12	6	1.4	2.4	0.0	6.3	1.0
13	6	7.4	2.9	3.3	10.7	1.2
14	6	4.4	3.2	0.0	7.8	1.3
15	6	2.6	2.1	0.4	5.4	0.9
16	6	17.2	4.2	12.1	24.4	1.7
17	6	16.3	4.9	11.1	24.0	2.0
18	6	14.1	5.7	7.7	23.9	2.3
19	6	20.7	2.8	17.8	24.4	1.1
20	6	20.1	2.5	17.0	23.7	1.0
21	6	14.9	4.7	8.4	20.4	1.9
22	6	19.3	4.5	15.1	27.6	1.8
23	6	21.4	4.5	15.5	28.0	1.9
24	6	27.9	3.8	21.0	31.3	1.5
25	6	0.3	0.5	0.0	1.2	0.2

Table 68. Medicine Lodge Peak study area summary statistics for density of "large" mountain big sagebrush.

Site	N	Mean (#)	Std. Dev.	Min. (#)	Max. (#)	Std. Error
1	6	53.5	14.3	31.0	69.0	5.8
2	6	66.2	12.1	56.0	86.0	4.9
3	6	20.7	6.1	11.0	29.0	2.5
4	6	19.7	22.4	1.0	57.0	9.1
5	6	26.8	15.8	4.0	53.0	6.5
6	6	3.5	2.1	1.0	7.0	0.8
7	6	9.7	10.3	0.0	28.0	4.2
8	6	51.3	17.0	31.0	76.0	6.9
9	6	20.3	7.9	6.0	28.0	3.2
10	6	29.8	16.2	10.0	59.0	6.6
11	6	0.0	0.0	0.0	0.0	0.0
12	6	9.8	9.5	2.0	27.0	3.9
13	6	47.3	15.5	25.0	69.0	6.3
14	6	29.7	14.8	8.0	49.0	6.0
15	6	19.3	15.3	0.0	37.0	6.2
16	6	79.8	14.3	61.0	98.0	5.8
17	6	73.8	18.5	42.0	94.0	7.5
18	6	75.5	25.0	53.0	117.0	10.2
19	6	86.5	7.1	76.0	95.0	2.9
20	6	76.2	5.9	69.0	83.0	2.4
21	6	62.2	13.0	43.0	76.0	5.3
22	6	71.0	17.7	40.0	93.0	7.2
23	6	91.3	8.9	83.0	106.0	3.6
24	6	123.5	10.6	104.0	136.0	4.3
25	6	3.0	3.8	0.0	10.0	1.5

Table 69. Medicine Lodge Peak study area summary statistics for density of "little" mountain big sagebrush.

Site	N	Mean (#)	Std. Dev.	Min. (#)	Max. (#)	Std. Error
1	6	43.0	19.5	23.0	78.0	7.9
2	6	33.5	8.0	25.0	45.0	3.3
3	6	22.8	7.3	14.0	35.0	3.0
4	6	23.5	13.1	10.0	43.0	5.4
5	6	22.5	6.3	13.0	28.0	2.6
6	6	6.0	4.3	2.0	14.0	1.8
7	6	8.5	6.6	1.0	17.0	2.7
8	6	18.3	3.5	14.0	23.0	1.4
9	6	25.0	15.8	5.0	53.0	6.5
10	6	18.0	9.7	6.0	35.0	3.9
11	6	1.0	1.5	0.0	4.0	0.6
12	6	6.3	3.1	2.0	11.0	1.3
13	6	24.8	11.0	14.0	43.0	4.5
14	6	16.2	7.3	6.0	28.0	3.0
15	6	7.8	3.8	4.0	14.0	1.6
16	6	41.2	28.4	12.0	84.0	11.6
17	6	21.2	10.0	12.0	35.0	4.1
18	6	16.2	7.2	7.0	27.0	2.9
19	6	19.7	5.2	10.0	25.0	2.1
20	6	14.5	5.6	10.0	25.0	2.3
21	6	21.5	10.0	6.0	32.0	4.1
22	6	22.3	12.3	8.0	40.0	5.0
23	6	14.7	8.1	3.0	27.0	3.3
24	6	28.0	15.2	9.0	48.0	6.2
25	6	4.3	3.4	1.0	8.0	1.4

Table 70. Medicine Lodge Peak study area summary statistics for density of dead sagebrush.

Site	N	Mean (#)	Std. Dev.	Min. (#)	Max. (#)	Std. Error
1	6	34.2	9.7	22.0	49.0	4.0
2	6	22.8	3.1	19.0	28.0	1.2
3	6	59.2	6.9	51.0	68.0	2.8
4	6	49.7	9.7	37.0	60.0	4.0
5	6	49.7	8.6	33.0	57.0	3.5
6	6	42.7	2.7	38.0	45.0	1.1
7	6	34.8	7.5	26.0	45.0	3.1
8	6	40.8	9.4	25.0	50.0	3.9
9	6	45.7	13.9	27.0	66.0	5.7
10	6	48.7	10.5	34.0	60.0	4.3
11	6	61.7	11.5	48.0	75.0	4.7
12	6	46.0	11.2	35.0	67.0	4.6
13	6	38.8	8.1	33.0	55.0	3.3
14	6	52.2	13.2	37.0	76.0	5.4
15	6	36.7	7.3	22.0	42.0	3.0
16	6	23.8	7.1	13.0	30.0	2.9
17	6	33.7	7.8	22.0	46.0	3.2
18	6	30.5	13.5	10.0	51.0	5.5
19	6	13.7	7.9	8.0	29.0	3.2
20	6	19.2	3.4	15.0	24.0	1.4
21	6	26.2	10.5	17.0	38.0	4.3
22	6	32.7	11.6	21.0	50.0	4.7
23	6	27.7	8.4	14.0	38.0	3.4
24	6	14.8	6.9	4.0	24.0	2.8
25	6	48.2	10.6	33.0	65.0	4.3

Table 71. Medicine Lodge Peak study area summary statistics for mountain big sagebrush age.

Site	N	Mean (years)	Std. Dev.	Min. (years)	Max. (years)	Std. Error
1	30	20.2	7.0	7.0	42.0	1.3
2	30	25.9	8.9	10.0	43.0	1.6
3	30	23.2	9.5	8.0	47.0	1.7
4	24	20.8	11.0	6.0	44.0	2.3
5	29	20.9	9.4	10.0	41.0	1.7
6	20	14.8	5.0	6.0	25.0	1.1
7	21	20.0	7.9	8.0	37.0	1.7
8	30	19.1	7.8	7.0	33.0	1.4
9	30	20.0	10.5	9.0	47.0	1.9
10	30	20.2	12.5	8.0	52.0	2.3
11	0	0.0	0.0	0.0	0.0	0.0
12	25	19.6	9.1	8.0	41.0	1.8
13	30	20.8	10.1	8.0	42.0	1.8
14	30	26.1	9.7	7.0	52.0	1.8
15	25	21.5	7.2	6.0	34.0	1.4
16	30	16.3	9.5	6.0	49.0	1.7
17	30	25.0	8.0	10.0	43.0	1.5
18	30	29.0	9.6	11.0	52.0	1.8
19	30	27.3	8.1	9.0	46.0	1.5
20	30	23.1	8.1	8.0	38.0	1.5
21	30	31.7	11.2	10.0	50.0	2.0
22	30	26.5	11.6	9.0	55.0	2.1
23	30	24.9	5.8	12.0	37.0	1.1
24	30	21.8	9.1	8.0	45.0	1.7
25	14	17.4	7.0	9.0	33.0	1.9

Table 72. Medicine Lodge Peak study area summary statistics for individual mountain big sagebrush production.

Site	N	Mean (g/plant)	Std. Dev.	Min. (g/plant)	Max. (g/plant)	Std. Error
1	60	39.4	29.6	5.5	163.5	3.8
2	60	46.4	39.4	11.9	220.9	5.1
3	60	28.7	32.7	6.0	212.7	4.2
4	35	20.6	15.9	6.0	78.7	2.7
5	54	30.9	28.8	6.3	139.6	3.9
6	21	14.7	7.6	5.9	41.1	1.7
7	36	17.1	9.6	6.7	46.8	1.6
8	60	33.7	34.8	7.1	217.6	4.5
9	56	21.4	16.0	5.5	89.8	2.1
10	60	22.0	14.0	6.7	71.2	1.8
11	0	0.0	0.0	0.0	0.0	0.0
12	38	15.9	10.5	5.8	54.9	1.7
13	59	27.5	18.4	6.7	76.8	2.4
14	58	28.2	21.9	6.2	132.5	2.9
15	44	23.3	13.9	7.5	70.3	2.1
16	60	36.7	35.0	6.0	200.3	4.5
17	60	72.1	95.9	10.9	603.6	12.4
18	60	47.3	42.8	9.5	301.2	5.5
19	60	50.3	35.0	10.8	168.1	4.5
20	60	80.2	64.0	16.2	300.0	8.3
21	60	60.3	40.9	7.1	170.8	5.3
22	60	59.8	46.0	8.6	207.7	5.9
23	60	61.4	50.2	7.7	241.0	6.5
24	60	82.4	92.3	8.1	457.6	11.9
25	18	12.4	4.7	5.8	21.0	1.1

Table 73. Medicine Lodge Peak study area summary statistics for total mountain big sagebrush production/transect.

