Ecological relationships of bitterbrush communities on the Mount Haggin Wildlife Management Area
by Glen Earnest Guenther

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Range Science
Montana State University
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Abstract:
A 2-year investigation was conducted on the Mount Haggin Wildlife Management Area of the ecology of bitterbrush (Purshia tridentata) stands. Eighteen study sites were selected that differed in a wide range of environmental factors. Bitterbrush cover on the 18 sites ranged from 19 to 55% and averaged 35%. A fecal analysis of Rocky Mountain mule deer (Odocoileus hemionus hemionus) pellets, averaged over the 18 sites, revealed that 53% of the deer's winter diet was bitterbrush and 22% was Oregon grape (Berberis repens). Both utilization (P=.0007, r=-.72) and percent bitterbrush in deer's diet (P=.01, r=-.58) were negatively correlated to elevation. The youngest bitterbrush plant from a sample of 360 plants was 7 years old. Five variables entered into a stepwise regression accounted for 79% (R2) of the variation in bitterbrush cover. Five site variables explained 85% (R2) of the variation in mule deer's diet. Utilization of bitterbrush leaders averaged 80% at the 18 sites. Two variables accounted for 69 percent (R2) of the variation in utilization of bitterbrush.

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of the requirements for the degree

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APPROVAL

of a thesis submitted by

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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.

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Signature Glen Guenther

Date 20, November 1989

To my parents, Stanley and Evelyn, who taught me
to appreciate the wonders of nature.

VITA

Glen Earnest Guenther was born in 1961 at Spokane, Washington. He is the fifth of six sons of Stanley and Evelyn (Wiltse) Guenther. He graduated from the University of Puget Sound in 1984 with a bachelor of arts degree in biology. He married Ines Maria Andrade in 1986. He has one son Glen Alberto age 2. His graduate career at Montana State University began in 1987.

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ABSTRACT

A 2-year investigation was conducted on the Mount Haggin Wildlife Management Area of the ecology of bitterbrush (Purshia tridentata) stands. Eighteen study sites were selected that differed in a wide range of environmental factors. Bitterbrush cover on the 18 sites ranged from 19 to 55% and averaged 35%. A fecal analysis of Rocky Mountain mule deer (Odocoileus hemionus hemionus) pellets, averaged over the 18 sites, revealed that 53% of the deer's winter diet was bitterbrush and 22% was Oregon grape (Berberis repens). Both utilization (P=.0007, r=-.72) and percent bitterbrush in deer's diet (P=.01, r=-.58) were negatively correlated to elevation. The youngest bitterbrush plant from a sample of 360 plants was 7 years old. Five variables entered into a stepwise regression accounted for 79% (R^2) of the variation in bitterbrush cover. Five site variables explained 85% (R^2) of the variation in mule deer's diet. Utilization of bitterbrush leaders averaged 80% at the 18 sites. Two variables accounted for 69 percent (R^2) of the variation in utilization of bitterbrush.

INTRODUCTION

Bitterbrush, (Purshia tridentata [Pursh] D. C.), is an important wildlife forage in many parts of the western United States. Many important big game winter ranges have experienced a decline in bitterbrush abundance due to the senescence of old stands and a failure of these stands to reproduce (Winward and Findley 1983). The decline in bitterbrush has been attributed to many factors such as: fire, succession, insects, and overgrazing (Nord 1965). Attempts to improve stands of bitterbrush have had variable results. There are many methods that can be used to improve the vigor of stands of bitterbrush such as: seeding, fire, rotomowing, proper grazing, and the introduction of new varieties. However, if the general ecology of an area is not known beforehand, any of these techniques can lead to a waste of resources and a decline in stand quality.

An understanding of the general ecology of a stand of bitterbrush can help managers avoid costly mistakes and provide them with the necessary tools to accomplish their goals. This investigation quantified the effects of elevation, slope, aspect, soil factors, competing plant species, browsing pressures, and other factors on the production and reproductive success of bitterbrush sites on the Mount Haggin Wildlife Management Area. The Mount Haggin area has a variety of environmental conditions which makes it an ideal area to study environmental effects on bitterbrush. The purpose of this study was to investigate the relationships of environmental factors that affect the success of bitterbrush.

LITERATURE REVIEW

Bitterbrush Distribution and General Ecology

McArthur et al. (1983) state that the genus *Purshia* is recorded from the Pliocene some 10 million years ago. Bitterbrush is distributed from about the 37° N parallel northward into southern British Columbia, mostly west of the continental divide.

Bitterbrush is an important winter forage for wildlife on many ranges in the western United States (Stanton 1959, Nord 1965, Giunta et al. 1978). Several researchers have reported that bitterbrush appears to be declining in large portions of its present range (Holmgren 1956, Hubbard 1957, Winward and Findley 1983).

Loss of bitterbrush has been attributed to several factors. Dasmann and Hjersman (1958) report that bitterbrush has been over utilized by deer and livestock in California. In a ponderosa pine forest, decline in bitterbrush establishment was attributed to a buildup of litter which lessened rodent caching and changed the microenvironment of the soil (Sherman and Chilcote 1972). Initially, logging was found to be harmful to the bitterbrush understory but in 5 years bitterbrush cover, density, and leader length in logged areas was higher than before logging (Edgerton 1983). Jensen and Urness (1979) have found that cold weather can cause severe damage to bitterbrush stands.

Leopold (1950) contends that in many areas bitterbrush stands became established due to overgrazing and now these stands are naturally being replaced by succession. However, Chadwick and Dalke (1965) report that bitterbrush is a climax species on stabilized sand dunes in Fremont

County, Idaho. A ponderosa pine/bitterbrush community in Idaho was determined to be a seral stage of a Douglas fir/snowberry habitat type that was maintained by livestock and wildlife use along with periodic fires (Peek et al. 1978).

Hot south facing slopes have the greatest tendency for supporting stands of bitterbrush (Tew 1983). Nord (1965) has noted that soil characteristics are very important to bitterbrush success. Plants prefer coarse-textured, deep, well-drained soils. Competition from grasses reduces bitterbrush production and growth in California (Hubbard and Sanderson 1961).

Bitterbrush leaves are deciduous and fall in autumn in response to moisture stress (Shaw and Monsen 1983). Kindschy (1982) found a linear relationship between bitterbrush leader production and precipitation. Peak yields of bitterbrush plants in Oregon occur when the plants are approximately 60 to 70 years old (McConnell and Smith 1977).

Winward and Findley (1983) report that the size of bitterbrush plants ranges from low prostrate shrubs to 13 foot tall shrubs. They also state that all bitterbrush ecotypes retain their characteristics in greenhouse situations.

Big Game and Livestock Use

Bitterbrush was the most abundant forage in the stomach of Rocky Mountain mule deer(*Odocoileus hemionus hemionus*) collected in the sagebrush-bitterbrush zone of the Bridger Mountains of Montana during the fall months with use declining over the winter (Wilkins 1957). While usually considered a winter forage for mule deer, bitterbrush

utilization has been recorded for elk (Cervus elaphus) (Cliff 1939), pronghorn antelope (Antilocapra americana) (Ferrel and Leach 1950), bighorn sheep (Ovis canadensis) (McCullough and Schneegas 1966), and moose (Alces alces) (Harry 1957). Burrel (1982) has indicated, with a preference index, that unavailability of bitterbrush forage is the cause of decreased bitterbrush use by mule deer in late winter in eastern Washington. Cliff (1939) found that bitterbrush was the most highly used winter forage for both deer and elk in the Blue Mountains of Oregon. The time of greatest diet overlap for mule deer and elk in northcentral Montana was during the winter (Kasworm et al. 1984).

There was a strong negative correlation between fawn survival and bitterbrush utilization in California (Dasmtann and Blaisdell 1954). In Idaho, peak bitterbrush use by mule deer occurred in January (Scholten 1983). Ferguson and Medin (1983) concluded from a 23 year study that mule deer use was not a significant factor in vegetational change. During the length of their study bitterbrush density decreased while canopy cover increased. Overutilization of bitterbrush on winter range by mule deer has been reported in Oregon (Edwards 1942), Nevada (Aldous 1945), and California (Dasmann 1949).

Recent studies have shown that in some instances livestock use on bitterbrush winter ranges is compatible with maintaining bitterbrush production. In northern Utah, pastures grazed in the spring and summer by horses showed an increase in seasonal bitterbrush twig production (Reiner and Urness 1982), but no use of bitterbrush by the horses was noted. Bitterbrush plants increased production when 100% of current year's annual growth was browsed in the fall by goats. (Urness and

Jensen 1983). However, Hormay (1943) states that no more than 60% of the current year's growth should be utilized to keep plants in good condition. Garrison (1953) concludes from his clipping studies that maximum use on good bitterbrush sites should be 60 to 65% and use should not exceed 50% on poorer sites. Jensen et al. (1972) assert that no regrowth occurs in plants browsed after mid-July in northern Utah.

Julander (1958) states that in Utah, sheep, mule deer and cattle all utilize bitterbrush. Smith et al. (1979) indicated that quality of mule deer forage was not detrimentally affected when sheep spring grazed a pasture and they found that current year's growth of bitterbrush leaders was actually greater in grazed pastures than non-grazed pastures. Neal (1982) found that heavily grazed spring pastures had significantly more seedlings than control pastures and he recommends heavy spring grazing every 15 to 20 years to maintain a stand of young vigorous browse plants. He also states that bitterbrush seedlings damaged by frost and insects can often negate any effect of grazing treatments.

Skovlin et al. (1968) found that moderate cattle grazing had little or no effect on mule deer bitterbrush use in the Blue Mountains of Oregon and Washington. Urness (1982) showed that spring grazing by sheep and cattle is compatible with winter mule deer use of bitterbrush as long as livestock are removed before current year twig growth begins on the bitterbrush plants. Summer grazing by livestock is often detrimental to bitterbrush plants. Martinson (1960) showed that summer use of bitterbrush at even moderate levels can decrease the vigor of an individual plant. Dasmann (1949) found that bitterbrush was one of the

few forages that mule deer and cattle compete for in his California study site.

Rodent and Insect Use

Hormay (1943) states that most plants in bitterbrush stands become established from rodent seed caches. Bitterbrush seeds are highly desired by rodents. Kelrick and Macmahon (1985) reported that bitterbrush seeds have 5598 calories/g and he theorizes that rodents select bitterbrush seeds due to their high carbohydrate content. However, Jenkins (1988) states that deer mice, pocket mice, and kangaroo rats only eat the embryo of bitterbrush seeds not the hull. Soluble carbohydrate content for whole seed is 59% but only 14% for just the embryo. The protein content of bitterbrush embryos is 39%. Gysel (1960) found large stands of bitterbrush in Rocky Mountain National Park with 30 to 50% of the plants dead due to girdling by mice.

Furniss (1983) found that 75% of the seeds in his study were damaged by insects. He states that bitterbrush is host to over 100 phytophagous insects. Edwards (1942) states that healthy plants not subjected to overutilization by browsers can rapidly recover from insect damage.

Nutrition

Bitterbrush has long been recognized as an important winter forage for wildlife. Welch et al. (1983) averaged the nutritional value of bitterbrush plants in the winter from several sources. They found an average of 47.5% for nutrient digestibility, an in vitro digestibility of 25.1%, crude protein levels of 7.9%, and phosphorus levels of .13%.

Bitterbrush leaves collected in September had a total nonstructural carbohydrate concentration of 18.4% and a total organic nitrogen concentration of 1.8% (Tiedemann et al. 1984). McConnell and Garrison (1966) report a fluctuation of total available carbohydrates in crown material ranging from a low of 4.8% during full flower to a high of 10.2% at leaf fall. They found a similar fluctuation in root material. Taproots appear to be a more important storage organ of nonstructural carbohydrates than the basal stem in bitterbrush plants (Menke and Trlica 1981).

Fire Ecology

Several methods have been tried to improve bitterbrush habitat with variable result. Probably the most controversial improvement technique is fire. Hobbs and Schimel (1984) have demonstrated that mountain shrub communities with bitterbrush had an increased mineralization rate 1 year after a burn. However, they recommend that fires not be repeated frequently due to the sterilizing effect of fires and a poor understanding of fire ecology.

Blaisdell and Mueggler (1956) have noted that sprouting of bitterbrush plants after a fire is common in Idaho. However, Murray (1983) found that after 30 years, yields on burned bitterbrush plots were 1/2 of unburned plots in Idaho. Wagstaff (1980) indicated that there was no evidence of sprouting or new seedlings after a summer fire in Utah. Five years after a fire in central Washington bitterbrush habitat there was no sign of re-colonization of bitterbrush by seedling or sprouting (Rickard and Sauer 1982). Bunting et al. (1985) report

that decumbent forms of bitterbrush sprout more frequently than upright forms.

Martin (1983) says that regeneration of bitterbrush stands after fire is related to the number of seasons since burning, site quality, and amount of livestock grazing. He found that seedlings became established quickly in prescribed burns in ponderosa pine/bitterbrush communities. Driver (1983) found that more plants sprouted in spring burns than fall burns and that burning when soil moisture was high resulted in sprouting while hot burns resulted in seedling establishment. However, Clark et al. (1982) showed that artificially watering burnt plants did not reduce mortality. Rice (1983) attributes bitterbrush's sprouting ability after a fire to fire intensity, genetic capability, soil moisture and type, and season of burn.

<u>Stand Regeneration</u>

Jones (1983) demonstrated that rotomowing greatly increased production of decadent bitterbrush stands. He also reported that deer overused the rotomowed area. Topping bitterbrush plants in Idaho produced 9 times the current year's growth of control plants (Ferguson and Basile 1966).

Considerable research has been directed towards bitterbrush seedlings. Leckenby and Toweill (1983) report that seedings have better establishment when planted in the fall. Carpenter (1983) states that the best time for planting seedlings is early spring. Bitterbrush seedlings do not compete very well against annuals especially cheatgrass (<u>Bromus</u> <u>tectorum</u>) (Holmgren 1956). Hubbard (1957) demonstrated that seedbed preparation can greatly increase bitterbrush seedling survival.