Site	N	Mean (g/transect)	Std. Dev.	Min. (g/transect)	Max. (g/transect)	Std. Error
1	6	2091	742	1224	3309	303
2	6	3013	684	2436	4205	279
3	6	544	140	367	704	57
4	6	450	592	7	1534	242
5	6	895	740	101	2259	302
6	6	51	39	12	123	16
7	6	176	216	0	582	88
8	6	1850	1065	553	3099	435
9	6	435	197	105	690	80
10	6	695	471	166	1533	192
11	6	0	0	0	0	0
12	6	157	159	16	388	65
13	6	1367	614	456	1927	251
14	6	909	595	108	1709	243
15	6	466	401	0	925	164
16	6	3007	1493	1796	5961	609
17	6	5423	2816	2168	9618	1150
18	6	3675	1699	1864	6324	693
19	6	4351	831	3276	5630	339
20	6	6084	879	4671	6866	359
21	6	3750	974	2136	4692	398
22	6	4220	1186	2686	5729	484
23	6	5582	1093	4167	6912	446
24	6	10152	2470	8144	14656	1009
25	6	37	43	0	108	17

Table 74. Medicine Lodge Peak study area summary statistics for grass canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	12.5	3.4	8.3	18.0	1.4
2	6	24.4	8.6	1.8	33.3	3.5
3	6	11.4	3.9	6.0	16.8	1.6
4	6	11.8	2.7	9.3	17.0	1.1
5	6	11.3	1.0	9.8	12.5	0.4
6	6	10.5	2.0	6.8	12.3	0.8
7	6	11.5	3.5	5.5	14.5	1.4
8	6	10.5	2.6	8.3	15.5	1.0
9	6	9.8	2.4	6.0	13.3	1.0
10	6	11.7	3.6	7.0	17.0	1.5
11	6	5.5	3.1	1.8	8.8	1.3
12	6	8.4	2.4	4.8	11.0	1.0
13	6	10.4	1.2	8.8	12.3	0.5
14	6	11.4	1.4	10.0	13.5	0.6
15	6	9.9	2.2	7.5	12.5	0.9
16	6	10.3	2.6	7.3	14.8	1.1
17	6	13.5	4.6	8.8	21.5	1.9
18	6	17.7	3.9	14.5	25.3	1.6
19	6	19.4	4.9	14.5	28.8	2.0
20	6	13.0	2.3	9.8	15.8	0.9
21	6	13.8	5.9	7.3	23.5	2.4
22	6	9.5	1.4	7.5	11.3	0.6
23	6	9.4	2.2	6.0	12.3	0.9
24	6	6.8	2.8	3.0	10.8	1.1
25	6	7.7	2.0	5.5	10.8	0.8

Table 75. Medicine Lodge Peak study area summary statistics for forb canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	13.5	3.8	9.8	19.0	1.6
2	6	16.0	2.2	13.8	19.0	0.9
3	6	23.0	4.6	17.0	30.0	1.9
4	6	19.4	7.5	11.8	30.3	3.1
5	6	24.6	5.5	16.0	31.3	2.2
6	6	25.2	5.3	18.8	33.5	2.2
7	6	23.1	4.4	16.0	26.5	1.8
8	6	31.8	8.2	20.5	40.8	3.3
9	6	25.3	4.3	17.3	29.8	1.7
10	6	18.7	5.1	13.0	27.3	2.1
11	6	12.7	3.7	8.3	16.5	1.5
12	6	23.9	5.9	15.5	32.0	2.4
13	6	23.0	6.8	16.8	32.3	2.8
14	6	25.4	6.7	17.0	35.5	2.7
15	6	29.0	11.9	16.0	45.3	4.8
16	6	38.4	5.5	29.8	45.3	2.3
17	6	26.8	5.8	18.3	34.5	2.4
18	6	24.4	6.1	17.3	34.5	2.5
19	6	19.2	4.5	12.3	25.0	1.9
20	6	24.8	3.6	18.3	28.8	1.5
21	6	18.4	3.9	14.5	25.0	1.6
22	6	19.1	4.4	13.8	24.8	1.8
23	6	21.3	3.4	18.3	27.5	1.4
24	6	17.2	2.8	14.8	21.8	1.2
25	6	16.9	3.8	12.0	23.0	1.5

Table 76. Medicine Lodge Peak study area summary statistics for total herbaceous canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	29.5	4.3	22.5	33.5	1.8
2	6	45.3	7.7	34.3	54.8	3.1
3	6	36.2	4.2	31.3	43.8	1.7
4	6	29.9	8.3	22.5	43.0	3.4
5	6	40.7	8.0	28.8	50.0	3.3
6	6	40.7	12.7	22.3	54.5	5.2
7	6	37.5	8.9	26.8	47.5	3.6
8	6	43.9	8.0	28.8	52.8	3.3
9	6	35.9	6.7	27.3	44.0	2.7
10	6	32.6	8.5	21.0	45.5	3.5
11	6	16.4	4.3	9.3	20.5	1.7
12	6	31.8	6.9	20.3	40.5	2.8
13	6	34.9	6.0	29.0	43.0	2.4
14	6	39.8	8.1	31.0	52.5	3.3
15	6	39.0	13.7	21.8	56.8	5.6
16	6	50.9	5.3	41.8	57.0	2.2
17	6	41.1	5.8	32.0	48.8	2.4
18	6	44.3	8.1	38.0	59.3	3.3
19	6	42.0	5.0	35.8	50.5	2.0
20	6	39.1	4.6	33.3	45.3	1.9
21	6	34.4	3.2	29.8	38.0	1.3
22	6	28.2	4.6	22.3	34.5	1.9
23	6	29.6	4.8	21.8	35.8	2.0
24	6	24.6	3.1	20.5	28.8	1.3
25	6	24.0	3.3	19.0	28.3	1.4

Table 77. Hells Canyon study area summary statistics for Douglas fir canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	16.5	10.3	4.6	29.9	4.2
2	6	17.2	9.6	5.0	26.8	3.9
3	6	8.9	6.0	2.6	19.3	2.4
4	6	3.4	4.1	0.0	9.7	1.7
5	6	5.7	7.4	0.0	20.0	3.0
6	6	16.6	5.3	11.5	26.3	2.2
7	6	32.7	5.9	26.4	42.0	2.4
8	6	25.5	7.1	14.0	31.7	2.9
9	6	26.5	8.0	14.3	36.0	3.3
10	6	17.5	11.6	3.8	35.7	4.7
11	6	23.4	12.1	6.6	38.4	4.9
12	6	22.8	11.0	7.9	39.0	4.5
13	6	2.8	5.1	0.0	12.8	2.1
14	6	64.6	18.1	32.7	83.9	7.4
15	6	40.2	7.1	32.5	49.7	2.9
16	6	40.2	1.7	38.1	42.6	0.7
17	6	22.9	6.8	15.0	32.5	2.8
18	6	20.2	7.4	14.0	34.2	3.0
19	6	47.3	6.1	38.9	55.6	2.5
20	6	43.9	16.3	25.8	70.3	6.6
21	6	11.7	5.1	5.1	20.2	2.1
22	6	43.4	15.8	17.7	64.1	6.5
23	6	54.1	10.2	38.0	67.8	4.2
24	6	6.0	5.5	0.0	13.5	2.2
25	6	0.6	1.5	0.0	3.7	0.6

Table 78. Hells Canyon study area summary statistics for total basal area.

Site	N	Mean (cm^2)	Std. Dev.	Min. (cm^2)	Max. (cm^2)	Std. Error
1	6	136.3	137.2	28.3	389.0	56.0
2	6	258.4	219.0	0.0	572.2	89.4
3	6	41.3	39.9	0.0	86.6	16.3
4	6	34.3	70.7	0.0	176.7	28.8
5	6	31.6	30.3	0.0	84.0	12.4
6	6	109.4	34.8	63.6	161.2	14.2
7	6	342.2	200.9	0.0	596.1	82.0
8	6	275.2	197.9	69.9	557.3	80.8
9	6	405.1	253.1	170.6	821.7	103.3
10	6	233.4	211.6	22.2	506.7	86.4
11	6	398.0	305.6	15.9	830.3	124.7
12	6	321.2	210.2	88.2	651.7	85.8
13	6	44.1	81.0	0.0	201.1	33.1
14	6	1556.7	767.6	251.4	2547.0	313.4
15	6	450.8	293.6	68.7	897.7	119.8
16	6	490.7	212.6	237.2	763.0	86.8
17	6	184.5	131.1	0.8	297.6	53.5
18	6	282.9	185.7	7.5	581.0	75.8
19	6	675.1	606.9	188.3	1840.5	247.8
20	6	463.4	355.0	6.3	842.2	144.9
21	6	188.6	150.0	53.4	415.5	61.2
22	6	641.8	266.3	227.0	1063.3	108.7
23	6	559.1	154.5	416.2	853.5	63.1
24	6	37.3	58.8	0.0	128.8	24.0
25	6	0.8	2.0	0.0	4.9	0.8

Table 79. Hells Canyon study area summary statistics for total Douglas fir density.

Site	N	Mean (#)	Std. Dev.	Min. (#)	Max. (#)	Std. Error
1	6	3.5	2.2	1.0	7.0	0.9
2	6	3.0	1.1	2.0	4.0	0.4
3	6	1.2	0.8	0.0	2.0	0.3
4	6	0.5	0.5	0.0	1.0	0.2
5	6	2.0	1.4	0.0	4.0	0.6
6	6	2.5	0.8	2.0	4.0	0.3
7	6	2.5	1.2	1.0	4.0	0.5
8	6	5.2	1.5	3.0	7.0	0.6
9	6	3.8	1.8	2.0	6.0	0.7
10	6	3.5	2.0	2.0	6.0	0.8
11	6	4.2	2.1	2.0	8.0	0.9
12	6	5.3	2.6	2.0	9.0	1.1
13	6	0.8	0.8	0.0	2.0	0.3
14	6	11.8	3.9	5.0	15.0	1.6
15	6	6.3	1.2	5.0	8.0	0.5
16	6	8.0	2.4	5.0	11.0	1.0
17	6	4.0	1.3	3.0	6.0	0.5
18	6	4.7	1.0	3.0	6.0	0.4
19	6	7.5	2.9	3.0	11.0	1.2
20	6	6.8	2.2	3.0	10.0	0.9
21	6	3.0	1.3	1.0	4.0	0.5
22	6	7.8	5.0	1.0	14.0	2.1
23	6	9.2	4.1	2.0	14.0	1.7
24	6	0.8	1.0	0.0	2.0	0.4
25	6	0.2	0.4	0.0	1.0	0.2

Table 80. Hells Canyon study area summary statistics for density of Douglas fir ≥ 1.5 m in height.

Site	N	Mean (#)	Std. Dev.	Min. (#)	Max. (#)	Std. Error
1	6	3.2	1.6	1.0	5.0	0.7
2	6	2.2	1.5	0.0	4.0	0.6
3	6	0.8	0.8	0.0	2.0	0.3
4	6	0.5	0.5	0.0	1.0	0.2
5	6	1.8	1.5	0.0	4.0	0.6
6	6	2.0	0.6	1.0	3.0	0.3
7	6	2.0	1.4	0.0	4.0	0.6
8	6	3.8	1.5	2.0	6.0	0.6
9	6	2.8	1.2	2.0	5.0	0.5
10	6	3.0	1.8	1.0	6.0	0.7
11	6	3.5	1.6	1.0	6.0	0.7
12	6	4.0	2.2	1.0	7.0	0.9
13	6	0.3	0.5	0.0	1.0	0.2
14	6	8.5	4.3	2.0	13.0	1.8
15	6	5.2	1.7	3.0	7.0	0.7
16	6	6.7	2.6	3.0	10.0	1.1
17	6	3.0	1.4	1.0	5.0	0.6
18	6	3.2	1.8	1.0	5.0	0.7
19	6	6.0	1.8	3.0	8.0	0.7
20	6	5.5	2.4	1.0	8.0	1.0
21	6	1.8	1.0	1.0	3.0	0.4
22	6	6.8	4.7	1.0	13.0	1.9
23	6	8.0	3.8	2.0	13.0	1.6
24	6	0.5	0.8	0.0	2.0	0.3
25	6	0.2	0.4	0.0	1.0	0.2

Table 81. Hells Canyon study area summary statistics for total Douglas fir height.

Site	N	Mean (m)	Std. Dev.	Min. (m)	Max. (m)	Std. Error
1	21	3.1	1.1	0.50	4.7	0.2
2	18	3.1	2.1	0.25	6.4	0.5
3	7	3.1	1.8	0.25	4.9	0.7
4	3	3.9	1.8	2.10	5.8	1.1
5	12	2.9	0.7	1.30	4.0	0.2
6	15	3.0	1.5	0.05	4.7	0.4
7	15	3.9	1.6	1:00	5.5	0.4
8	31	2.8	1.6	0.20	5.5	0.3
9	23	3.3	1.8	0.40	5.3	0.4
10	21	3.3	1.5	0.55	5.8	0.3
11	24	3.6	1.6	0.30	5.8	0.3
12	32	3.1	1.6	0.20	5.3	0.3
13	5	2.1	2.3	0.30	5.2	1.0
14	71	4.0	2.7	0.10	8.8	0.3
15	36	3.2	1.6	0.50	5.8	0.3
16	48	3.4	1.6	0.15	6.4	0.2
17	24	3.0	1.7	0.30	6.1	0.3
18	31	2.7	1.9	0.15	5.8	0.3
19	45	3.2	1.8	0.30	6.1	0.3
20	41	3.2	1.8	0.25	7.0	0.3
21	18	2.7	2.0	0.10	6.4	0.5
22	50	3.5	1.8	0.30	6.4	0.2
23	55	3.4	1.4	0.50	5.5	0.2
24	5	2.7	2.2	0.30	4.4	1.0
25	1	2.7	0.0	2.70	2.7	0.0

Table 82. Hells Canyon study area summary statistics for height of Douglas fir ≥ 1.5 m in height.

Site	N	Mean (m)	Std. Dev.	Min. (m)	Max. (m)	Std. Error
1	19	3.4	0.9	1.8	4.7	0.2
2	13	4.1	1.6	1.7	6.4	0.4
3	5	4.1	0.5	3.7	4.9	0.2
4	3	3.9	1.8	2.1	5.8	1.1
5	11	3.1	0.6	2.3	4.0	0.2
6	12	3.7	0.5	3.0	4.7	0.2
7	12	4.5	0.9	2.1	5.5	0.3
8	23	3.5	1.1	1.7	5.5	0.2
9	17	4.1	1.2	1.8	5.3	0.3
10	18	3.7	1.1	1.6	5.8	0.3
11	21	4.1	1.1	1.8	5.8	0.2
12	24	3.9	0.9	1.7	5.3	0.2
13	2	4.6	0.9	4.0	5.2	0.6
14	51	5.3	1.9	1.5	8.8	0.3
15	30	3.7	1.3	1.8	5.8	0.2
16	40	3.9	1.1	1.8	6.4	0.2
17	18	3.7	1.3	1.6	6.1	0.3
18	20	3.8	1.3	1.6	5.8	0.3
19	36	3.8	1.4	1.6	6.1	0.2
20	33	3.8	1.4	1.8	7.0	0.2
21	11	4.0	1.3	2.1	6.4	0.4
22	41	4.1	1.3	1.5	6.4	0.2
23	48	3.8	1.1	1.6	5.5	0.2
24	3	4.3	0.3	4.0	4.4	0.2
25	1	2.7	0.0	2.7	2.7	0.0

Table 83. Hells Canyon study area summary statistics for Douglas fir age.

Site	N	Mean (years)	Std. Dev.	Min. (years)	Max. (years)	Std. Error
1	18	18.8	4.7	10.0	27.0	1.1
2	16	17.2	11.3	3.0	36.0	2.8
3	7	18.6	6.6	7.0	26.0	2.5
4	2	22.0	11.3	14.0	30.0	8.0
5	12	17.5	3.8	11.0	23.0	1.1
6	15	15.9	6.3	1.0	25.0	1.6
7	15	21.3	8.0	8.0	34.0	2.1
8	29	16.5	7.9	2.0	35.0	1.5
9	23	17.0	6.8	5.0	26.0	1.4
10	21	18.8	6.2	7.0	33.0	1.4
11	22	18.7	7.1	7.0	34.0	1.5
12	26	16.7	6.9	3.0	28.0	1.4
13	5	13.0	11.9	3.0	30.0	5.3
14	30	24.2	12.0	3.0	42.0	2.2
15	31	17.2	8.7	5.0	36.0	1.6
16	31	17.1	5.7	5.0	33.0	1.0
17	21	17.0	7.5	3.0	30.0	1.6
18	27	18.4	8.8	4.0	39.0	1.7
19	29	18.9	9.0	3.0	40.0	1.7
20	28	17.5	6.3	3.0	30.0	1.2
21	18	15.7	10.5	1.0	38.0	2.5
22	28	19.8	7.7	6.0	34.0	1.5
23	27	20.1	6.9	8.0	32.0	1.3
24	5	16.4	8.0	5.0	24.0	3.6
25	1	16.0	0.0	16.0	16.0	0.0

Table 84. Hells Canyon study area summary statistics for mountain big sagebrush canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	14.4	2.0	12.5	17.4	0.8
2	6	15.4	2.6	12.1	18.7	1.1
3	6	15.5	3.5	10.4	19.5	1.4
4	6	20.4	4.3	14.9	24.4	1.8
5	6	21.6	3.3	17.2	26.1	1.3
6	6	19.6	3.0	16.5	25.0	1.2
7	6	11.9	6.7	6.8	24.9	2.7
8	6	10.1	3.9	6.3	17.6	1.6
9	6	11.7	4.4	7.0	19.2	1.8
10	6	8.9	3.0	4.8	12.3	1.2
11	6	10.1	2.5	8.0	14.2	1.0
12	6	13.2	2.2	10.8	15.9	0.9
13	6	17.1	4.9	11.8	25.9	2.0
14	6	0.4	0.5	0.0	1.3	0.2
15	6	2.2	1.5	0.8	4.5	0.6
16	6	2.5	0.6	1.8	3.4	0.3
17	6	10.3	4.2	5.0	16.6	1.7
18	6	9.7	3.0	5.3	14.3	1.2
19	6	5.1	2.7	3.4	10.2	1.1
20	6	2.5	1.8	0.3	4.4	0.7
21	6	19.4	3.2	15.1	24.2	1.3
22	6	4.0	2.2	1.1	6.7	0.9
23	6	2.0	1.9	0.2	4.3	0.8
24	6	22.4	5.1	16.5	28.9	2.1
25	6	26.1	4.2	18.5	30.9	1.7

Table 85. Hells Canyon study area summary statistics for density of "large" mountain big sagebrush.

Site	N	Mean (#)	Std. Dev.	Min. (#)	Max. (#)	Std. Error
1	6	63.0	6.3	57.0	70.0	2.6
2	6	75.7	15.4	57.0	98.0	6.3
3	6	63.7	9.8	49.0	73.0	4.0
4	6	71.8	16.2	48.0	89.0	6.6
5	6	71.3	17.3	46.0	89.0	7.1
6	6	81.2	8.7	70.0	92.0	3.5
7	6	43.8	9.6	34.0	59.0	3.9
8	6	47.5	9.9	39.0	65.0	4.0
9	6	52.3	10.0	35.0	63.0	4.1
10	6	59.8	8.5	46.0	69.0	3.5
11	6	58.0	15.2	42.0	85.0	6.2
12	6	56.8	2.9	52.0	59.0	1.2
13	6	67.7	8.0	58.0	80.0	3.3
14	6	1.3	1.4	0.0	4.0	0.6
15	6	13.2	7.0	7.0	25.0	2.8
16	6	13.8	3.6	8.0	19.0	1.5
17	6	44.8	9.2	34.0	59.0	3.8
18	6	41.8	9.1	32.0	58.0	3.7
19	6	16.7	5.3	7.0	22.0	2.2
20	6	11.3	5.2	4.0	19.0	2.1
21	6	70.7	5.6	62.0	76.0	2.3
22	6	20.5	15.3	6.0	44.0	6.3
23	6	9.7	5.1	4.0	18.0	2.1
24	6	73.0	15.8	60.0	100.0	6.4
25	6	96.8	11.0	87.0	118.0	4.5

Table 86. Hells Canyon study area summary statistics for density of "little" mountain big sagebrush.