Seedlings in Oregon emerge at the same time that established plants start to leaf (Stanton 1959). Bitterbrush seedlings protected from browsing were significantly taller and had more crown cover than browsed seedlings (Dealy 1970). Plants in an exclosure were twice as big as plants outside that were subjected to light to moderate grazing (Monsen and Shaw 1983). Giunta et al. (1978) concluded that the factors most important in stand regeneration are: a large seed crop, a properly balanced rodent population for seed dispersal, favorable winter conditions to ensure emergence of sprouts at optimum time, and favorable spring conditions suitable for seedling survival.

Factors associated with the seed coat or pericarp of bitterbrush seeds inhibit germination of bitterbrush seeds. Dormancy can be broken by cool-moist stratification (Young and Evans 1976) and also by hydrogen peroxide or thiourea treatment (Everett and Meeuwig 1975). Usually 5 to 20% of a seed lot will germinate without any enhancement (Young and Evans 1983).

Measurements

Dean et al. (1981) formed an equation to predict bitterbrush annual production (using maximum diameter, crown denseness, crown depth and shrub height) that explained 84% of the variation in annual bitterbrush production. A sufficient relationship exists among the diameter, length, and weight of bitterbrush twigs that utilization of plants can be estimated by measuring diameters of browsed twigs (Basile and Hutchings 1966) and (Jensen and Urness 1981). McConnell and Smith (1963) state that age of bitterbrush can be estimated from stem diameter. However, the stem size is site-specific and the technique is

less reliable as plants become older. They suggest that a more reliable method of determining the age of bitterbrush plants is counting annual rings in the stem.

STUDY AREA DESCRIPTION

Location

The study area is located in the northern portion of the Mount Haggin Wildlife Management Area, approximately 10 miles southeast of Anaconda, Montana. The study area is located between the Continental Divide and the Anaconda-Pintler Mountain Range. The 23,000 hectare Wildlife Management Area is owned and managed by the Montana Department of Fish, Wildlife, and Parks who purchased the land in 1976 (Frisina 1987). The 18 sites studied in this investigation are all located in the northern end of the Wildlife Management Area in the southern half of T. 4 N., R. 10-11 W. and in T. 3 N., R. 10 W. (Figure 1). The study area is bounded by State Highway 274 on the western edge, the northern boundary of the Mount Haggin Wildlife Management Area to the north, German Gulch on the eastern edge. The southern edge is the Deerlodge National Forest boundary.

Topography, Geology, and Soils

Topography of the area is characterized by mountainous slopes. The study sites are located near the Continental Divide east of the Anaconda range and are along the western edge of the Boulder batholith (Noel 1956). Noel states that the intrusion of the batholith probably took place near the end of the Laramide revolution. The Anaconda mountain range was formed from metamorphosed rocks from the Belt series and igneous rocks of the Boulder batholith. The severe folding and thrusting of these mountains occurred during the Laramide revolution. The study site is in the western part of the thrust belt in Montana.

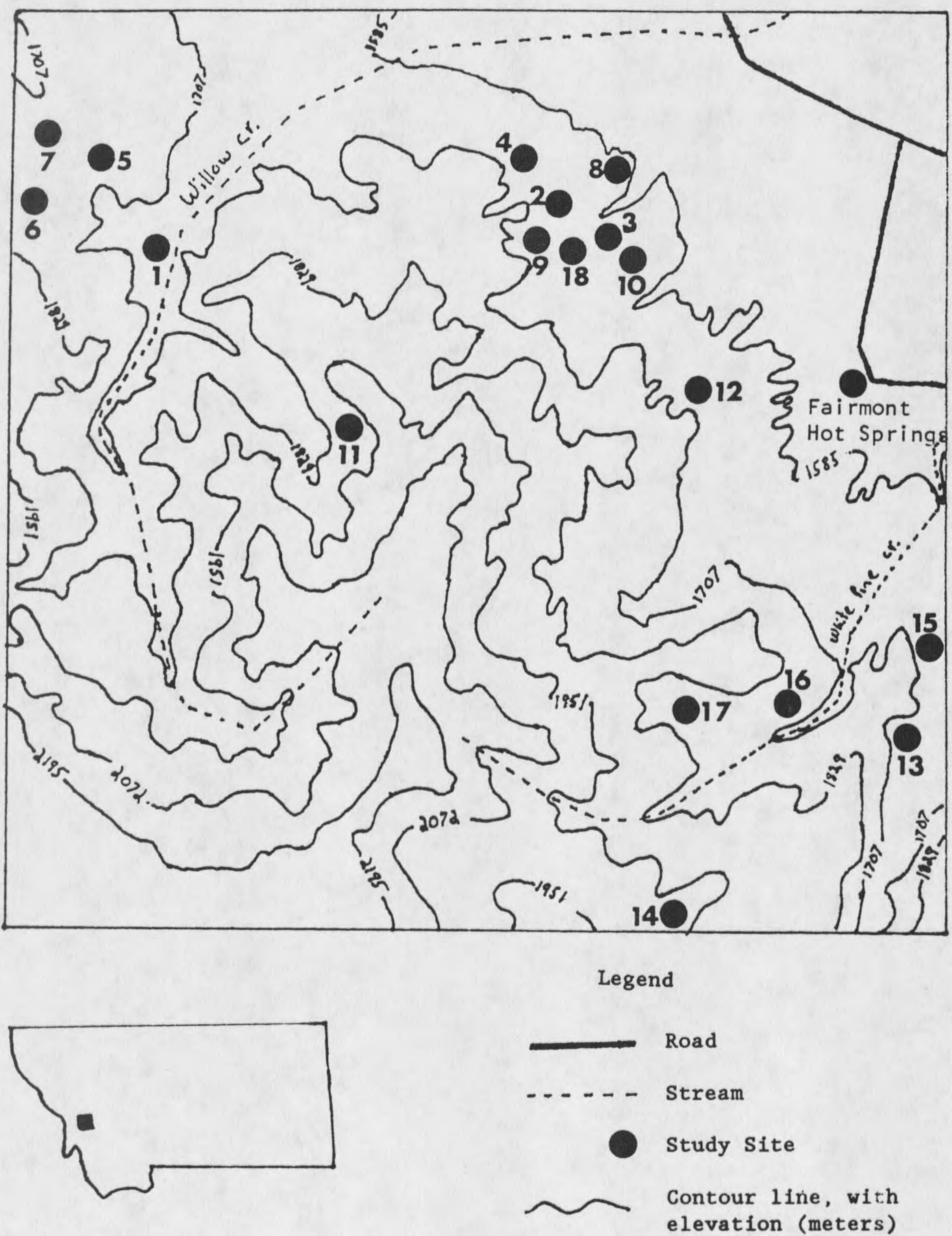

Figure 1. Map of study site area showing topographic features with elevation expressed in meters.

Parent materials in the area are mostly volcanic rocks, granodiorite, and quartzite (Iagmin 1972). Iagmin (1972) reports that late Cretaceous or early Paleocene igneous intrusions, consisting mostly of granodiorite dominate the area. Elevation of the 18 study sites ranges from 1580 m to 1940 m. The soils in the area are from granitic residium and colluvium. Soils are mostly mollisolls with some alfisols at the higher elevations and some inceptisols on the steeper slopes (SCS unpublished). A large portion of the soils in the area has been classified as loamy skeletal, mixed typic argiborolls.

Climate

A weather station located at Anaconda reports average yearly precipitation of 340 mm, with 47% falling in the months of April through July (NOOA 1989). The month of June is the wettest month of the year, averaging 70 mm of precipitation, while February is the driest month with an average of 16 mm. The weather station reports a mean annual temperature of 3.8° C. During 1988 the Anaconda weather station received only 230 mm of precipitation; 350 mm came in 1987. In 1988 there were 73 frost free days recorded at the Anaconda station. The highest temperature recorded for the year was 35° C and the low for the year was -25° C.

Animals

Frisina (1986) reports that the Mount Haggin area is important year-round range for several big game species, mule deer, Rocky Mountain elk, and moose. Less abundant big game species found in the area include the black bear (*Ursus americanus*), pronghorn antelope, and whitetail deer (*Odocoileus virginianus*). Two common nongame species in

the area are sandhill cranes (Grus canadensis) and beaver (Castor canadensis). In 1980 the area provided 17,535 man-days of elk hunting and 15,561 man-days of deer hunting (Frisina 1982). In spite of the heavy hunting pressure the deer and elk populations have continued to increase.

The Mount Haggin area has been intensively grazed in the past by domestic sheep, cattle, mules, and horses. Past improper grazing by livestock has contributed to some of the low range condition evident in portions of the management area. A rest rotation grazing system for cattle has helped to improve the range condition of land south of the bitterbrush winter range (Frisina 1986).

Vegetation

A large number of plant species occur in the study area (Appendix A). Vegetation in the study area is predominantly bitterbrush grassland although many of the sites have been heavily invaded by spotted knapweed (Centaurea maculosa). Mueggler and Stewart (1980) recognize 3 bitterbrush habitat types in Montana. Two of these occur in the study area - Bitterbrush/rough fescue (Festuca scabrella) and bitterbrush/bluebunch wheatgrass (Agropyron spicatum). Sites 5, 6, and 7 do not seem to fit into the habitat types of Mueggler and Stewart since they have no rough fescue or bluebunch wheatgrass cover. It is possible that there are some habitat types in the area that have not yet been described. Also much of the vegetation of the Mount Haggin area is in early successional stages due to the combined effects of improper grazing and the Anaconda smelter. The loss of dominant vegetation in the area makes it difficult to predict the habitat type.

Other common shrubs in the area include snowberry (Symphoricarpos albus) and Oregon grape (Berberis repens). Common grasses are Kentucky bluegrass (Poa pratensis), basin wildrye (Elymus cinereus), needleandthread (Stipa comata), rough fescue, bluebunch wheatgrass, and green needlegrass (Stipa viridula). The most abundant forbs are whitetop (Cardaria draba), spotted knapweed, long-leaved aster (Aster chilensis), and spreading dogbane (Apocynum androsaemifolium). Some sites are presently being invaded by Douglas fir (Pseudotsuga menziesii).

METHODS

Vegetation Measurements

Eighteen sites were selected for the study and the same measurements were made at each site. Sites were chosen to represent the variation of slope, aspect, elevation, and soil texture that are present on the Mount Haggin Wildlife Management Area. Sites were also selected to illustrate the variation of bitterbrush in cover, size, density, and diversity of associated species. Measurements at the sites used in this study began in June of 1988. Final measurements were made in the area in June of 1989.

At each site a line was placed perpendicular to the slope and the beginning of 5 lines each of 15.24 m (50 feet) were permanently marked every 3 m with a section of rebar. All 5 lines ran parallel to each other and to the contour of the site (Figure 2). The lines were used to orient plots to measure plant cover, bitterbrush density, and deer and elk pellet density.

On each line, shrub canopy cover was measured using a plumb bob by the line interception method (Canfield 1941). In addition to live shrub cover dead bitterbrush cover also was measured. Discontinuities in the cover greater than 8 cm were recorded as changes in cover.

Coverage of grasses and forbs was estimated by the method detailed by Daubenmire (1959). Along each transect line a 2x5 dm sampling frame was placed every 1.5 m (total of 10 per line). Plant cover of all species within the quadrat was categorized into 1 of 6 canopy coverage classes after Daubenmire (1959). In addition to live plants, litter,

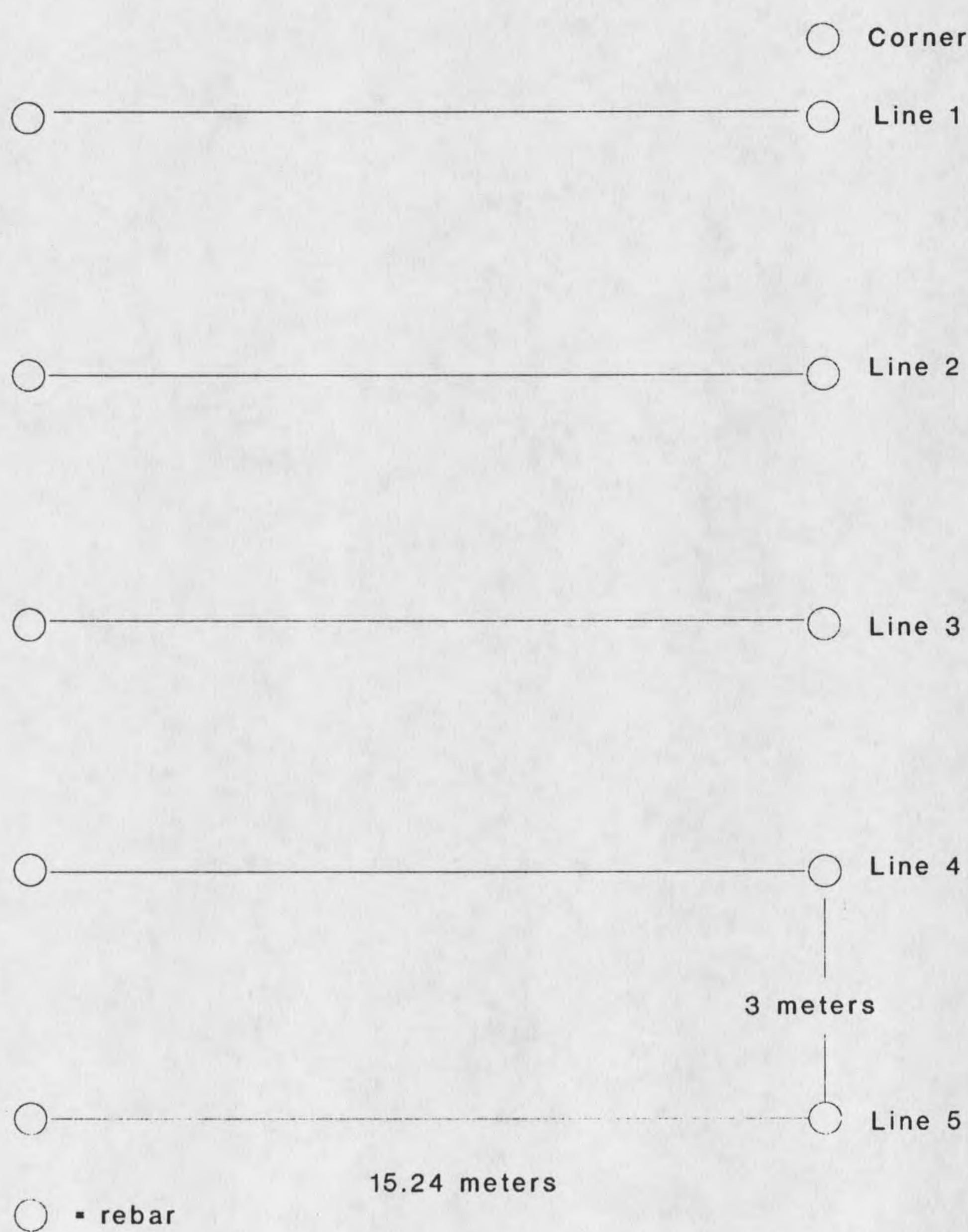

Figure 2. Transects for vegetation analysis.

rock, and bare ground cover were estimated in each Daubenmire quadrat and placed into a canopy coverage class.