Site	N	Mean (#)	Std. Dev.	Min. (#)	Max. (#)	Std. Error
1	6	87.8	28.4	44.0	119.0	11.6
2	6	67.2	20.8	43.0	95.0	8.5
3	6	27.8	15.6	1.0	47.0	6.4
4	6	18.8	7.4	6.0	26.0	3.0
5	6	38.8	9.1	24.0	50.0	3.7
6	6	65.8	17.7	54.0	101.0	7.2
7	6	25.3	9.8	12.0	41.0	4.0
8	6	60.3	36.6	23.0	130.0	14.9
9	6	32.8	16.9	15.0	60.0	6.9
10	6	108.3	57.0	31.0	170.0	23.3
11	6	84.8	63.0	31.0	193.0	25.7
12	6	53.8	15.5	35.0	74.0	6.3
13	6	22.2	14.5	11.0	51.0	5.9
14	6	16.8	3.3	14.0	23.0	1.4
15	6	27.7	10.4	16.0	45.0	4.3
16	6	35.7	15.0	15.0	54.0	6.1
17	6	32.8	4.5	27.0	39.0	1.9
18	6	84.2	28.6	55.0	127.0	11.7
19	6	73.5	16.7	42.0	86.0	6.8
20	6	33.5	13.2	13.0	49.0	5.4
21	6	38.8	12.3	27.0	55.0	5.0
22	6	18.5	17.1	2.0	42.0	7.0
23	6	50.2	17.7	22.0	76.0	7.2
24	6	32.5	22.7	14.0	62.0	9.3
25	6	48.8	36.9	21.0	121.0	15.1

Table 87. Hells Canyon study area summary statistics for density of dead sagebrush.

Site	N	Mean (#)	Std. Dev.	Min. (#)	Max. (#)	Std. Error
1	6	20.2	6.1	10.0	28.0	2.5
2	6	20.2	7.7	11.0	34.0	3.1
3	6	32.3	9.6	24.0	48.0	3.9
4	6	20.5	4.0	16.0	26.0	1.6
5	6	18.7	6.9	9.0	30.0	2.8
6	6	12.8	4.4	6.0	19.0	1.8
7	6	27.8	7.3	16.0	38.0	3.0
8	6	26.8	5.4	21.0	33.0	2.2
9	6	34.5	4.6	28.0	40.0	1.9
10	6	26.0	6.2	17.0	33.0	2.5
11	6	22.0	14.5	2.0	37.0	5.9
12	6	27.0	3.6	23.0	32.0	1.5
13	6	20.8	5.4	14.0	27.0	2.2
14	6	48.2	9.2	37.0	61.0	3.7
15	6	49.5	5.2	41.0	54.0	2.1
16	6	67.3	6.3	58.0	73.0	2.6
17	6	43.7	8.8	28.0	52.0	3.6
18	6	41.5	9.2	30.0	50.0	3.8
19	6	33.5	5.2	26.0	39.0	2.1
20	6	52.3	7.0	42.0	60.0	2.9
21	6	27.3	3.1	22.0	30.0	1.3
22	6	54.7	13.5	32.0	74.0	5.5
23	6	49.8	8.6	42.0	66.0	3.5
24	6	21.2	4.4	17.0	27.0	1.8
25	6	11.3	5.0	7.0	21.0	2.0

Table 88. Hells Canyon study area summary statistics for mountain big sagebrush age.

Site	N	Mean (years)	Std. Dev.	Min. (years)	Max. (years)	Std. Error
1	30	21.9	7.3	8.0	38.0	1.3
2	30	29.7	10.5	13.0	55.0	1.9
3	30	25.6	7.0	5.0	42.0	1.3
4	30	20.3	5.1	8.0	34.0	0.9
5	30	27.4	12.5	9.0	52.0	2.3
6	30	31.5	6.8	18.0	46.0	1.2
7	30	29.0	9.0	12.0	47.0	1.6
8	30	29.3	13.2	6.0	56.0	2.4
9	30	31.7	13.7	12.0	60.0	2.5
10	30	25.4	9.8	6.0	49.0	1.8
11	30	27.8	11.5	8.0	54.0	2.1
12	30	30.8	13.7	10.0	54.0	2.5
13	30	38.1	12.4	14.0	57.0	2.3
14	8	7.0	3.9	4.0	16.0	1.4
15	30	23.7	17.0	4.0	54.0	3.1
16	30	28.2	9.9	9.0	44.0	1.8
17	30	26.5	11.1	10.0	58.0	2.0
18	30	31.9	13.5	5.0	58.0	2.5
19	30	14.3	9.5	5.0	48.0	1.7
20	29	28.9	14.3	6.0	62.0	2.7
21	30	30.2	7.9	12.0	44.0	1.5
22	30	27.4	11.5	7.0	45.0	2.1
23	29	12.4	8.0	4.0	33.0	1.5
24	30	31.1	8.0	4.0	50.0	2.1
25	30	16.8	3.7	11.0	24.0	0.7

Table 89. Hells Canyon study area summary statistics for individual mountain big sagebrush production.

Site	N	Mean (g/plant)	Std. Dev.	Min. (g/plant)	Max. (g/plant)	Std. Error
1	60	41.8	29.7	9.2	138.1	3.8
2	60	38.2	28.3	9.2	122.4	3.6
3	60	39.7	22.5	7.3	102.9	2.9
4	60	49.6	28.2	12.4	144.2	3.6
5	60	53.0	42.9	6.7	292.1	5.5
6	60	46.5	32.8	5.6	180.7	4.2
7	60	38.2	24.8	7.2	111.7	3.2
8	60	31.6	24.2	6.3	113.2	3.1
9	60	40.9	27.8	6.7	169.1	3.6
10	60	37.8	28.7	8.0	163.3	3.7
11	60	31.2	26.4	8.7	179.6	3.4
12	60	36.0	26.0	7.0	146.7	3.4
13	60	52.5	47.5	11.0	360.2	6.1
14	8	9.5	3.1	6.7	15.6	1.1
15	52	18.7	9.8	6.0	42.6	1.4
16	58	17.9	7.8	6.8	34.5	1.0
17	59	26.9	15.4	7.0	86.6	2.0
18	60	27.0	16.3	7.2	76.6	2.1
19	57	14.0	6.1	6.2	34.0	0.8
20	52	16.7	8.0	6.0	37.6	1.1
21	60	36.1	21.2	9.3	106.9	2.7
22	56	20.1	10.4	7.1	64.3	1.4
23	48	14.1	7.0	5.8	36.9	1.0
24	60	51.4	33.6	6.6	196.6	4.3
25	60	54.2	35.4	8.6	221.6	4.6

Table 90. Hells Canyon study area summary statistics for total mountain big sagebrush production/transect.

Site	N	Mean (g/transect)	Std. Dev.	Min. (g/transect)	Max. (g/transect)	Std. Error
1	6	2600	244	2123	2778	100
2	6	2851	753	1958	4077	308
3	6	2557	714	1484	3345	292
4	6	3565	911	2331	4483	372
5	6	3878	1822	2186	6345	744
6	6	3779	837	2571	5009	342
7	6	1666	469	1112	2384	191
8	6	1604	1175	735	3930	480
9	6	2114	460	1595	2785	188
10	6	2283	574	1407	3067	234
11	6	1790	834	1163	3418	341
12	6	2025	437	1723	2879	178
13	6	3509	505	2963	4451	206
14	6	13	16	0	44	6
15	6	246	134	108	471	55
16	6	251	80	121	359	33
17	6	1225	376	743	1868	153
18	6	1138	312	804	1625	128
19	6	232	81	122	337	33
20	6	195	116	54	354	47
21	6	2548	390	2245	3221	159
22	6	396	295	85	909	120
23	6	144	114	55	367	47
24	6	3706	1006	2188	4838	411
25	6	5228	1205	4185	7280	492

Table 91. Hells Canyon study area summary statistics for grass canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	23.4	6.1	17.3	31.0	2.5
2	6	23.8	6.3	15.8	33.3	2.6
3	6	21.3	4.5	15.8	28.3	1.8
4	6	26.0	6.5	18.3	34.5	2.7
5	6	29.3	7.4	19.5	38.3	3.0
6	6	20.4	3.4	17.3	25.0	1.4
7	6	19.9	2.8	17.0	24.0	1.1
8	6	30.0	2.9	26.3	33.5	1.2
9	6	24.8	4.0	21.3	32.3	1.6
10	6	26.3	3.8	19.5	29.8	1.5
11	6	25.2	6.9	14.3	32.5	2.8
12	6	23.7	5.3	14.5	28.5	2.2
13	6	30.8	4.0	23.8	35.5	1.6
14	6	8.2	2.8	5.5	11.3	1.1
15	6	13.5	4.4	8.3	19.5	1.8
16	6	14.6	2.3	10.8	17.0	0.9
17	6	14.4	3.5	9.8	18.3	1.4
18	6	25.2	4.0	20.5	31.0	1.6
19	6	14.2	3.7	9.5	19.0	1.5
20	6	13.1	1.5	11.0	14.8	0.6
21	6	18.4	4.8	12.0	25.3	2.0
22	6	15.8	5.3	8.8	22.3	2.2
23	6	12.7	5.1	6.0	20.5	2.1
24	6	22.7	4.2	17.0	27.0	1.7
25	6	25.4	4.1	19.8	29.8	1.7

Table 92. Hells Canyon study area summary statistics for forb canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	17.2	4.0	10.8	20.5	1.7
2	6	15.3	3.8	10.0	20.5	1.6
3	6	14.7	4.7	8.8	23.0	1.9
4	6	13.3	3.5	9.8	19.3	1.4
5	6	12.8	3.4	8.8	19.0	1.4
6	6	14.8	2.7	10.0	17.3	1.1
7	6	12.0	4.5	6.8	20.5	1.9
8	6	15.9	3.0	12.5	19.8	1.2
9	6	14.3	2.1	12.3	17.3	0.8
10	6	14.3	1.3	12.5	15.8	0.5
11	6	16.3	2.9	12.5	20.5	1.2
12	6	16.8	4.3	12.3	22.8	1.7
13	6	12.7	2.0	9.8	14.8	0.8
14	6	9.8	3.7	4.8	13.8	1.5
15	6	14.1	3.8	9.3	19.3	1.6
16	6	14.6	4.0	9.3	19.5	1.6
17	6	13.0	4.0	10.0	20.8	1.6
18	6	15.9	4.7	9.5	23.0	1.9
19	6	17.5	3.5	12.3	20.8	1.4
20	6	14.2	3.4	8.5	18.0	1.4
21	6	13.4	6.1	9.5	25.5	2.5
22	6	11.6	6.9	4.0	23.5	2.8
23	6	10.1	2.8	6.3	13.3	1.1
24	6	12.3	2.2	9.8	14.8	0.9
25	6	12.8	2.5	9.8	16.8	1.0

Table 93. Hells Canyon study area summary statistics for total herbaceous canopy cover.