Density of bitterbrush plants was measured along each line by counting all of the bitterbrush plants that were rooted within 1 meter of the lower and upper side of each transect line. The volume of each plant rooted within 1 meter of the transect line was estimated by using the longest dimension of the plant, the greatest width perpendicular to the length, and the plant's height, measured as the distance from the base of the main stem to the top of the crown.

Animal Use Measurements

Deer and elk presence were estimated by counting pellet groups in a 2-meter belt transect centered on each base line transect. The majority of any pellet group had to be inside the belt transect to be counted. Only pellets determined to have been deposited the previous winter were counted. Approximate pellet age was determined by degree of weathering as suggested by color and sheen.

Utilization of bitterbrush current year's growth by mule deer and elk was estimated by tagging 50 branches at each site in August after current year's growth was completed. Each branch held approximately 4 new leaders and each leader was measured to the nearest centimeter. The following June the tags were relocated and the lengths of the leaders were remeasured. The portion removed was considered the percent utilized.

Samples from deer pellet groups from each of the 18 sites were sent to the Colorado State Composition Analysis Laboratory for examination of deer diet. At each site 2 pellets were selected from 10 different

pellet groups and were mixed together in 1 sample of 20 pellets. From this sample mean composition of plants at each site was determined from 5 slides of 20 fields each.

Site Characteristics

The aspect of each site was measured using a compass. Percent slope at each site was determined by using a level to measure the decrease in height 15.2 m (50 feet) down slope. The 15.2 m was measured as a horizontal distance not as distance along the ground. The slope was calculated by dividing the change in elevation (height) by the distance traveled (15.2 m). Soil texture, percent organic matter, electrical conductivity, and pH at each site were determined from a composite of soils taken from a depth of 15 cm from 3 separate soil pits at each site. Soil analysis was done by the Montana State University Soils Laboratory. Bouyucous mechanical analysis was used to determine soil texture. Electrical conductivity and pH were determined in 1 part soil to 2 part water extractions.

Seed Germination

Seeds of bitterbrush were collected from several sites (2, 3, 6, 8, and 10) and all of the seeds were mixed together. Seeds were then randomly selected for the germination trial. Four groups of 50 seeds each were placed on germination blotters in petri dishes. The seeds were cold-stratified for 16 days at 5°C. The seeds were then placed in a germinator at a temperature of 15°C for 4 weeks. Seeds were considered germinated when the radical emerged at least 5 mm.

Data Compilation

Line intercept measurements were calculated as a percent of the total line. All bitterbrush area measurements were converted to units per m^2. Canopy cover and volume were calculated by the methods suggested by Rittenhouse and Sneva (1977). Area was determined by the formula $A = (L_1/2)(L_2/2)\pi$, where L_1 is the longest canopy measurement and L_2 is the widest canopy measurement perpendicular to the longest canopy measurement. Shrub volume was computed by using the formula $V = 4/6(H/2)A$, where H is the plant height and A is the area calculated above.

Statistical Analysis

Statistical analysis was done with the SAS statistical package (SAS Institute Inc. 1988). Measurements from the 5 transect lines at each of the 18 sites were averaged to get a site average that was used for correlation and regression. The regression procedure used was forward selection step wise. In forward selection the procedure begins with no variables in the model and then adds variables 1 by 1 to the model. At each step the variable added is the 1 that maximizes the fit of the model. To be added to the model each variable had to have a significance level $P \leq 0.15$.

A large number of variables in a regression equation can bias the statistics and artificially inflate the R^2. To ensure that the statistics were not biased the number of variables allowed to be selected for the equation were kept at 9 or less. The reason 9 was selected was that this is one half of the number of sites (observations) in this study. Analysis of both linear and quadratic functions were

performed. This regression procedure fits linear regression models by the least squares method.

The results of the regression models in this study should be interpreted with caution. In observational studies such as this there can be considerable difficulty in interpreting the results. The regression models are therefore presented as merely useful approximations that need to be field tested in the future to determine their usefulness.

Pearson product-moment correlations were used to highlight relationships between variables and to select variables to be used in the regression equations. Correlation measures the linear relationship between 2 variables and does not imply a cause and effect. The sample correlations obtained in this study are used to estimate the true correlations that exist between the variables studied at the Mount Haggin Wildlife Management Area.

RESULTS AND DISCUSSION

Edaphic Factors

Soil characteristics of the 18 study sites (Table 1) were typical of previously reported bitterbrush habitat (Giunta et al. 1978, Nord 1965). Soil pH varied from 5.2 to 6.7. Giunta et al. (1978) report that bitterbrush normally occurs in soils that are neutral to moderately acidic. Electrical conductivity ranged from 0.02 mmhos/cm to 0.09 mmhos/cm. The low salinity of the soils in this study is consistent with previous investigations (Nord 1965).

Table 1. Soil pH, electrical conductivity, percent organic matter, and textural classes at the 18 study sites at the Mount Haggin Wildlife Management Area.

Site	pH	Ec[1]	% OM	% Sand	% Silt	% Clay	Textural Class
1	6.4	0.06	2.51	68	15	17	Sandy Loam
2	5.8	0.04	1.40	65	15	20	Sandy Loam
3	5.5	0.04	1.81	68	16	16	Sandy Loam
4	5.9	0.04	2.43	56	16	28	Sandy Clay Loam
5	5.2	0.09	3.55	65	18	17	Sandy Loam
6	6.1	0.08	3.44	65	17	18	Sandy Loam
7	5.4	0.06	1.60	65	15	20	Sandy Loam
8	6.0	0.02	0.79	77	12	11	Sandy Loam
9	6.3	0.03	1.33	71	16	13	Sandy Loam
10	5.7	0.03	0.96	72	18	10	Sandy Loam
11	6.4	0.07	3.44	57	20	23	Sandy Clay Loam
12	5.7	0.05	3.14	71	16	13	Sandy Loam
13	6.0	0.08	2.77	48	16	36	Sandy Clay
14	6.7	0.06	2.77	69	15	16	Sandy Loam
15	6.7	0.04	2.11	53	26	21	Sandy Clay Loam
16	5.6	0.06	3.00	41	25	34	Clay Loam
17	6.2	0.06	4.42	53	20	27	Sandy Clay Loam
18	5.6	0.03	1.88	69	15	16	Sandy Loam
Mean	6.0	0.05	2.41	63	17	20	

[1] (mmhos/cm)

Table 2 is a correlation matrix of the variables measured in the study area. All correlations in this text refer to this table. Electrical conductivity was positively correlated to elevation (P=.008, r=.72). This correlation demonstrates that electrical conductivity of the soil tends to become larger as the elevation increases. This positive association is probably related to the fact that the organic matter in the soil is also significantly positively correlated to elevation (P=.01, r=.57). Percent organic matter in soil samples varied from 0.79 to 4.42. Percent sand in soil samples ranged from 41 to 77. At the majority of the sites, soil texture was classified as sandy loam (USDA 1951). The coarse texture of the soil observed in this study is also typical of bitterbrush habitat (Nord 1965).

Elevation, Slope, and Aspect

Bitterbrush occupies a fairly narrow band of elevation at Mount Haggin. Site elevation ranged from 1577 m to 1943 m (Table 3). The elevation extremes used in this study are very close to the upper and lower limits of the elevational range of bitterbrush occurring in the entire Mount Haggin area. Percent slope of the 18 sites varied from 9 to 49 (Table 3). The fairly steep slopes reflect the general mountainous physiography of the study area.

The positive correlation of slope to elevation (P=.08, r=.42) found at the 18 sites may show that at higher elevation bitterbrush grows better where the slope is steeper because the plants are exposed to more sunlight. Aspect of sites ranged from 65-260° (Table 3). Almost all bitterbrush in the Mount Haggin area was found on east to south facing slopes. Little bitterbrush was found growing on west facing slopes and

Table 2. Correlation matrix of site variables at the Mount Haggin Wildlife Management Area.

	Putr Cover	Putr Height	Dead/ total	Number species	Putr Dead	Tot. cover	Litter	Bare ground	Tot. shrub	nonPutr Shrub	Per. forb	Per. grass	Knap-weed	Putr size	Putr density	Deer pellets	Elk Pellets
Bitterbrush cover	1.00	0.56a	-0.49b	-0.21	0.04	0.20	0.43c	0.01	0.48b	-0.47b	0.03	-0.27	0.07	0.55b	-0.19	0.37	-0.41c
Height	0.56a	1.00	-0.40c	0.06	-0.14	0.39	0.26	-0.18	0.30	-0.26	0.31	-0.10	0.20	0.76a	-0.54b	0.23	-0.50b
Dead bitterbrush/tot	-0.49b	-0.40c	1.00	-0.22	0.84a	-0.12	0.29	-0.07	0.02	0.50b	0.10	-0.22	0.17	-0.42c	0.36	0.26	0.17
Number species	-0.21	0.06	-0.22	1.00	-0.44c	0.59a	-0.48b	-0.51b	-0.15	0.10	-0.08	0.87a	-0.57a	-0.33	0.14	-0.59a	0.34
Dead bitterbrush	0.04	-0.14	0.84a	-0.44c	1.00	-0.13	0.60a	-0.02	0.24	0.24	0.11	-0.46b	0.25	-0.16	0.31	0.54b	-0.08
Tot. plant cover	0.20	0.39	-0.12	0.59a	-0.13	1.00	0.13	-0.69a	0.51b	0.21	0.10	0.50b	-0.29	0.17	0.02	-0.14	0.23
Litter	0.43c	0.26	0.29	-0.48b	0.60a	0.13	1.00	-0.14	0.58a	0.13	0.00	-0.47b	0.20	0.43c	-0.22	0.69a	-0.21
Bare ground	0.01	-0.18	-0.07	-0.51b	-0.02	-0.69a	-0.14	1.00	-0.17	-0.29	-0.07	-0.56a	0.23	-0.00	-0.05	0.16	-0.41c
Total shrub	0.48b	0.30	0.02	-0.15	0.24	0.51b	0.58a	-0.17	1.00	0.45c	-0.39	-0.17	-0.27	0.33	-0.04	0.19	-0.25
Nonbitterbrush shrub	-0.47b	-0.26	0.50b	0.10	0.24	0.21	0.13	-0.29	0.45c	1.00	-0.54b	0.19	-0.47b	-0.31	0.11	-0.29	0.11
Perennial forb	0.03	0.31	0.10	-0.08	0.11	0.10	0.00	-0.07	-0.39	-0.54b	1.00	-0.26	0.82a	0.30	-0.09	0.48b	-0.06
Perennial grass	-0.27	-0.10	-0.22	0.87a	-0.46b	0.50b	-0.47b	-0.56a	-0.17	0.19	-0.26	1.00	-0.71a	-0.31	0.08	-0.74a	0.60a
Knapweed	0.07	0.20	0.17	-0.57a	0.25	-0.29	0.20	0.23	-0.27	-0.47b	0.82a	-0.71a	1.00	0.40c	-0.17	0.71a	-0.29
Bitterbrush size	0.55b	0.76a	-0.42c	-0.33	-0.16	0.17	0.43c	-0.00	0.33	-0.31	0.30	-0.31	0.40c	1.00	-0.71a	0.49b	-0.41c
Bitterbrush density	-0.19	-0.54b	0.36	0.14	0.31	0.02	-0.22	-0.05	-0.04	0.11	-0.09	0.08	-0.17	-0.71a	1.00	-0.22	0.38
Deer pellets	0.37	0.23	0.26	-0.59a	0.54b	-0.14	0.69a	0.16	0.19	-0.29	0.48b	-0.74a	0.71a	0.49b	-0.22	1.00	-0.46b
Elk pellets	-0.41c	-0.50b	0.17	0.34	-0.08	0.23	-0.21	-0.41c	-0.25	0.11	-0.06	0.60a	-0.29	-0.41c	0.38	-0.46b	1.00
Elevation	-0.38	-0.37	0.06	0.33	-0.19	0.19	-0.30	-0.29	-0.10	0.33	-0.33	0.68a	-0.57a	-0.35	0.33	-0.70a	0.76a
Slope	-0.04	0.07	-0.27	0.17	-0.37	-0.03	-0.15	0.23	0.07	0.18	-0.33	0.24	-0.42c	0.04	-0.08	-0.39	-0.03
Aspect	0.48b	0.38	-0.45c	0.18	-0.30	0.31	-0.13	-0.07	0.17	-0.28	0.10	0.09	-0.07	0.19	-0.17	-0.16	-0.12
Tot. Bitterbrush vol	0.80a	0.77a	-0.29	-0.31	0.13	0.31	0.61a	-0.08	0.55b	-0.31	0.26	-0.40c	0.34	0.86a	-0.38	0.59a	-0.42c
Ave. Bitterbrush vol	0.40c	0.65a	-0.02	-0.42c	0.23	0.02	0.32	0.04	0.07	-0.41c	0.68a	-0.52b	0.72a	0.73a	-0.28	0.66a	-0.46c
Average age	0.16	0.10	0.23	-0.34	0.39	-0.14	0.17	0.41c	0.41c	0.22	-0.35	-0.30	-0.19	-0.06	0.28	-0.03	-0.29
Twig length	0.43c	0.41c	0.02	0.24	0.18	0.64a	0.46c	-0.59a	0.53b	0.18	0.07	0.06	-0.04	0.20	-0.12	0.22	-0.15
pH	-0.28	-0.13	0.09	0.45c	-0.05	0.35	0.01	-0.39	0.10	0.27	-0.19	0.37	-0.39	-0.33	0.36	-0.25	0.36
Electrical cond.	-0.32	-0.34	-0.03	0.33	-0.27	0.16	-0.37	-0.29	-0.07	0.39	-0.42c	0.62a	-0.59a	-0.40c	0.15	-0.72a	0.42c
Sand	0.20	-0.11	0.18	-0.71a	0.35	-0.30	0.39	0.48b	0.18	-0.23	0.16	-0.71a	0.49b	0.13	0.18	0.43c	-0.01
Silt	-0.12	0.26	-0.31	0.49b	-0.42c	0.08	-0.13	-0.31	-0.24	0.08	-0.10	0.47b	-0.30	0.11	-0.32	-0.23	-0.13
Clay	-0.20	0.01	-0.08	0.68a	-0.25	0.35	-0.44c	-0.47b	-0.12	0.26	-0.16	0.69a	-0.49b	-0.22	-0.08	-0.44c	0.08
Organic matter	-0.44c	-0.18	0.03	0.54b	-0.27	0.28	-0.26	-0.54b	-0.15	0.39	-0.27	0.71a	-0.50b	-0.30	-0.03	-0.63a	0.50b
Utilization	0.33	0.39	0.15	-0.62a	0.41c	-0.30	0.45c	0.35	0.16	-0.22	0.32	-0.80a	0.58a	0.37	-0.24	0.66a	-0.71a
%Bitterbrush in diet	0.29	0.24	0.12	0.00	0.36	-0.03	0.19	0.09	-0.06	-0.40c	0.37	-0.32	0.37	0.07	0.09	0.48b	-0.22