Site	N	Mean (%)	Std. Dev.	Min. (%)	Max. (%)	Std. Error
1	6	46.1	9.2	35.0	57.0	3.8
2	6	43.6	8.2	36.0	55.0	3.4
3	6	36.0	5.7	29.5	43.8	2.3
4	6	38.8	12.7	28.8	60.8	5.2
5	6	43.9	6.7	36.8	54.8	2.7
6	6	38.7	5.6	31.0	44.5	2.3
7	6	33.2	4.1	29.5	41.0	1.7
8	6	49.8	6.6	39.5	57.0	2.7
9	6	43.9	7.4	35.8	57.3	3.0
10	6	46.0	4.5	40.3	52.5	1.8
11	6	42.4	5.7	34.5	47.5	2.3
12	6	44.3	6.9	36.8	52.5	2.8
13	6	46.5	2.5	42.8	50.3	1.0
14	6	16.0	4.4	10.8	21.8	1.8
15	6	27.8	9.6	18.0	40.3	3.9
16	6	28.4	5.9	19.8	36.0	2.4
17	6	26.4	6.6	20.0	38.3	2.7
18	6	41.2	3.4	38.0	45.5	1.4
19	6	30.5	5.4	23.5	37.0	2.2
20	6	27.1	7.0	18.3	36.8	2.8
21	6	33.0	8.0	23.5	45.0	3.3
22	6	27.9	12.0	16.5	48.8	4.9
23	6	23.9	7.4	16.5	37.8	3.0
24	6	33.5	6.2	22.0	38.5	2.6
25	6	41.1	8.2	26.3	50.0	3.3

APPENDIX E

REGRESSION COEFFICIENT STANDARD ERRORS

Table 94. Regression coefficient standard errors for mountain big sagebrush canopy cover models.

Study Area	b_0	b_1	b_2	b_3
SLM	1.67	0.042	0.084	-
MLP	1.19	0.084	0.001	-
HC	1.37	0.109	0.002	-
Overall	0.85	0.063	0.001	-

Confidence intervals of the form $b_k \pm t(1-\alpha/2;n-p)s\{b_k\}$

Table 95. Regression coefficient standard errors for density of "large" mountain big sagebrush models.

Study Area	b_0	b_1	b_2	b_3
SLM	5.25	0.380	0.006	1.639
MLP	4.79	0.337	0.005	-
HC	3.39	0.114	-	-
Overall	4.15	0.195	0.003	1.330
Overall[1]	2.68	0.198	0.003	-

1 - Only using Douglas fir canopy cover in the model.
Confidence intervals of the form $b_k \pm t(1-\alpha/2;n-p)s\{b_k\}$

Table 96. Regression coefficient standard errors for grass canopy cover models.

Study Area	b_0	b_1	b_2	b_3
SLM	1.71	0.134	0.002	-
MLP	0.91	0.026	-	-
HC	1.32	0.044	-	-
Overall	0.067	0.017	0.001	-
Overall[1]	0.061	0.002	-	-

1 - Only using Douglas fir canopy cover in the model.
Confidence intervals of the form $b_k \pm t(1-\alpha/2;n-p)s\{b_k\}$

Table 97. Regression coefficient standard errors for total herbaceous canopy cover models.

Study Area	b_0	b_1	b_2	b_3
SLM	1.83	0.064	-	-
MLP	4.43	0.004	1.156	-
HC	2.85	0.225	0.004	-
Overall	1.27	0.002	-	-
Overall[1]	1.93	0.144	0.002	-

1 - Only using Douglas fir canopy cover in the model.
Confidence intervals of the form $b_k \pm t(1-\alpha/2;n-p)s\{b_k\}$

APPENDIX F

PREDICTED VALUES AND PREDICTION INTERVALS

Table 98. Mountain big sagebrush canopy cover model validation results for the Sugerloaf Mountain study area.

	Medicine Lodge Peak			Hells Canyon		
Site	Predicted Value	80% Prediction Interval	Observed Value	Predicted Value	80% Prediction Interval	Observed Value
1	8.7	4.8-12.6	12.0	10.2	6.3-14.1	14.4+
2	12.6	8.6-16.6	11.6	10.3	6.4-14.2	15.4+
3	6.7	2.8-10.7	4.4	12.0	8.1-16.0	15.5
4	4.0	0.0-8.0	2.7	12.8	8.7-16.9	20.4+
5	8.8	4.7-12.9	6.1	13.0	9.0-17.0	21.6+
6	3.0	0.0-7.1	0.5	10.7	6.8-14.6	19.6+
7	3.8	0.0-7.8	1.4	6.0	2.1-9.9	11.9
8	9.3	5.4-13.2	9.5	8.5	4.6-12.4	10.1
9	4.6	0.7-8.6	5.3	8.1	4.2-12.1	11.7
10	5.2	1.2-9.1	5.3	10.0	6.1-13.9	8.9
11	0.0	0.0-0.6	0.0	8.6	4.7-12.5	10.1
12	1.1	0.0-5.3	1.4	8.6	4.7-12.5	13.2+
13	7.2	3.3-11.1	7.4	14.5	10.4-18.5	17.1
14	7.0	3.1-11.0	4.4	0.0	0.0-2.3	0.4
15	5.4	1.4-9.4	2.6	4.9	0.9-9.0	2.2
16	10.2	6.3-14.1	17.2+	4.9	0.8-8.9	2.5
17	13.1	9.1-17.1	16.3	9.0	5.1-12.9	10.3
18	11.0	7.1-14.9	14.1	9.4	5.5-13.3	9.7
19	12.9	8.9-16.9	20.7+	2.9	0.0-7.0	5.1
20	13.5	9.4-17.6	20.1+	3.9	0.0-8.0	2.5
21	11.0	7.1-14.9	14.9	11.9	7.8-15.8	19.4+
22	10.5	6.6-14.5	19.3+	3.7	0.0-7.7	4.0
23	13.7	9.7-17.8	21.4+	1.1	0.0-5.3	2.0
24	16.0	11.8-20.1	27.9+	13.2	9.2-17.2	22.4+
25	0.1	0.0-4.5	0.3	14.5	10.4-18.5	26.1+

Note: Negative values were truncated to 0.
+ Values fell outside of prediction intervals.

Table 99. Density of "large" mountain big sagebrush model validation results for the Sugerloaf Mountain study area.

	Medicine Lodge Peak			Hells Canyon		
Site	Predicted Value	80 % Prediction Interval	Observed Value	Predicted Value	80% Prediction Interval	Observed Value
1	49.8	38.4-61.3	53.2	58.8	47.3-70.2	63.0
2	77.9	66.1-89.8	66.2	57.5	46.1-68.9	75.7+
3	33.7	22.2-45.3	20.7+	73.3	61.7-84.9	63.7
4	22.8	11.2-34.5	19.7	87.9	75.2-100.5	71.8+
5	33.7	21.4-45.9	26.8	79.1	67.2-90.9	71.3
6	13.5	1.4-25.6	3.5	58.2	46.8-69.6	81.2+
7	17.6	5.7-29.6	9.7	35.8	24.3-47.4	43.8
8	52.1	40.6-63.5	51.3	42.3	30.7-53.9	47.5
9	24.4	12.6-36.1	20.3	42.7	31.2-54.2	52.3
10	28.7	17.2-40.3	29.8	57.7	46.3-69.2	59.8
11	0.0	0.0-16.7	0.0	48.4	36.9-59.9	58.0
12	9.2	0.0-21.7	9.8	47.8	36.3-59.3	56.8
13	39.3	27.8-50.8	47.3	82.1	70.1-94.2	67.7+
14	34.6	23.0-46.2	29.7	4.6	0.0-20.0	1.3
15	28.2	16.6-39.8	19.3	23.3	11.7-35.0	13.2
16	67.3	55.5-79.1	79.8+	24.1	12.5-35.7	13.8
17	79.7	67.8-91.6	73.8	47.3	35.8-58.8	44.8
18	60.7	49.3-72.2	75.5+	50.7	39.1-62.2	41.8
19	75.6	63.9-87.3	86.5	15.4	3.5-27.3	16.7
20	85.5	73.2-97.9	76.2	19.0	7.3-30.8	11.3
21	69.2	57.5-80.9	62.2	66.2	54.7-77.7	70.7
22	62.3	50.9-73.7	71.0	21.5	9.9-33.2	20.5
23	87.4	75.0-99.8	91.3	9.8	0.0-22.3	9.7
24	84.2	71.6-96.8	123.5+	77.7	65.9-89.5	73.0
25	2.9	0.0-16.6	3.0	89.3	76.8-101.9	96.8

Note: Negative values were truncated to 0.
+ Values fell outside of prediction inter

Table 100. Grass canopy cover model validation results for the Sugerloaf Mountain study area.

	Medicine Lodge Peak			Hells Canyon		
Site	Predicted Value	80 % Prediction Interval	Observed Value	Predicted Value	80% Prediction Interval	Observed Value
1	16.5	12.0-21.0	12.5	19.1	14.6-23.6	23.4
2	23.5	18.9-28.1	24.4	18.8	14.3-23.3	23.8+
3	13.3	8.7-17.8	11.4	22.6	18.1-27.2	21.3
4	11.2	6.6-15.8	11.8	25.6	20.8-30.3	26.0
5	14.7	10.1-19.2	11.3	24.3	19.7-28.9	29.3+
6	10.6	5.9-15.2	10.5	19.0	14.5-23.5	20.4
7	11.2	6.6-15.7	11.5	13.4	8.8-17.9	19.9+
8	17.2	12.6-21.7	10.5+	15.6	11.1-20.1	30.0+
9	12.0	7.5-16.6	9.8	15.3	10.7-19.8	24.8+
10	12.2	7.7-16.8	11.7	18.6	14.1-23.1	26.3+
11	10.5	3.0-18.1	5.5	16.3	11.8-20.8	25.2+
12	9.9	4.9-14.8	8.4	16.6	12.0-21.1	23.7+
13	14.5	10.0-19.1	10.4	25.9	21.1-30.6	30.8+
14	13.7	9.2-18.3	11.4	9.8	3.8-15.7	8.2
15	12.4	7.9-16.9	9.9	11.6	7.1-16.2	13.5
16	20.0	15.5-24.5	10.3	11.6	7.1-16.2	14.6
17	24.3	19.7-29.0	13.5+	16.5	12.0-21.0	14.4
18	19.7	15.2-24.2	17.7	17.5	13.0-22.0	25.2+
19	23.5	18.9-28.1	19.4	10.5	5.8-15.1	14.2
20	26.7	22.1-31.8	13.0+	11.0	6.4-15.6	13.1
21	20.7	16.2-25.2	13.8+	21.2	16.7-25.8	18.4
22	19.7	15.2-24.2	9.5+	11.1	6.5-15.6	16.4+
23	26.8	21.9-31.6	9.4+	9.8	4.9-14.8	12.7
24	27.5	22.5-32.4	6.8+	24.1	19.5-28.8	22.7
25	9.7	4.3-15.0	7.7	27.2	22.3-32.0	25.4

Note: Negative values were truncated to 0.
+ Values fell outside of prediction intervals.

Table 101. Total herbaceous canopy cover model validation results for the Sugerloaf Mountain study area.

	Medicine Lodge Peak			Hells Canyon		
Site	Predicted Value	80% Prediction Interval	Observed Value	Predicted Value	80% Prediction Interval	Observed Value
1	29.6	22.9-36.2	29.5	31.9	25.3-38.6	46.1+
2	35.3	28.5-42.1	45.3+	31.7	25.0-38.3	43.6+
3	25.9	19.2-32.6	36.2+	34.7	27.9-41.4	36.0
4	22.4	15.6-29.2	29.9	36.7	29.8-43.5	38.8
5	27.6	21.0-34.3	40.7+	35.8	29.0-42.7	43.9+
6	21.0	14.1-27.9	40.7+	31.9	25.2-38.5	38.7+
7	22.4	15.6-29.2	37.5+	26.0	19.4-32.7	33.2+
8	30.2	23.6-36.8	43.9+	28.7	22.0-35.3	49.8+
9	24.0	17.2-30.7	35.9+	28.3	21.7-34.9	43.9+
10	24.3	17.6-31.1	32.6+	31.6	24.9-38.2	46.0+
11	11.3	3.5-19.1	16.4	29.4	22.8-36.0	42.4+
12	18.3	11.3-25.4	31.8+	29.6	23.0-36.3	44.3+
13	27.5	20.8-34.1	34.9+	36.9	30.0-43.8	46.5+
14	26.5	19.9-33.2	39.8+	14.5	7.0-21.9	16.0
15	24.6	17.9-31.3	39.0+	23.3	16.5-30.1	27.8
16	32.7	26.0-39.4	50.9+	23.3	16.5-30.1	28.4
17	35.9	29.1-42.7	41.1	29.6	23.0-36.2	26.4
18	32.5	25.8-39.1	44.3+	30.6	23.9-37.2	41.2+
19	35.3	28.5-42.1	42.0	20.7	13.8-27.6	30.5+
20	37.6	30.7-44.5	39.1	22.0	15.1-28.8	27.1
21	33.3	26.6-40.0	34.4	33.7	26.9-40.4	33.0
22	32.5	25.8-39.1	28.2	22.2	15.3-29.0	27.9
23	37.4	30.5-44.3	29.6+	18.3	11.2-25.4	23.9
24	37.9	30.9-44.8	24.6+	35.7	28.9-42.5	33.5
25	16.3	9.1-23.6	24.0+	37.7	30.8-44.6	41.1

Note: Negative values were truncated to 0.
+ Values fell outside of prediction intervals.

Table 102. Mountain big sagebrush canopy cover model validation results for the Medicine Lodge Peak study area.

	Sugerloaf Mountain			Hells Canyon		
Site	Predicted Value	80 % Prediction Interval	Observed Value	Predicted Value	80% Prediction Interval	Observed Value
1	8.0	4.4-11.6	7.7	12.9	9.3-16.5	14.4
2	0.7	0.0-4.4	1.2	12.6	9.0-16.2	15.4
3	11.7	8.1-15.3	12.3	17.3	13.7-20.9	15.5
4	11.8	8.2-15.4	11.0	20.9	17.1-24.6	20.4
5	4.9	1.3-8.6	6.6	19.3	15.7-23.0	21.6
6	11.9	8.3-15.5	11.3	12.9	9.3-16.5	19.6+
7	4.3	0.7-7.9	3.9	5.7	2.1-9.3	11.9+
8	3.8	0.2-7.4	4.3	8.6	4.9-12.2	10.1
9	23.2	19.4-27.1	20.0	8.1	4.5-11.8	11.7
10	18.1	14.4-21.7	13.4+	12.4	8.8-16.0	8.9
11	11.2	7.6-14.8	9.5	9.5	5.9-13.1	10.1
12	13.3	9.7-16.9	7.1+	9.8	6.2-13.4	13.2
13	8.3	4.7-11.9	6.0	21.3	17.5-25.0	17.1+
14	15.6	12.0-19.2	15.3	0.0	0.0-3.6	0.4
15	3.4	0.0-7.1	2.4	3.3	0.0-6.9	2.2
16	10.8	7.2-14.4	6.6+	3.3	0.0-6.9	2.5
17	0.0	0.0-3.6	0.8	9.7	6.1-13.3	10.3
18	19.0	15.3-22.7	20.3	11.0	7.4-14.6	9.7
19	20.3	16.7-24.1	10.3+	1.6	0.0-5.2	5.1
20	10.6	7.0-14.2	6.5+	2.3	0.0-6.0	2.5
21	22.5	18.7-26.3	8.5+	15.6	12.0-19.2	19.4+
22	5.5	1.8-9.1	1.7+	2.4	0.0-6.1	4.0
23	13.1	9.5-16.7	7.6+	0.4	0.0-4.1	2.0
24	2.0	0.0-5.6	2.2	19.1	15.5-22.8	22.4
25	6.4	2.7-10.0	5.3	22.8	19.0-26.6	26.1

Note: Negative values were truncated to 0.
+ Values fell outside of prediction intervals.

Table 103. Density of "large" mountain big sagebrush model validation results for the Medicine Lodge Peak study area.

	Sugerloaf Mountain			Hells Canyon		
Site	Predicted Value	80 % Prediction Interval	Observed Value	Predicted Value	80 % Prediction Interval	Observed Value
1	39.8	25.2-54.3	37.0	59.7	45.2-74.2	63.0
2	7.2	0.0-22.1	11.3	58.2	43.7-72.7	75.7+
3	54.9	40.4-69.4	48.2	76.9	62.2-91.5	63.7
4	55.1	40.6-69.6	50.5	90.6	75.6-105.6	71.8+
5	26.8	12.2-41.4	36.2	84.7	69.9-99.5	71.3
6	55.7	41.2-70.2	55.8	59.5	45.0-74.0	81.2+
7	24.1	9.5-38.7	22.2	30.1	15.5-44.7	43.8
8	21.9	7.3-36.6	32.0	42.1	27.5-56.6	47.5
9	99.6	84.2-115.0	87.5	40.3	25.7-54.9	52.3
10	79.8	65.1-94.4	85.7	57.6	43.1-72.1	59.8
11	52.7	38.2-67.2	61.7	45.9	31.4-60.5	58.0
12	61.2	46.7-75.7	56.5	47.0	32.5-61.6	56.8
13	41.0	26.4-55.6	48.2	92.1	77.1-107.2	67.7+
14	70.3	55.8-84.8	92.3+	0.0	0.0-15.7	1.3
15	20.2	5.6-34.9	29.7	19.6	5.0-34.2	13.2
16	51.1	36.6-65.6	54.8	19.6	5.0-34.2	13.8
17	0.9	0.0-16.6	7.2	46.9	32.3-61.4	44.8
18	83.5	68.7-98.2	76.7	52.1	37.6-66.6	41.8
19	88.8	73.8-103.7	69.8+	11.6	0.0-26.3	16.7
20	50.5	36.0-65.0	61.5	15.2	0.5-29.8	11.3
21	96.9	81.6-112.2	72.0+	70.3	55.8-84.8	70.7
22	29.2	14.6-43.8	15.7	15.8	1.1-30.4	20.5
23	60.3	45.8-74.8	55.3	5.6	0.0-20.5	9.7
24	13.5	0.0-28.2	18.8	84.0	69.2-98.8	73.0
25	32.9	18.3-47.5	36.7	98.0	82.6-113.3	96.8

Note: Negative values were truncated to 0.
+ Values fell outside of prediction intervals.

Table 104. Grass canopy cover model validation results for the Medicine Lodge Peak study area.

	Sugerloaf Mountain			Hells Canyon		
Site	Predicted Value	80 % Prediction Interval	Observed Value	Predicted Value	80% Prediction Interval	Observed Value
1	11.6	8.4-14.7	10.8	12.6	9.4-15.8	23.4+
2	9.1	5.8-12.4	12.3	12.6	9.3-15.7	23.8+
3	12.3	9.2-15.5	19.8+	13.3	10.1-16.6	21.3+
4	12.4	9.2-15.5	16.4+	13.9	10.6-17.1	26.0+
5	10.8	7.6-14.0	14.7+	13.6	10.4-16.9	29.3+
6	12.4	9.2-15.6	19.3+	12.6	9.4-15.8	20.4+
7	10.6	7.4-13.8	10.4	11.0	7.8-14.2	19.9+
8	10.4	7.2-13.6	10.0	11.7	8.5-14.9	30.0+
9	14.2	10.9-17.5	25.6+	11.6	8.4-14.8	24.8+
10	13.4	10.2-16.7	20.7+	12.5	9.3-15.7	26.3+
11	12.2	9.1-15.4	25.5+	11.9	8.7-15.1	25.2+
12	12.6	9.4-15.8	20.3+	12.0	8.8-15.1	23.7+
13	11.6	8.5-14.8	12.6	13.9	10.6-17.2	30.8+
14	13.0	9.8-16.3	17.5+	7.9	4.5-11.3	8.2
15	10.3	7.1-13.5	14.7+	10.3	7.1-13.5	13.5
16	12.2	9.0-15.3	17.3+	10.3	7.1-13.5	14.6+
17	8.2	4.8-11.5	9.2	11.9	8.8-15.1	14.4
18	13.6	10.3-16.8	22.7+	12.2	9.0-15.4	25.2+
19	13.8	10.5-17.1	21.0+	9.6	6.3-12.8	14.2+
20	12.1	8.9-15.3	20.5+	9.9	6.7-13.1	13.1
21	14.1	10.8-17.4	33.5+	13.0	9.8-16.3	18.4+
22	10.9	7.8-14.1	9.7	9.9	6.7-13.2	16.4+
23	12.6	9.4-15.8	22.0+	8.9	5.6-12.2	12.7+
24	9.7	6.5-13.0	9.6	13.6	10.3-16.9	22.7+
25	11.2	8.0-14.3	14.3	14.1	10.8-17.4	25.4+

Note: Negative values were truncated to 0.
+ Values fell outside of prediction intervals.