a - (P<=0.01)
b - (P<=0.05)
c - (P<=0.10)

Table 2. (Continued).

	Elev-tion	Slope	Aspect	Total volume	Ave. volume	Ave. age	Twig length	pH	EC	SAND	SILT	CLAY	OM	Utili-zation	%Putr in diet
Bitterbrush cover	-0.38	-0.04	0.48b	0.80a	0.40c	0.16	0.43c	-0.28	-0.32	0.20	-0.12	-0.20	-0.44c	0.33	0.29
Height	-0.37	0.07	0.38	0.77a	0.65a	0.10	0.41c	-0.13	-0.34	-0.11	0.26	0.01	-0.18	0.39	0.24
Dead bitterbrush/tot	0.06	-0.27	-0.45c	-0.29	-0.02	0.23	0.02	0.09	-0.03	0.18	-0.31	-0.08	0.03	0.15	0.12
Number species	0.33	0.17	0.18	-0.31	-0.42c	-0.34	0.24	0.45c	0.33	-0.71a	0.49b	0.68a	0.54b	-0.62a	0.00
Dead bitterbrush	-0.19	-0.37	-0.30	0.13	0.23	0.39	0.18	-0.05	-0.27	0.35	-0.42c	-0.25	-0.27	0.41c	0.36
Tot. plant cover	0.19	-0.03	0.31	0.31	0.02	-0.14	0.64a	0.35	0.16	-0.30	0.08	0.35	0.28	-0.30	-0.03
Litter	-0.30	-0.15	-0.13	0.61a	0.32	0.17	0.46c	0.01	-0.37	0.39	-0.13	-0.44c	-0.26	0.45c	0.19
Bare ground	-0.29	0.23	-0.07	-0.08	0.04	0.41c	-0.59a	-0.39	-0.29	0.48b	-0.31	-0.47b	-0.54b	0.35	0.09
Total shrub	-0.10	0.07	0.17	0.55b	0.07	0.41c	0.53b	0.10	-0.07	0.18	-0.24	-0.12	-0.15	0.16	-0.06
Nonbitterbrush shrub	0.33	0.18	-0.28	-0.31	-0.41c	0.22	0.18	0.27	0.39	-0.23	0.08	0.26	0.39	-0.22	-0.40c
Perennial forb	-0.33	-0.33	0.10	0.26	0.68a	-0.35	0.07	-0.19	-0.42c	0.16	-0.10	-0.16	-0.27	0.32	0.37
Perennial grass	0.68a	0.24	0.09	-0.40c	-0.52b	-0.30	0.06	0.37	0.62a	-0.71a	0.47b	0.69a	0.71a	-0.80a	-0.32
Knapweed	-0.57a	-0.42c	-0.07	0.34	0.72a	-0.19	-0.04	-0.39	-0.59a	0.49b	-0.30	-0.49b	-0.50b	0.58a	0.37
Bitterbrush size	-0.35	0.04	0.19	0.86a	0.73a	-0.06	0.20	-0.33	-0.40c	0.13	0.11	-0.22	-0.30	0.37	0.07
Bitterbrush density	0.33	-0.08	-0.17	-0.38	-0.28	0.28	-0.12	0.36	0.15	0.18	-0.32	-0.08	-0.03	-0.24	0.09
Deer pellets	-0.70a	-0.39	-0.16	0.59a	0.66a	-0.03	0.22	-0.25	-0.72a	0.43c	-0.23	-0.44c	-0.63a	0.66a	0.48b
Elk pellets	0.76a	-0.03	-0.12	-0.42c	-0.46c	-0.29	-0.15	0.36	0.42c	-0.01	-0.13	0.08	0.50b	-0.71a	-0.22
Elevation	1.00	0.42c	-0.14	-0.42c	-0.44c	0.06	-0.29	0.26	0.72a	-0.22	0.15	0.22	0.57a	-0.72a	-0.58a
Slope	0.42c	1.00	0.26	-0.06	-0.16	0.17	-0.22	0.21	0.16	-0.09	0.45c	-0.10	0.03	-0.18	-0.44c
Aspect	-0.14	0.26	1.00	0.26	0.05	-0.10	0.38	0.08	-0.07	0.11	-0.11	-0.09	-0.11	0.14	-0.05
Tot. Bitterbrush vol	-0.42c	-0.06	0.26	1.00	0.73a	0.13	0.42c	-0.22	-0.54b	0.28	-0.09	-0.31	-0.49b	0.42c	0.35
Ave. Bitterbrush vol	-0.44c	-0.16	0.05	0.73a	1.00	0.06	0.06	-0.31	-0.54b	0.21	-0.03	-0.26	-0.51b	0.61a	0.29
Average age	0.06	0.17	-0.10	0.13	0.06	1.00	-0.17	-0.09	0.06	0.33	-0.34	-0.26	-0.29	0.29	-0.04
Twig length	-0.29	-0.22	0.38	0.42c	0.06	-0.17	1.00	0.01	-0.02	-0.10	0.06	0.10	0.19	0.07	0.16
pH	0.26	0.21	0.08	-0.22	-0.31	-0.09	0.01	1.00	-0.05	-0.09	0.18	0.03	0.13	-0.16	-0.05
Electrical cond.	0.72a	0.16	-0.07	-0.54b	-0.54b	0.06	-0.02	-0.05	1.00	-0.44c	0.21	0.46b	0.77a	-0.54b	-0.77a
Sand	-0.22	-0.09	0.11	0.28	0.21	0.33	-0.10	-0.09	-0.44c	1.00	-0.72a	-0.94a	-0.52b	0.42c	0.19
Silt	0.15	0.45c	-0.11	-0.09	-0.03	-0.34	0.06	0.18	0.21	-0.72a	1.00	0.45c	0.39	-0.18	-0.25
Clay	0.22	-0.10	-0.09	-0.31	-0.26	-0.26	0.10	0.03	0.46b	-0.94a	0.45c	1.00	0.48b	-0.45c	-0.12
Organic matter	0.57a	0.03	-0.11	-0.49b	-0.51b	-0.29	0.19	0.13	0.77a	-0.52b	0.39	0.48b	1.00	-0.58a	-0.49
Utilization	-0.72a	-0.18	0.14	0.42c	0.61a	0.29	0.07	-0.16	-0.54b	0.42c	-0.18	-0.45c	-0.58a	1.00	0.20
%Bitterbrush in diet	-0.58a	-0.44c	-0.05	0.35	0.29	-0.04	0.16	-0.05	-0.77a	0.19	-0.25	-0.12	-0.49	0.20	1.00

a - ($P \leq 0.01$)
b - ($P \leq 0.05$)
c - ($P \leq 0.10$)

only 1 west facing slope, site 3, had enough bitterbrush to be included in the study. Bitterbrush was not found to any extent on north facing slopes.

Table 3. Elevation, slope, and aspect at 18 sites at the Mount Haggin Wildlife Management Area.

Site	Elevation (m)	Slope (%)	Aspect (Degrees)
1	1658	25	125
2	1638	16	85
3	1631	38	260
4	1654	15	65
5	1783	31	110
6	1829	32	100
7	1745	49	115
8	1577	28	160
9	1615	29	170
10	1646	32	115
11	1753	44	135
12	1615	18	110
13	1707	13	180
14	1943	38	120
15	1661	48	130
16	1716	35	90
17	1737	29	155
18	1585	9	80
Mean	1694	29	128

Bitterbrush cover in this study was positively correlated to aspect ($P=.04$, $r=.48$). Since almost all sites in the study are between east and south facing slopes it appears that bitterbrush does best on south facing slopes. Tew (1983) reported that bitterbrush was most frequently found on south facing slopes on the Boise National Forest.

Bitterbrush Cover

Bitterbrush cover as measured by line intercept varied from 19 to 55% and averaged 35% (Table 4). Volume of bitterbrush plants varied from 6.72 m^3 to 40.84 m^3 per site. The volume of bitterbrush plants presented is the total volume of bitterbrush that was measured along the 152.4 m^2 of belt transect on each site. Average height of bitterbrush plants ranged from 37 to 77 cm. Density of bitterbrush plants on the different sites varied from 2,952 to 11,155 plants/hectare and averaged 5,767 plants/hectare.

Table 4. Mean bitterbrush cover, volume, height, density, and percent dead at the 18 study sites at the Mount Haggin Wildlife Management Area.

Site	% Cover	Volume[1] (m^3)	Height (cm)	Density (plants/ha)	% Dead
1	33	13.83	51	11155	8
2	26	9.04	45	10630	19
3	48	24.66	68	4199	7
4	32	19.15	52	5118	14
5	45	14.63	45	6430	10
6	29	15.14	48	5709	15
7	27	12.19	54	4068	7
8	52	27.28	46	6234	13
9	55	30.77	77	5643	15
10	46	40.84	78	3018	9
11	19	6.72	44	6430	13
12	22	8.16	48	2952	4
13	39	13.40	55	4724	5
14	24	8.40	37	10761	7
15	29	10.92	55	3675	4
16	41	20.13	63	5249	5
17	32	21.21	74	3543	8
18	30	19.22	53	4265	16
Mean	35	17.54	55	5767	10

[1] Volume of bitterbrush found in 152.4 m^2 belt transect.

Dead bitterbrush cover encountered along the line transects ranged from 4 to 19%. Bitterbrush cover was highly correlated (P=.01, r=.56) to average bitterbrush height and total bitterbrush volume(P=.0001, r=.80). The high correlation of bitterbrush cover to total bitterbrush volume is not surprising since the area of the plants should be related to the cover measured by the line intercept method since both measurements reflect the width of bitterbrush plants.

The high correlation of bitterbrush cover to bitterbrush height indicates that taller plants are bigger overall and cover more area. Interestingly, bitterbrush cover is not significantly correlated to density (P=.46, r=-.19). This indicates that sites with higher density of bitterbrush have smaller average size plants.

A visual inspection showed that a significant portion of the study area contains dead or senescent bitterbrush plants. However, bitterbrush cover was not correlated to dead bitterbrush cover. This might indicate that lower bitterbrush cover at some sites is not directly due to a bitterbrush die-off but rather to intrinsic differences in the environment inherent to each site. A second calculation of dead bitterbrush was made by dividing the amount of dead bitterbrush at each site by the total amount of bitterbrush (both dead and alive) at each site. This ratio of dead bitterbrush was found to be negatively correlated to bitterbrush cover (P=.04, r=-.49). This implies that areas with less bitterbrush are loosing proportionately more bitterbrush than the higher cover sites.

The average size of bitterbrush plants was measured by assuming that the shape of the plants resembled a circle. Therefore area was

calculated by multiplying the average radius squared by pi. Average size of bitterbrush plants varied considerably among sites (Figure 3).

A stepwise regression of bitterbrush cover, as measured by line intercept, used 5 variables to explain 79% of the variation seen in bitterbrush cover (Table 5). The first variable entered into the equation was aspect. In this study almost all bitterbrush stands were found on south or east facing slopes. This positive relationship between bitterbrush cover implies that south facing slopes are more conducive to higher bitterbrush cover.

Table 5. Regression analysis of bitterbrush cover (Y) with select variables and the resulting equation[1].