Table 105. Total herbaceous canopy cover model validation results for the Medicine Lodge Peak study area.

	Sugerloaf Mountain			Hells Canyon		
Site	Predicted Value /1	80% Prediction Interval /1	Observed Value /1	Predicted Value	80% Prediction Interval	Observed Value
1	-	-	-	38.4	30.2-46.6	46.1
2	-	-	-	39.1	31.0-47.3	43.6
3	-	-	-	42.0	33.7-50.3	36.0
4	-	-	-	41.7	33.4-50.1	38.8
5	-	-	-	38.9	30.5-47.2	43.9
6	-	-	-	39.9	31.7-48.1	38.7
7	-	-	-	39.4	31.2-47.5	33.2
8	-	-	-	36.7	28.6-44.9	49.8+
9	-	-	-	37.0	28.9-45.1	43.9
10	-	-	-	38.1	29.9-46.2	46.0
11	-	-	-	36.7	28.6-44.8	42.4
12	-	-	-	37.5	29.4-45.6	44.3
13	-	-	-	44.1	35.7-52.6	46.5
14	-	-	-	24.3	15.0-33.7	16.0
15	-	-	-	35.2	27.1-43.3	27.8
16	-	-	-	35.3	27.3-43.4	28.4
17	-	-	-	38.4	30.2-46.6	26.4+
18	-	-	-	37.7	29.6-45.8	41.2
19	-	-	-	31.9	23.7-40.1	30.5
20	-	-	-	35.0	26.9-43.1	27.1
21	-	-	-	39.8	31.6-48.0	33.0
22	-	-	-	33.8	25.7-41.9	27.9
23	-	-	-	33.6	25.5-41.7	23.9+
24	-	-	-	43.1	34.7-51.6	33.5+
25	-	-	-	37.9	29.4-46.3	41.1

Note: Negative values were truncated to 0.
+ Values fell outside of prediction intervals.
/1 - Model was unable to generate a predicted value and interval for the Sugerloaf Mountain study area as HTG15M was not measured for this study area.

Table 106. Mountain big sagebrush canopy cover model validation results for the Hells Canyon study area.

	Sugerloaf Mountain			Medicine Lodge Peak		
Site	Predicted Value	80% Prediction Interval	Observed Value	Predicted Value	80% Prediction Interval	Observed Value
1	9.7	5.9-13.4	7.7	11.3	7.6-15.0	12.0
2	1.9	0.0-5.7	1.2	19.4	15.6-23.2	11.6+
3	13.3	9.6-17.0	12.3	7.2	3.5-11.0	4.4
4	13.3	9.6-17.0	11.0	4.2	0.4-7.9	2.7
5	6.6	2.8-10.3	6.6	9.1	5.3-12.8	6.1
6	13.5	9.8-17.2	11.3	3.1	0.0-6.9	0.5
7	5.9	2.2-9.7	3.9	4.1	0.4-7.9	1.4
8	5.4	1.7-9.2	4.3	12.1	8.4-15.8	9.5
9	23.8	19.7-27.8	20.0	5.4	1.7-9.2	5.3
10	19.1	15.4-22.9	13.4+	5.7	2.0-9.5	5.3
11	12.7	9.0-16.4	9.5	0.0	0.0-5.0	0.0
12	14.7	11.0-18.4	7.1+	1.5	0.0-5.4	1.4
13	10.0	6.2-13.7	6.0+	8.9	5.2-12.6	7.4
14	16.9	13.2-20.6	15.3	7.9	4.1-11.6	4.4
15	5.0	1.3-8.8	2.4	6.0	2.3-9.8	2.6
16	12.4	8.7-16.1	6.6+	15.5	11.8-19.2	17.2
17	0.3	0.0-4.6	0.8	20.3	16.5-24.1	16.3+
18	20.0	16.2-23.8	20.3	15.1	11.5-18.8	14.1
19	21.2	17.4-25.1	10.3+	19.4	15.6-23.2	20.7
20	12.2	8.5-15.9	6.5+	23.2	19.2-27.2	20.1
21	23.1	19.2-27.1	8.5+	16.3	12.6-20.0	14.9
22	7.2	3.4-10.9	1.7+	15.1	11.5-18.8	19.3+
23	14.5	10.8-18.2	7.6+	22.9	19.0-26.9	21.4
24	3.4	0.0-7.2	2.2	23.7	19.7-27.7	27.9+
25	8.0	4.3-11.8	5.3	0.5	0.0-4.7	0.3

Note: Negative values were truncated to 0.
\+ Values fell outside of prediction intervals.

Table 107. Density of "large" mountain big sagebrush model results for the Hells Canyon study area.

	Sugerloaf Mountain			Medicine Lodge Peak		
Site	Predicted Value	80% Prediction Interval	Observed Value	Predicted Value	80% Prediction Interval	Observed Value
1	45.9	32.9-58.8	37.0	51.3	38.4-64.3	53.2
2	9.7	0.0-23.3	11.3	74.0	60.8-87.2	66.2
3	57.3	44.4-70.3	48.2	36.8	23.8-49.8	20.7+
4	57.5	44.5-70.5	50.5	23.2	10.0-36.4	19.7
5	34.2	21.2-47.3	36.2	43.7	30.8-56.7	26.8+
6	57.9	45.0-70.9	55.8	17.6	4.3-30.9	3.5+
7	31.5	18.5-44.6	22.2	23.0	9.8-36.3	9.7+
8	29.2	16.1-42.3	32.0	53.9	41.0-66.9	51.3
9	84.3	70.9-97.8	87.5	29.2	16.1-42.3	20.3
10	73.3	60.1-86.5	85.7	30.7	17.6-43.7	29.8
11	55.8	42.8-68.7	61.7	0.0	0.0-0.0	0.0
12	61.7	48.7-74.7	56.5	7.0	0.0-20.6	9.8
13	46.9	33.9-59.8	48.2	43.1	30.2-56.1	47.3
14	67.5	54.5-80.6	92.3+	39.3	26.3-52.2	29.7
15	27.4	14.2-40.5	29.7	31.8	18.7-44.9	19.3
16	54.6	41.7-67.6	54.8	63.7	50.6-76.7	79.8+
17	0.0	0.0-10.1	7.2	76.3	63.1-89.5	73.8
18	75.4	62.2-88.7	76.7	62.8	49.8-75.8	75.5
19	78.4	65.2-91.7	69.8	74.0	60.8-87.2	86.5
20	54.2	41.2-67.1	61.5	83.0	69.6-96.5	76.2
21	82.9	69.5-96.3	72.0	66.0	52.9-79.0	62.2
22	36.5	23.5-49.5	15.7+	62.8	49.8-75.8	71.0
23	61.1	48.1-74.1	55.3	82.5	69.1-95.9	91.3
24	19.2	5.9-32.5	18.8	84.2	70.7-97.6	123.5+
25	40.0	27.0-53.0	36.7	0.0	0.0-13.0	3.0

Note: Negative values were truncated to 0.
\+ Values fell outside of prediction intervals.

Table 108. Grass canopy cover model validation results for the Hells Canyon study area.

	Sugerloaf Mountain			Medicine Lodge Peak		
Site	Predicted Value	80% Prediction Interval	Observed Value	Predicted Value	80% Prediction Interval	Observed Value
1	20.3	15.3-25.4	10.8+	21.4	16.4-26.4	12.5+
2	13.1	7.8-18.4	12.3	25.9	20.7-31.1	24.4
3	22.6	17.5-27.7	19.8	18.5	13.4-23.6	11.4+
4	22.6	17.6-27.7	16.4+	15.8	10.7-21.0	11.8
5	18.0	12.9-23.1	14.7	19.9	14.8-24.9	11.3+
6	22.7	17.6-27.8	19.3	14.7	9.5-19.9	10.5
7	17.5	12.4-22.6	10.4+	15.8	10.6-20.9	11.5
8	17.0	11.9-22.1	10.0+	21.9	16.9-27.0	10.5+
9	28.0	22.7-33.2	25.6	17.0	11.9-22.1	9.8+
10	25.8	20.6-30.9	20.7	17.3	12.2-22.4	11.7+
11	22.3	17.2-27.3	25.5	7.1	1.3-12.9	5.5
12	23.5	18.4-28.5	20.3	12.6	7.3-17.9	8.4
13	20.5	15.5-25.6	12.6+	19.8	14.7-24.8	10.4+
14	24.6	19.5-29.7	17.5+	19.0	13.9-24.1	11.4+
15	16.6	11.5-21.8	14.7	17.5	12.4-22.6	9.9+
16	22.1	17.0-27.1	17.3	23.8	18.8-28.9	10.3+
17	10.4	4.9-15.9	9.2	26.4	21.2-31.5	13.5+
18	26.2	21.0-31.3	22.7	23.7	18.6-28.8	17.7+
19	26.8	21.6-32.0	21.0+	25.9	20.7-31.1	19.4+
20	22.0	16.9-27.0	20.5	27.7	22.5-32.9	13.0+
21	27.7	22.4-32.9	33.5+	24.3	19.2-29.4	13.8+
22	18.5	13.4-23.5	9.7+	23.7	18.6-28.8	9.5+
23	23.3	18.3-28.4	22.0	27.6	22.4-32.8	9.4+
24	15.0	9.8-20.2	9.6+	27.9	22.7-33.2	6.8+
25	19.1	14.1-24.2	14.3	11.0	5.6-16.5	7.7

Note: Negative values were truncated to 0.
+ Values fell outside of prediction intervals.