Step	Variable	R^2	Significance of F-to-enter	Final Significance of F
1	X_1 Aspect	.23	.04	.01
2	X_2 Litter	.47	.02	.00
3	X_3 Nonbitterbrush shrub	.64	.03	.01
4	X_4 Percent knapweed cover	.70	.12	.03
5	X_5 Soil pH	.79	.05	.05

[1] $Y = 46.3 + 0.10X_1 + 0.72X_2 - 0.57X_3 - 0.41X_4 - 8.05X_5$

The second variable to enter the equation is litter. Perhaps more litter on the ground somehow signifies an increased productiveness of the site. However, since bitterbrush is often the dominant plant in the area an increase in litter might reflect an increase in bitterbrush litter in the area due to an increase in bitterbrush cover. The use of

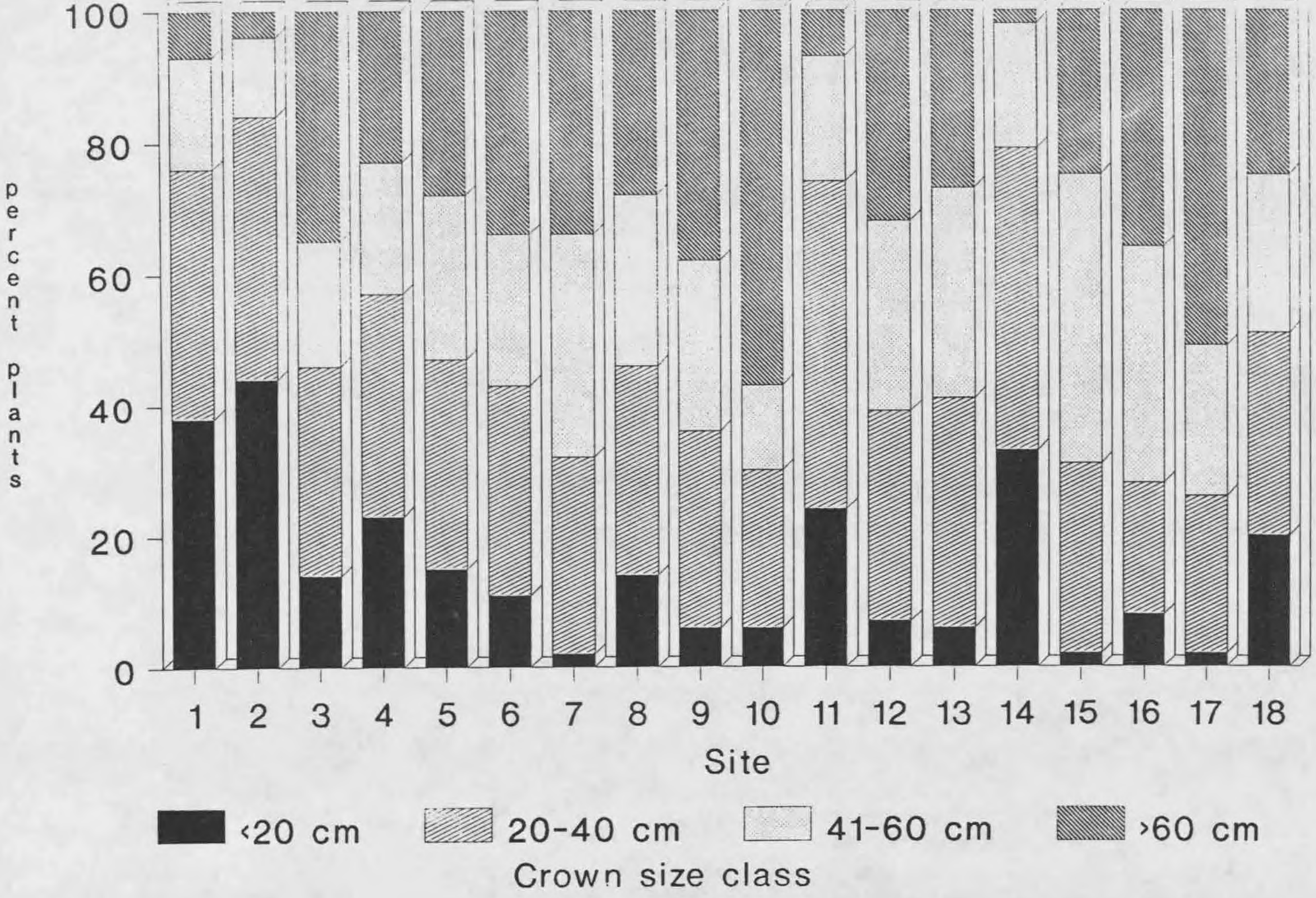

Figure 3. Percent of bitterbrush plants in 4 crown radius classes at 18 sites at the Mount Haggin Wildilfe Management Area.

the litter variable may be questionable, but when this variable was removed no other variables would enter the equation. The negative relationships between bitterbrush and nonbitterbrush shrub cover and between bitterbrush and spotted knapweed cover suggest that competition is occurring between bitterbrush and these species. The negative relationship to soil pH might exhibit a preference of bitterbrush to lower pH. Nord (1965) has stated that bitterbrush does not do well in saline soils.

During the study bitterbrush cover was recorded by 3 different methods: line intercept, density, and canopy coverage by plots (Figure 4). Bitterbrush cover was calculated during the density part of the study since length and width measurements were made on each plant and only plants rooted within the belt transects were measured so a known area was used. This measurement consistently gave a higher cover measurement than the other methods and this can be at least partially explained by 2 factors. First, this method assumes that the plants are perfect circles which is not the case in reality. Many of the plants have gaps and holes that are assumed to be cover by this method.

Secondly, this method does not subtract out the dead bitterbrush that often occurs in the middle of the plant. When the dead bitterbrush recorded during the line intercept measurements is added to the line intercept cover the density measurements come much closer to the line intercept method. The Daubenmire method consistently gave the lowest bitterbrush cover (Figure 4).

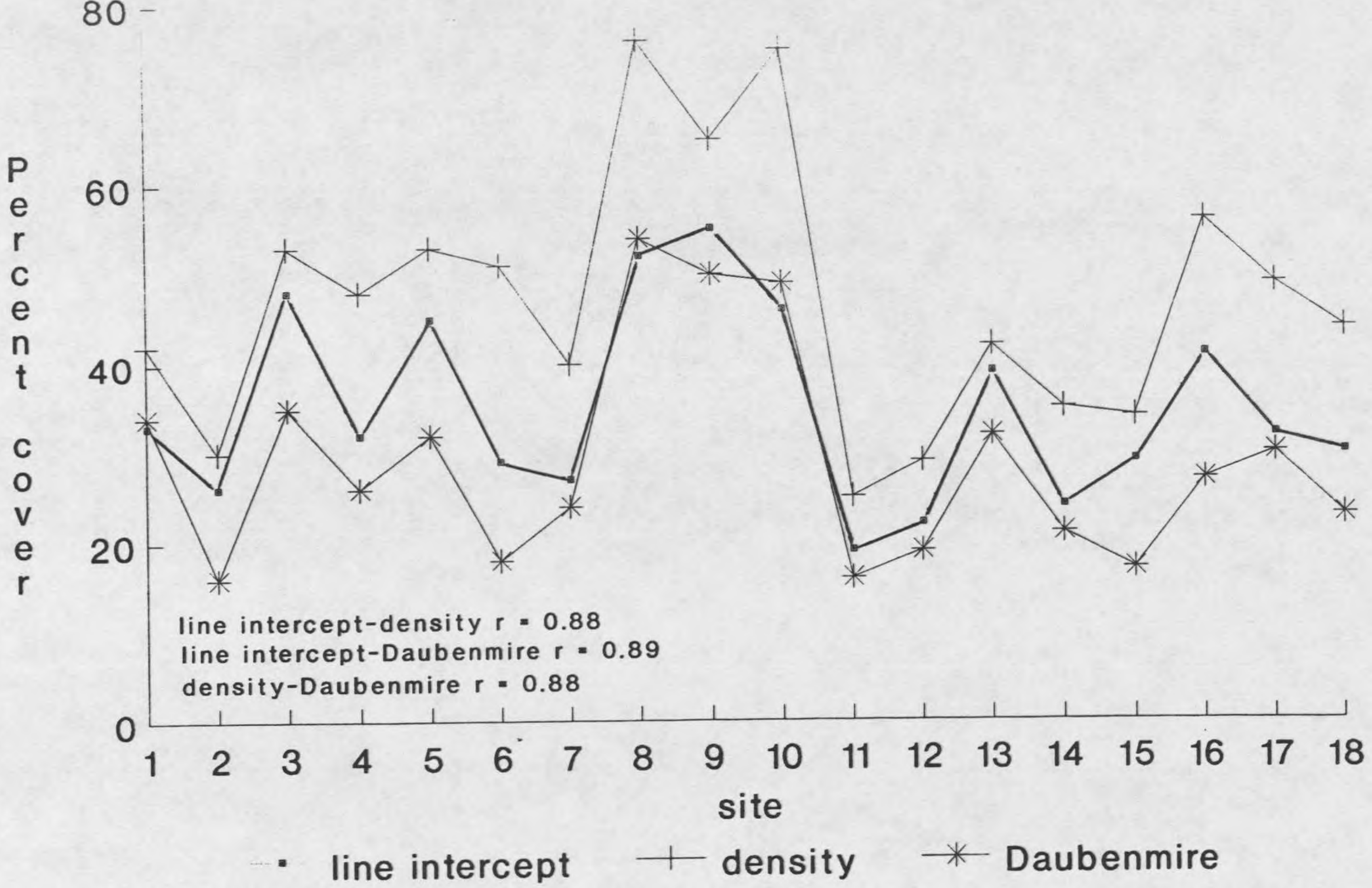

Figure 4. Bitterbrush cover as measured by line intercept, density, and Daubenmire methods at 18 sites at the Mount Haggin Wildlife Management Area.

Dead Bitterbrush

A mean of 10% dead bitterbrush was found throughout the study area (Table 4). There are undoubtedly several reasons for the amount of dead bitterbrush observed. Some of the dead bitterbrush found on the sites is the natural effect of old senescent plants. An infestation of tent caterpillars (Malacosoma californicum) approximately two years before the study began further contributed to the dead bitterbrush seen in the study area. The tent caterpillar is a known defoliator of bitterbrush (Furniss 1983).

Very few tent caterpillars were observed in the area during the study. Outbreaks of the caterpillars are usually short lived due to a native virus that attacks the caterpillars at high density (Clark 1955). This is a probable explanation for the lack of tent caterpillars seen during the study. Furniss (1983) reports that over 100 species of insects are known to feed on bitterbrush but only the more conspicuous insects such as tent caterpillars are reported by resource managers. So it is possible that other insect species are contributing to the death of some plants in the area.

Heavy browsing of the bitterbrush plants can also contribute to dead bitterbrush (Dasmann 1949, Edwards 1942). The amount of dead bitterbrush cover at each site was expressed in 2 different ways. The total of dead bitterbrush recorded along the line intercept transects was the first. However, since a higher cover of bitterbrush might have more dead bitterbrush due only to the fact that the area has more total bitterbrush a second measurement was the amount of dead bitterbrush as a percentage of total bitterbrush present at each site. In the following

discussion "dead" will refer to the amount of dead bitterbrush measured along the line intercepts while "dead ratio" will refer to the dead bitterbrush as a percentage of total bitterbrush cover.

The 2 variables were highly correlated to each other (P=.0001, r=.84). However, the 2 variables were very different in their correlations to other variables. Dead bitterbrush was significantly correlated to litter (P=.009, r=.60), perennial grass (P=.05, r=-.46), and deer pellet density (P=.02, r=.54). However, the dead ratio was highly correlated to bitterbrush cover (P=.04, r=-.49), and nonbitterbrush shrub (P=.03, r=.50). The correlation of dead bitterbrush with deer pellet density indicates that deer are present in higher densities in areas of this winter range with more dead bitterbrush. In the regression analysis of dead bitterbrush (Table 6) deer pellet density is the first variable entered into the regression. This might be an indication that high use by deer in the area is contributing to the amount of dead bitterbrush in the area.

Three other variables were entered into the regression even though they were not significantly correlated to dead bitterbrush. The second variable entered into the equation was average bitterbrush size, which was measured as 1/2 the length of a bitterbrush plant along its longest axis multiplied by 1/2 the width of the bitterbrush plant along the axis perpendicular to the longest axis multiplied by pi. The negative association of this variable in the equation indicates that as the average size of the bitterbrush plants increases the amount of dead bitterbrush decreases. There are at least 2 explanations for this

phenomenon. First perhaps is the possibility that the deer cannot reach all of the browse in the larger bitterbrush plants.

Table 6. Regression analysis of percent dead bitterbrush (Y) with select variables and the resulting equation[1].

Step	Variable	R^2	Significance of F-to-enter	Final Significance of F
1	X_1 Deer pellet density	.30	.02	.00
2	X_2 Mean bitterbrush size	.54	.01	.00
3	X_3 Mean bitterbrush age	.68	.03	.01
4	X_4 Percent organic matter	.75	.08	.08

[1] $Y = -6.41 + 0.16X_1 - 0.00049X_2 + 0.24X_3 + 1.70X_4$

Another possibility is that in heavily browsed areas larger plants have been so heavily browsed that they have been broken into what appears to be 2 or more smaller plants. Due to the layering nature of many of the plants in the area it is difficult to ascertain plant numbers. When density counts were made in the area, density of plant groups might be a better definition of what was measured. Most of the plants or plant groups have more than 1 stem arising from the group. Distinguishing whether these groups represent 1 or several plants would have been very time consuming, so if each group appeared to be 1 plant they were counted as such. Nearby plants that appeared to have separate origins were counted separately. If a plant group had been so heavily browsed that all of the central plants had died it would appear to be

separate plants and would have been counted accordingly during the density measurements.

The positive relationship of dead bitterbrush to bitterbrush age in the regression equation intuitively appears to be a reasonable relationship. The negative relationship of dead bitterbrush to organic matter is perhaps due to the harsher environment present with less organic matter in the soil.

The regression equation of the dead ratio of bitterbrush had 2 of the same variables as dead bitterbrush - deer pellet density and the size of the bitterbrush plants (Table 7). The 2 variables did not appear to be as important here as in the dead bitterbrush regression equation.

Table 7. Regression analysis of dead bitterbrush as a percentage of total bitterbrush cover (Y) with select variables and the resulting equation[1].

Step	Variable	R^2	Significance of F-to-enter	Final Significance of F
1	X_1 Nonbitterbrush shrub	.25	.03	.00
2	X_2 Percent knapweed cover	.49	.03	.07
3	X_3 Size bitterbrush plants	.65	.02	.00
4	X_4 Deer pellet density	.76	.03	.00
5	X_5 Site elevation	.83	.02	.05

[1] $Y = -53.3 + 0.56X_1 + 0.34X_2 - 0.001X_3 + 0.24X_4 + 0.012X_5$

In the dead ratio equation the first variable to enter was the amount of nonbitterbrush shrub cover. This relationship might imply that there is some competition occurring among bitterbrush and other shrubs, leading to an increased amount of dead bitterbrush in some of the plants.

The entrance of spotted knapweed into the regression equation suggests that sites with a high amount of spotted knapweed have lower bitterbrush vigor. There is no evidence that knapweed is causing a decline in bitterbrush vigor. Some of the sites have experienced a considerable amount of retrogressive succession and knapweed has entered these sites after the decline in native vegetation. So the positive relationship between knapweed cover and dead bitterbrush might reflect past improper use of sites.

The last variable to enter the equation is site elevation which is positively related to the dead ratio of bitterbrush. At some of the higher elevation sites it appears that bitterbrush plants are being replaced by other species that are better adapted to the higher elevations. The predictive value of the 2 different types of dead bitterbrush equations has not been tested.

Age

The average age of the bitterbrush stands varied considerably from site to site (Figure 5). This variable was highly correlated with the average diameter of the stem base of the plants ($P=.0001$, $r=.89$). When the age of all 360 bitterbrush plants measured in this study was charted, several peak years of bitterbrush establishment are evident (Figure 6). One interesting note is the occurrence of many of the peak

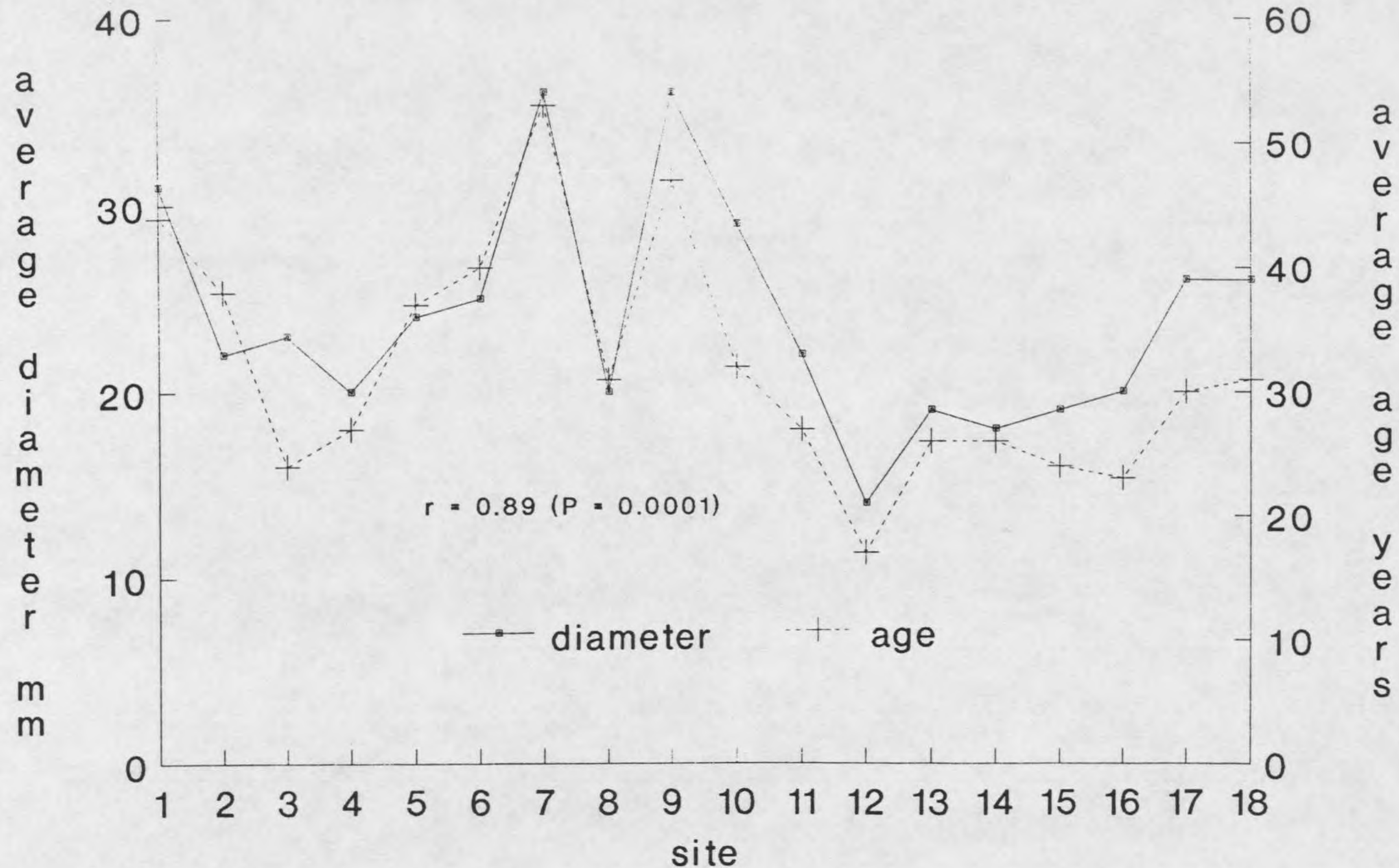

Figure 5. Average age and basal diameter of bitterbrush plants at 18 sites at the Mount Haggin Wildlife Management Area.

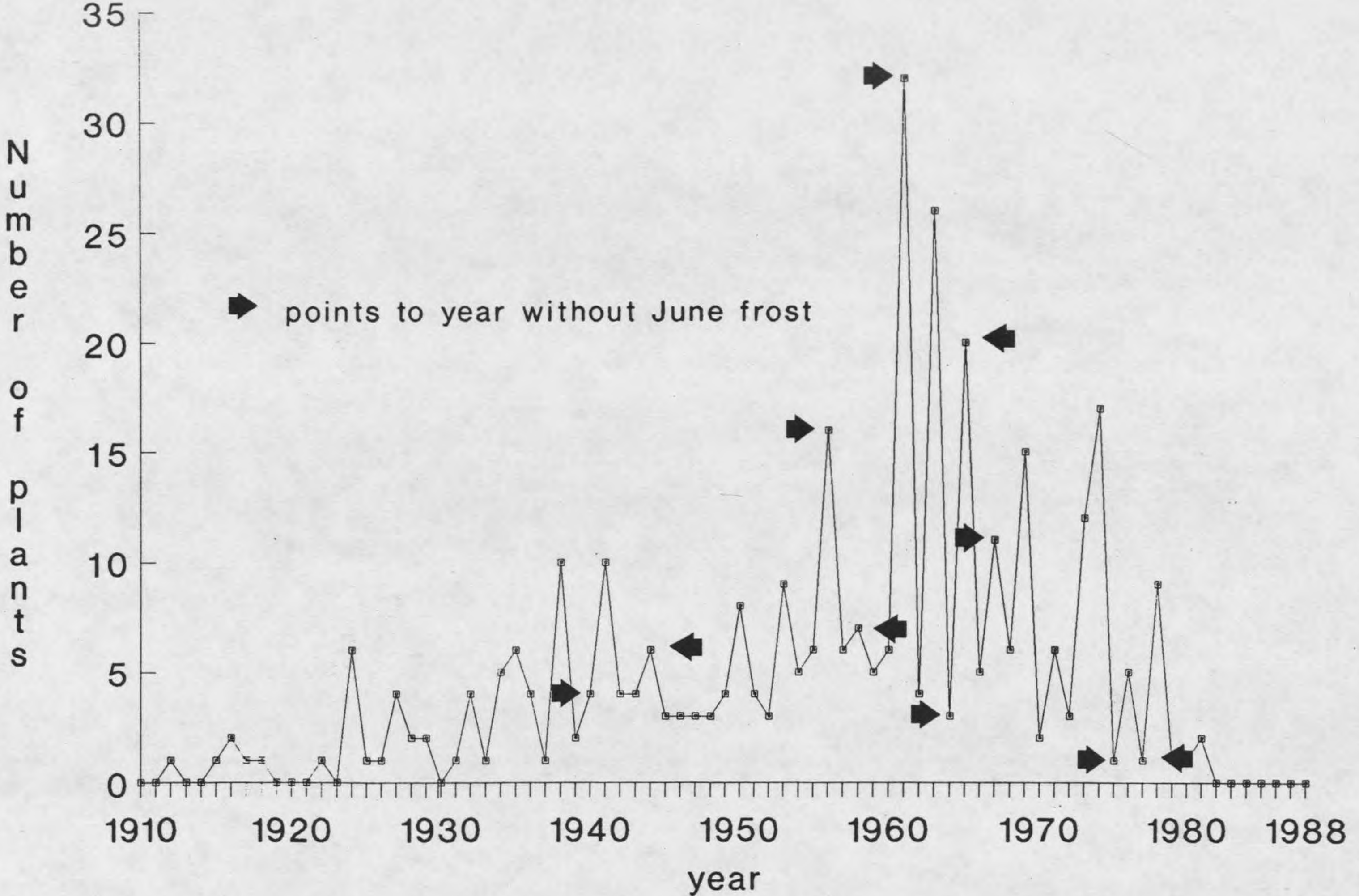

Figure 6. Year of establishment for 360 plants at 18 sites at the Mount Haggin Wildlife Management Area.

bitterbrush establishment years during years that did not have any freezing temperatures in the month of June. A distressing revelation from the data is the lack of young bitterbrush plants on the sites. The youngest plant aged out of the 360 samples was 7 years old even though there was at least 1 plant represented for each year during the preceding 50 years. Furthermore, no bitterbrush seedlings were noted during the summer of 1988 or the spring of 1989 even though considerable effort was directed towards finding seedlings. According to McConnell and Smith (1977) peak bitterbrush production does not occur until plants are 60 to 70 years old. Compared to these figures the bitterbrush stands in this study are comparatively young.

Associated Plant Species

The plant cover measured by the Daubenmire method varied considerably in its composition from site to site (Figure 7 and Appendix A). On 3 of the 18 sites bitterbrush did not have the highest cover measurements (Appendix A). On sites 2 and 12 spotted knapweed was the dominant vegetation. Rough fescue had the highest cover measurement on site 14. The lack of young bitterbrush plants and the abundance of dead bitterbrush on these sites suggests that bitterbrush is perhaps being replaced by other species.

Next to bitterbrush the shrub with the highest cover measurement for all 18 sites is Oregon grape with a mean cover of 3%, although found on only 6 sites (Appendix A). Following bitterbrush, which occurred on all 18 sites, Wood's rose *Rosa woodsii* was the next most frequent shrub, occurring in 8 of the 18 study sites (Appendix A). Three grass species occurred in at least half of the study sites: cheatgrass in 11 sites,

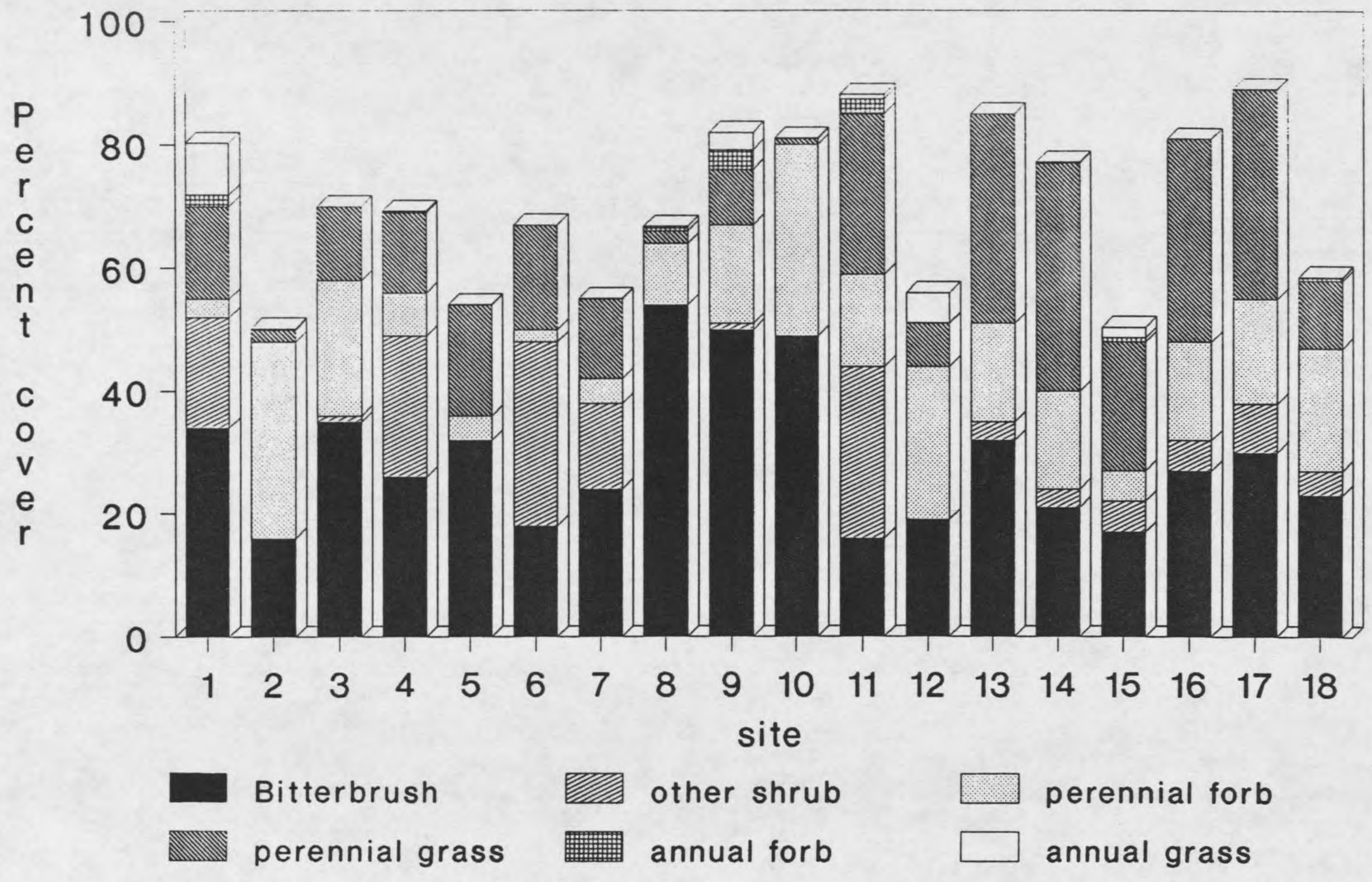

Figure 7. Percent plant cover at 18 sites at the Mount Haggin Wildlife Management Area.

bluebunch wheatgrass in 15 sites, and Kentucky bluegrass in 16 sites. The grass with the highest cover for all sites is Kentucky bluegrass with a mean of 6%. Perennial grass cover was positively correlated with elevation (P=.002, r=.68), electrical conductivity of the soil (P=.006, r=.62), percent clay in the soil (P=.002, r=.69), and organic matter (P=.001, r=.71). These relationships may suggest the type of sites on which perennial grass is most successful.