Table 109. Total herbaceous canopy cover model validation results for the Hells Canyon study area.

	Sugerloaf Mountain			Medicine Lodge Peak		
Site	Predicted Value	80% Prediction Interval	Observed Value	Predicted Value	80% Prediction Interval	Observed Value
1	38.3	30.5-46.0	27.3+	39.4	31.6-47.1	29.5+
2	24.7	16.7-32.8	23.8	41.1	33.2-48.9	45.3
3	40.2	32.6-47.9	40.8	35.9	28.2-43.7	36.2
4	40.3	32.6-47.9	31.3+	31.1	23.3-38.9	29.9
5	35.1	27.4-42.9	27.5	37.8	30.0-45.6	40.7
6	40.3	32.6-48.0	40.5	28.6	20.8-36.5	40.7+
7	34.2	26.5-42.0	25.1	31.0	23.2-38.8	37.5
8	33.4	25.7-41.2	19.4+	39.8	32.1-47.5	43.9
9	40.4	32.0-48.7	31.9+	33.4	25.7-41.2	35.9
10	41.1	33.3-48.9	30.7+	33.9	26.2-41.7	32.6
11	40.0	32.3-47.7	36.6	4.4	0.0-16.2	16.4+
12	40.7	33.0-48.3	29.0+	23.2	15.1-31.4	31.8+
13	38.5	30.8-46.2	25.5+	37.7	29.9-45.4	34.9
14	41.0	33.3-48.7	34.5	36.6	28.9-44.4	39.8
15	32.7	25.0-40.5	29.7	34.3	26.6-42.1	39.0
16	39.9	32.2-47.6	28.1+	40.8	33.2-48.5	50.9+
17	16.7	7.7-25.7	11.9	41.0	33.1-48.9	41.1
18	41.0	33.2-48.9	33.7	40.8	33.1-48.4	44.3
19	40.9	32.9-48.9	33.7	41.1	33.2-48.9	42.0
20	39.8	32.1-47.5	29.5+	40.5	32.2-48.8	39.1
21	40.5	32.3-48.8	44.0	41.0	33.3-48.6	34.4
22	35.9	28.1-43.6	16.0+	40.8	33.1-48.4	28.2+
23	40.6	33.0-48.3	29.7+	40.6	32.3-48.8	29.6+
24	29.4	21.5-37.2	19.5	40.4	32.0-48.7	24.6+
25	36.8	29.1-44.6	28.0+	18.6	9.9-27.3	24.0

Note: Negative values were truncated to 0.
+ Values fell outside of prediction intervals.

Table 110. Mountain big sagebrush canopy cover overall model validation results.

Observation	Predicted Value	80% Prediction Interval	Observed Value
SLM #4	11.2	7.4-15.1	11.0
SLM #6	11.4	7.5-15.3	11.3
SLM #14	14.8	10.9-18.7	15.3
MLP #1	9.3	5.4-13.2	12.0
MLP #2	17.3	13.4-21.2	11.6+
MLP #4	2.9	0.0-6.8	2.7
MLP #6	2.1	0.0-6.0	0.5
MLP #21	14.2	10.3-18.1	14.9
MLP #22	13.0	9.2-16.9	19.3+
HC #8	8.3	4.4-12.2	10.1
HC #11	9.1	5.3-13.0	10.1
HC #16	3.5	0.0-7.4	2.5
HC #17	9.4	5.5-13.2	10.3
HC #21	14.8	10.9-18.7	19.4+
HC #25	21.4	17.4-25.4	26.1+

Note: Negative values were truncated to 0.
+Value fell outside of prediction interval.

Table 111. Density of "large" mountain big sagebrush overall model validation results.

Observation	Predicted Value	80% Prediction Interval	Observed Value
SLM #4	54.5	43.6-65.5	50.5
SLM #6	54.1	43.2-65.0	55.8
SLM #14	65.6	54.6-76.6	92.3+
MLP #1	50.2	39.3-61.2	53.2
MLP #2	77.0	65.9-88.1	66.2
MLP #4	23.2	12.2-34.2	19.7
MLP #6	12.5	1.4-23.6	3.5
MLP #21	69.3	58.2-80.3	62.2
MLP #22	61.9	51.0-72.9	71.0
HC #8	42.0	31.0-53.0	47.5
HC #11	48.6	37.7-59.6	58.0
HC #16	24.2	13.2-35.2	13.8
HC #17	47.1	36.1-58.0	44.8
HC #21	65.1	54.2-76.1	70.7
HC #25	87.1	75.8-98.4	96.8

Note: Negative values were truncated to 0.
+Value fell outside of prediction interval.

Table 112. Density of "large" mountain big sagebrush overall model validation results when only Douglas fir cover is used in the model.

Observation	Predicted Value	80% Prediction Interval	Observed Value
SLM #4	54.8	42.8-66.8	50.5
SLM #6	55.3	43.3-67.3	55.8
SLM #14	66.2	54.2-78.2	92.3+
MLP #1	48.2	36.2-60.2	53.2
MLP #2	73.9	61.8-86.0	66.2
MLP #4	21.8	9.7-33.8	19.7
MLP #6	17.2	5.1-29.3	3.5+
MLP #21	64.3	52.3-76.4	62.2
MLP #22	60.7	48.7-72.7	71.0
HC #8	44.5	32.5-56.5	47.5
HC #11	47.6	35.6-59.6	58.0
HC #16	24.7	12.6-36.7	13.8
HC #17	48.3	36.3-60.4	44.8
HC #21	66.2	54.2-78.2	70.7
HC #25	85.8	73.4-98.2	96.8

Note: Negative values were truncated to 0.
+Value fell outside of prediction interval.

Table 113. Grass canopy cover overall model validation results.

Observation	Predicted Value	80% Prediction Interval	Observed Value
SLM #4	17.3	12.1-24.8	16.4
SLM #6	16.0	11.2-23.0	19.3
SLM #14	16.7	11.6-23.9	17.5
MLP #1	15.7	10.9-22.5	12.5
MLP #2	21.1	14.6-30.3	24.4
MLP #4	12.7	8.8-18.2	11.8
MLP #6	8.3	5.7-12.0	10.5
MLP #21	19.4	13.5-27.8	13.8
MLP #22	17.6	12.3-25.2	9.5+
HC #8	15.5	10.8-22.2	30.0+
HC #11	16.7	11.6-23.9	25.2+
HC #16	12.7	8.8-18.2	14.6
HC #17	16.9	11.8-24.3	14.4
HC #21	18.3	12.8-26.3	18.4
HC #25	23.2	16.0-33.4	25.4

Note: Negative values were truncated to 0.
+Value fell outside of prediction interval.

Table 114. Grass canopy cover overall model validation results when only Douglas fir cover is used in the model.

Observation	Predicted Value	80% Prediction Interval	Observed Value
SLM #4	17.4	11.8-25.5	16.4
SLM #6	17.4	11.9-25.6	19.3
SLM #14	19.5	13.3-28.6	17.5
MLP #1	16.2	11.0-23.7	12.5
MLP #2	21.0	14.2-30.8	24.4
MLP #4	11.7	8.0-17.2	11.8
MLP #6	11.0	7.5-16.2	10.5
MLP #21	19.1	13.0-28.1	13.8
MLP #22	18.4	12.6-27.1	9.5+
HC #8	15.5	10.6-22.8	30.0+
HC #11	16.1	11.0-23.6	25.2+
HC #16	12.2	8.3-17.9	14.6
HC #17	16.2	11.1-23.8	14.4
HC #21	19.5	13.3-28.6	18.4
HC #25	23.4	15.8-34.5	25.4

Note: Negative values were truncated to 0.
+Value fell outside of prediction interval.

Table 115. Total herbaceous canopy cover overall model validation results.

Observation	Predicted Value	80% Prediction Interval	Observed Value
SLM #4	33.1	24.2-42.0	31.3
SLM #6	34.6	25.7-43.6	40.5
SLM #14	36.8	27.9-45.8	34.5
MLP #1	32.2	23.3-41.1	29.5
MLP #2	39.2	30.2-48.2	45.3
MLP #4	30.3	21.3-39.2	29.9
MLP #6	28.5	19.5-37.5	40.7+
MLP #21	36.9	28.0-45.9	34.4
MLP #22	36.7	27.7-45.7	28.2
HC #8	36.1	27.2-45.1	49.8+
HC #11	34.3	25.3-43.2	42.4
HC #16	32.8	23.9-41.8	28.4
HC #17	37.5	28.5-46.5	26.4+
HC #21	37.4	28.5-46.4	33.0
HC #25	40.3	31.2-49.3	41.1

Note: Negative values were truncated to 0.
+Value fell outside of prediction interval.

Table 116. Total herbaceous canopy cover overall model validation results when only Douglas fir cover is used in the model.

Observation	Predicted Value	80% Prediction Interval	Observed Value
SLM #4	36.7	27.7-45.6	31.3
SLM #6	36.7	27.7-45.7	40.5
SLM #14	37.5	28.5-46.5	34.5
MLP #1	35.9	26.9-44.9	29.5
MLP #2	37.7	28.7-46.8	45.3
MLP #4	29.6	20.6-38.6	29.9
MLP #6	27.8	18.8-36.8	40.7+
MLP #21	37.4	28.4-46.4	34.4
MLP #22	37.2	28.2-46.2	28.2
HC #8	35.3	26.3-44.3	49.8+
HC #11	35.8	26.8-44.8	42.4
HC #16	30.6	21.6-39.6	28.4
HC #17	35.9	26.9-44.9	26.4+
HC #21	37.5	28.5-46.5	33.0
HC #25	37.7	28.4-46.9	41.1

Note: Negative values were truncated to 0.
+Value fell outside of prediction interval.