Two forbs occurred on at least half of the study sites: spotted knapweed in 9 sites, and tumble mustard *Sisymbrium altissimum* in 10 sites. Spotted knapweed, with a mean of 8% for all 18 sites, is the forb with the highest cover measurement in the study.

Spotted knapweed, tumble mustard, cheatgrass and Kentucky blue grass are all introduced species and their ubiquity in the study sites indicates that the sites are in a depressed ecological condition. Spotted knapweed cover was negatively correlated to the number of species at each site (P=.01, r= -.57). This negative correlation of spotted knapweed to abundance of plant species on a site exhibits the loss of diversity in sites invaded by spotted knapweed. Spotted knapweed cover was negatively correlated to elevation (P=.01, r= -.57), perennial grass cover (P=.001, r=-.71), and electrical conductivity (P=.009, r=-.59) and spotted knapweed was positively correlated to percent sand in the soil (P=.04, r=.49).

The higher knapweed cover at the low elevation (1500-1700 m) sites is probably a reflection of the higher level of retrogressive succession that has occurred at these sites. Sites with high spotted knapweed cover show numerous examples of pedestaling of live and dead bunchgrass

plants which indicates that in the past these sites had more perennial grass cover. The negative correlation of spotted knapweed cover with perennial grass cover indicates that knapweed has replaced perennial grasses in areas where the perennial grass has been lost to previous disturbances. Although difficult to prove, it is likely that past improper grazing and close proximity to the Anaconda smelter have contributed to the loss of perennial grass cover in the area.

The amount of litter on the ground as measured by the Daubenmire method averaged from 33 to 62% at the 18 sites (Table 8). Bare ground ranged from 2 to 47% and was not correlated with the amount of litter. This could be due to the different types of plant cover that occur at each site and to the different amount of litter each plant type contributes to the total. For example, litter was highly correlated to bitterbrush volume (P=.007, r=.61) while bare ground was negatively correlated to perennial grass cover (P=.01, r=-.56). The number of species present at the 18 sites ranged from 8 to 27 species (Table 9).

Seed Germination

All of the seeds (178) that germinated in the germination trial germinated within 2 weeks even though seeds were left in the oven for 4 weeks. Mean germination rate was 89% (Standard deviation = 6.2). These results are similar to other bitterbrush germination trials (Young and Evans 1976). Since no seedlings were seen in the study area it appears that environmental conditions have not been conducive to seedling establishment in the past few years. Nord (1965) noticed that bitterbrush seedlings are usually not found near adult bitterbrush plants. Since a fairly high density of bitterbrush plants occur in the

study area it is possible that bitterbrush plants have autoallelopathic tendencies. Another possibility is that climatic conditions such as precipitation and temperature have not been favorable for bitterbrush establishment in the past 10 years.

Table 8. Percent litter, bare ground, and rock measured at the 18 study sites at Mount Haggin Wildlife Management Area.

Site	Litter	Bare Ground	Rock
1	37	17	0
2	37	24	2
3	37	17	3
4	50	12	4
5	46	25	1
6	56	2	0
7	32	47	1
8	56	28	4
9	62	18	2
10	57	17	0
11	49	11	0
12	40	26	1
13	33	5	5
14	34	12	0
15	39	22	6
16	39	7	2
17	40	3	8
18	52	19	0
mean	44	17	2

Deer Diet

The diet of mule deer in this study was determined by fecal analysis. Sparks and Malechek (1968) found that fecal analysis accurately recorded composition of plants in deer that were fed a known diet. Anthony and Smith (1974) have demonstrated that results from fecal analysis are quite similar to rumen analysis. In this study some

plant material was identified to species and the rest was usually identified at the genus level. Figure 8 presents plant content of the feces in major groups. A more complete description of plant material in the diet is presented in Appendix B.

Table 9. Number of plant species observed at the 18 study sites at the Mount Haggin Wildlife Management Area.

Site Number	Number of species	Site Number	Number of Species
1	20	10	8
2	12	11	23
3	16	12	13
4	15	13	23
5	12	14	23
6	10	15	19
7	13	16	27
8	11	17	26
9	16	18	14
		mean	17

Bitterbrush, Oregon grape, and Rocky Mountain juniper (Juniperus scopulorum) made up the majority of the winter diet of the mule deer at the 18 sites. Together these 3 species made up 87% of the mule deer diet (Table 10). Woody plants commonly make up the majority of the diet of mule deer during winter in the northern Rockies (Cooperrider et al. 1986). In this study woody plants comprise about 97% of the mule deer diet during the winter months.

Bitterbrush was the only plant that occurred in the pellet groups at all 18 sites. Rocky Mountain juniper was present in the pellet groups at 17 sites. Five other taxa occurred in over half of the sites: Oregon grape, Douglas fir, lodgepole pine (Pinus contorta), rubber

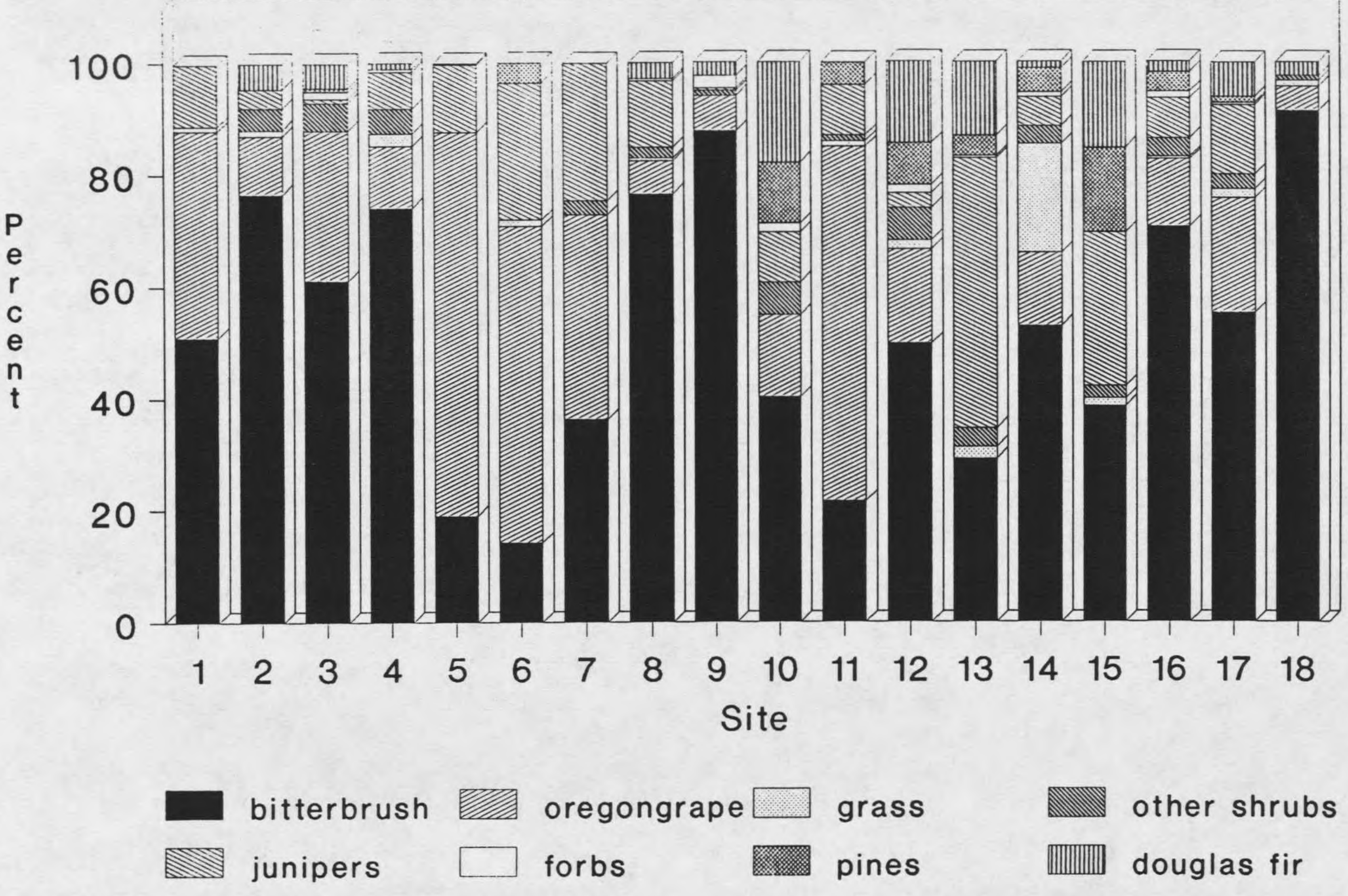

Figure 8. Plant species composition of deer feces at 18 sites at the Mount Haggin Wildlife Management Area.

rabbitbrush (Chrysothamnus nauseosus), and bluegrass species (Poa spp.). The trees in the above list were not common in the bitterbrush transects, but did occur nearby.

Table 10. Mean percent plant contents of mule deer feces at all 18 sites at the Mount Haggin Wildlife Management Area.

Species	Average	Sites Present
Purshia tridentata	52.60	18
Berberis repens	22.44	16
Juniperus scopulorum	11.96	17
Pseudotsuga menziesii	4.90	13
Pinus contorta	3.02	11
Chrysothamnus nauseosus	1.60	13
Festuca spp.	1.06	4
Poa spp.	0.55	11
Lupinus spp.	0.31	9
Seed	0.24	5
Sheperdia-Elaeagnus	0.22	6
Tetradymia canescens	0.18	3
Agropyron spp.	0.14	3
Artemisia frigida	0.13	4
Chrysothamnus viscidiflorus	0.11	2
Bromus spp.	0.10	3
Symphoricarpos albus	0.09	3
Carex spp.	0.07	2
Family-Asteraceae	0.07	2
Amelanchier alnifolia	0.05	2
Balsamorhiza sagittata	0.05	2
Arctostaphylos uva-ursi	0.03	1
Phlox spp.	0.03	1
Rubus spp.	0.03	1
Antennaria-Cirsium	0.02	1
Verbascum spp.	0.02	1
Vegetative Class		
Shrub	77.48	18
Tree	19.88	18
Grass	1.92	13
Forb	0.50	10

Although bitterbrush was by far the most common plant in the diet, 53% over the entire study area, it was not the most abundant plant in the diet at all of the study sites (Figure 8). Oregon grape was the most abundant species in the mule deer diet at 4 sites. Oregon grape use by site was positively correlated (P=.05, r=.47) to the elevation of the sites. At the higher elevations a large portion of the bitterbrush in the diet was replaced by Oregon grape.

Percent bitterbrush in the diet was correlated to several environmental factors. The strongest correlation was a negative correlation to electrical conductivity of the soil (P=.0002,r=-.77). This relationship is hard to explain and perhaps reflects the association of electrical conductivity to another variable that was not measured. Bitterbrush plants are known to have differences in palatability, (Edgerton et al. 1983) but it seems unlikely that variation in electrical conductivity could cause much difference in palatability when all of the sites have relatively low electrical conductivity measurements.

Bitterbrush in the diet was also significantly negatively correlated to elevation (P=.01, r=-.58). Bitterbrush in the deer's diet was positively correlated (P=.04, r=.48) to density of deer pellets. This relationship seems to show that deer are concentrated in high bitterbrush use areas. Interestingly though, bitterbrush in the diet as measured in the feces was not significantly correlated to bitterbrush utilization even though utilization was significantly correlated to elevation (P=.0007, r=-.72) and to deer pellet densities (P=.003, r=.66) in the same manner as bitterbrush in the deer diets.

A stepwise regression analysis was performed using percent bitterbrush in the mule deer diets as the dependent variable (Table 11). The first variable to enter the regression was elevation, which was negatively correlated to bitterbrush in the deer diet. The higher amount of bitterbrush in the diet at lower elevations might be partially related to less choice of food at lower sites. For instance, after bitterbrush the most frequent food found in the deer's diet was Oregon grape which was positively correlated to elevation (P=.08, r=.42). The negative effect of utilization on the regression equation might reflect the overbrowsing of bitterbrush observed in the area. As the deer overuse the bitterbrush they have to turn to other forages.

Table 11. Regression analysis of percent bitterbrush in mule deer diet (Y) with select variables and the resulting equation[1].

Step	Variable	R^2	Significance of F-to-enter	Final Significance of F
1	X_1 Elevation	.34	.01	.00
2	X_2 Utilization	.43	.13	.00
3	X_3 % Dead bitterbrush	.60	.03	.00
4	X_4 % Oregon grape cover	.77	.01	.00
5	X_5 Bitterbrush height	.85	.03	.00

[1] $Y = 420.2 - 0.051X_1 - 1.90X_2 + 3.85X_3 - 1.86X_4 + 0.64X_5$

The relation between elevation and utilization in this equation is confusing since they were both highly negatively correlated to each

other, but in this equation they both have a negative relationship to bitterbrush in the mule deer diet. The positive relationship of dead bitterbrush in this equation might be another reflection of overuse, The positive relationship of bitterbrush height might express a relationship of availability of bitterbrush leaders to the height of the bitterbrush plants, since shorter plants are more likely to be covered with snow. However, areas with less bitterbrush in the diet had high amounts of Oregon grape in the diet and the Oregon grape plants in the study area are much shorter than the bitterbrush plants. Perhaps the deer are utilizing these two forages at different times during the winter months.

Utilization

Utilization of bitterbrush twigs was calculated by measuring current year's growth in August 1988 and then remeasuring the same leaders the following spring. Utilization ranged from 57 to 96% (Figure 9) and averaged 80%. Hormay (1943) stated that not more than 60% of current years twig growth should be browsed in any year if the plant is to retain its vigor and seed production. The majority of plants observed in the study area appeared to be quite hedged from overbrowsing in previous years.

In some utilization studies researchers measure utilization by just counting leaders browsed instead of measuring the actual amount of leader browsed. Counting leaders browsed is less time consuming than measuring total utilization and in this study was highly correlated to total utilization (P=.0001, r=.94). However only counting leaders overestimated utilization by about 10% (Figure 9). Utilization was highly negatively correlated to elevation (P=.0007, r=-.72). Since deer

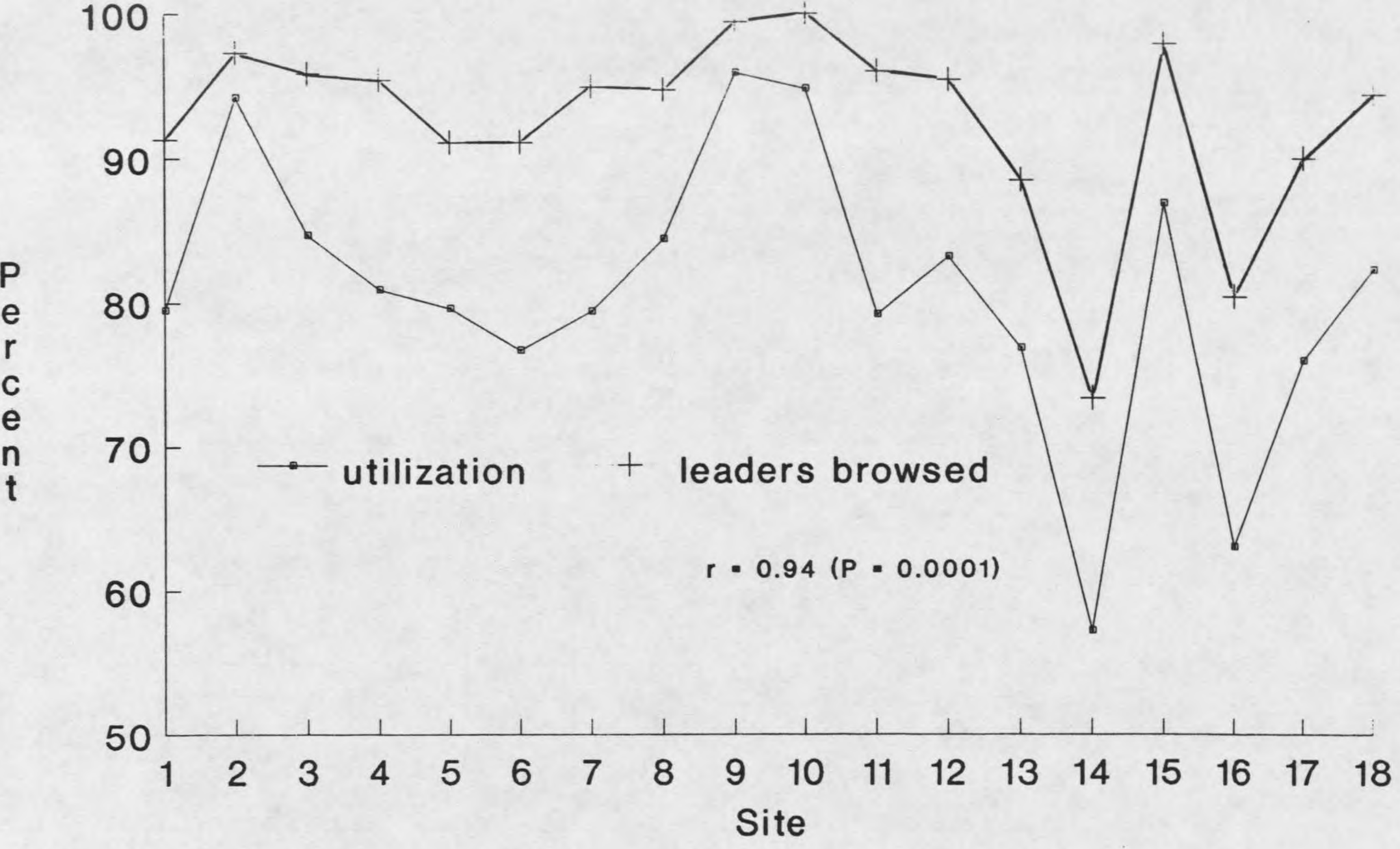

Figure 9. Bitterbrush utilization and leaders browsed at 18 sites at the Mount Haggin Wildlife Management Area.

are usually restricted to lower elevations in the winter due to an inability to forage in the deeper snow found at higher elevations these results are not surprising.

Like percent bitterbrush in deer diet, utilization was also negatively correlated to electrical conductivity (P=.02, r=-.46) and organic matter (P=.01, r=-.58). Furthermore, utilization was negatively correlated to perennial grass cover (P=.0001, r=-.80). This correlation is probably related to the positive correlation of perennial grass cover to elevation (P=.001, r=.68). However, the correlation between perennial grass cover and utilization is stronger than that between utilization and elevation.

Perhaps the negative correlation to perennial grass cover might be linked to site preference of mule deer. Perennial grass was not very important in the winter diet of the deer (Table 10), which account for most of the bitterbrush utilization observed in this study. Utilization was highly negatively correlated (P=.0009, r=-.71) to the density of elk pellets. This correlation, along with the much higher deer pellet density in the area, demonstrates that most of the bitterbrush utilization in the sites is the result of deer browsing. The majority of the bitterbrush sites are only used by cattle for a short time in the spring and no utilization of twigs was noted of twigs which were tagged in August.

Utilization was negatively correlated to the number of species found at a site (P=006, r=-.62). This is perhaps partially due to the lack of choice in the diet. Since so few species make up the majority

of the deer's diet this correlation does not explain a great deal of the differences seen in utilization.

Utilization was highly significantly correlated to the average volume of individual bitterbrush plants (P=.007, r=.61). This might show a preference of deer to the larger plants or at least to sites where the larger plants are present. Perhaps the higher utilization of larger plants reflects snow covering a larger portion of the smaller plants. However utilization was not significantly correlated to average bitterbrush height (P=.11, r=.39). Utilization was positively correlated to dead bitterbrush cover (P=.09, r=.41). This relationship might reflect the overutilization of bitterbrush which appears to be occurring as shown in the utilization data.

Two variables were used in a stepwise regression of bitterbrush utilization which explained 69% of the variation exhibited in utilization (Table 12).

Table 12. Regression analysis of bitterbrush utilization (Y) with select variables and the resulting equation[1].

Step	Variable	R^2	Significance of F-to-enter	Final Significance of F
1	X_1 Elevation	.52	.00	.00
2	X_2 Number of species	.69	.01	.00

[1] $Y = 195.1 - 0.018X_1 - 0.73X_2$

The first variable to enter the equation was elevation, again emphasizing the importance of elevation to deer presence. The second variable was number of species found at each site. The negative relationship to number of species may indicate fewer choices of food available to the animals.

Pellet Density

Utilization was also highly correlated to the deer pellet density of each site (P=.003, r=.66). For the study area at least, pellet group counts appear to be a fairly good indicator of utilization. Deer pellet density ranged from 720 to 7,610 pellet groups/hectare (Table 13). The density of elk pellet groups was generally considerably less than deer pellets and ranged from 70 to 2760 pellet groups/hectare. Elk pellet density was positively correlated to elevation (P=.0002, r=.76) while deer pellet density was negatively correlated to elevation (P=.001, r=-.70). Deer pellet density was negatively correlated to elk pellet density (P=.05, r=-.46).

Table 13. Deer and elk pellet density/hectare at the 18 study sites at the Mount Haggin Wildlife Management Area.

Site	Deer	Elk	Site	Deer	Elk
1	2030	390	10	7610	130
2	5710	260	11	3610	920
3	3020	330	12	4000	660
4	4130	660	13	2230	920
5	2760	920	14	720	2760
6	3080	1050	15	3020	200
7	1710	70	16	3220	330
8	7280	260	17	2230	920
9	5050	70	18	6760	850
			Mean	3787	650

A stepwise regression of deer pellet density explained 85% of the variation present in deer pellet density by using 4 variables (Table 14). The first variable to enter the equation was elevation. This probably is at least partially due to the fact that deer have a harder time feeding and walking in the deeper snow that occurs at higher elevations. The relationship to average bitterbrush plant volume and total bitterbrush volume at the site might show that there is more food available at these sites and this attracts more animals.

Table 14. Regression analysis of density of deer pellet groups (Y) with select variables and the resulting equation[1].

Step	Variable	R^2	Significance of F-to-enter	Final Significance of F
1	X_1 Elevation	.49	.00	.00
2	X_2 Mean bitterbrush volume	.65	.02	.01
3	X_3 Mean bitterbrush height	.75	.03	.00
4	X_4 Tot. bitterbrush volume	.85	.01	.01

[1] $Y = 376.8 - 0.050X_1 + 73.1X_2 - 1.77X_3 + 1.92X_4$

The only 1 of the 4 regression variables that was not correlated to deer pellet density was average bitterbrush height. Its negative relationship in the equation is hard to explain. Perhaps the relationship has something to do with the hedging of plants that occurs in highly used sites and therefore sites that are more heavily used will have shorter plants due to the hedging.

SUMMARY AND CONCLUSIONS

The 2 primary goals of this investigation were to accurately describe the bitterbrush communities on the Mount Haggin Wildlife Management Area and to develop environmental explanations for differences observed among these communities. The underlying causes of differences in vegetation at separate sites are complex and not easily understood. Due to the complexity of the subject matter it would be impossible to explain all of the variation that exists among these bitterbrush communities. Even if all of the site variables could be accurately recorded chance occurrence of plants and seeds in an area would no doubt confound any results. Nevertheless this investigation has been able to detect some of the relationships that occur in the bitterbrush communities.

Bitterbrush cover ranged from 19 to 55% in the 18 study sites and the average for the entire study area was 35%. The largest bitterbrush stands were found on south facing slopes. Density of bitterbrush plants varied from 2,952 to 11,155 plants/hectare. The variables of aspect, litter, nonbitterbrush shrub cover, spotted knapweed cover, and soil pH were used in a regression equation to explain 79% of the variation observed in bitterbrush cover. Bitterbrush cover was measured by 3 different methods: line intercept, Daubenmire, and area measurement of plants rooted within a belt transect. The 3 measures of cover were all highly correlated although the Daubenmire method consistently gave a lower cover measurement.

Dead bitterbrush cover on the sites ranged from 4 to 19% and averaged 10%. A regression equation using deer pellet density, mean bitterbrush size, mean bitterbrush age, and percent organic matter in the soil explained 75% of the variation in dead bitterbrush cover.

The youngest bitterbrush plant found in the study site was 7 years old and no seedlings were found during 2 field seasons. The lack of young bitterbrush plants may be a concern in the future. More research is needed to determine the reasons for the lack of young plants. The shortage of young plants could be due to unfavorable climatological conditions for seedling establishment, invasion of weedy plants, or natural succession.

The low range condition of several sites was evident from the abundance of introduced weeds such as spotted knapweed, tumble mustard, and cheatgrass. Other common plants in the study area were bluebunch wheatgrass, rough fescue, Kentucky bluegrass, Oregon grape, and Wood's rose. Past overgrazing has contributed to the decline in native perennial grasses.

Deer pellet density ranged from 720 to 7,610 pellet groups/hectare. Deer pellet density proved to be a reliable indicator of bitterbrush utilization in this investigation.

Bitterbrush made up 53% of the winter diet of mule deer in the study area as measured by fecal analysis. Oregon grape made up an additional 22% of the diet. All together woody plants made up 97% of the mule deer winter diet on the study sites. Percent bitterbrush in the diet was significantly negatively correlated to elevation. A regression equation using elevation, percent utilization, percent dead

bitterbrush, percent Oregon grape cover, and bitterbrush plant height was able to explain 85% of the variation in percent bitterbrush in the mule deer's diet. The high amount of bitterbrush in the mule deer diet establishes the importance of this shrub in the winter diet of mule deer at the Mount Haggin Wildlife Management Area.

Bitterbrush utilization in the study sites ranged from 57 to 96% and averaged 80%. This level of use is much higher than the recommended 60% level. The hedged form class of the plants indicates that over browsing had occurred before this investigation. Utilization was significantly negatively correlated to elevation. Only counting number of bitterbrush leaders browsed proved to be strongly correlated to measuring total utilization in this study.

More research should be directed towards alleviating the overutilization of bitterbrush in the study area. Continued use of the bitterbrush at the current high level could seriously damage the productivity of the bitterbrush stands, which will in turn increase the level of use on the remaining plants, eventually causing their destruction.

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APPENDICES

APPENDIX A

COVER OF PLANT SPECIES IN THE STUDY AREA

Table 15. Percent cover of plants identified in Daubenmire transects at 18 sites at the Mount Haggin Wildlife Management Area.

Shrubs, Half-Shrubs, and Trees

	Site #																			Sites
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Mean	With
Amelanchier alnifolia	0	0	0	0	T	0	4	0	0	0	3	0	0	0	0	.8	0	0	0.43	4
Berberis repens	2	0	0	0	0	25	.2	0	0	0	16	0	0	0	0	.1	7	0	2.79	6
Chrysothamnus nauseosus	0	.3	.3	0	0	0	0	0	1	0	0	0	3	3	.9	0	T	0	0.47	7
Chrysothamnus viscidiflorus	0	0	0	0	0	0	0	0	0	0	0	0	.4	T	0	0	0	0	0.02	2
Gutierrezia sarothrae	.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	0	0.02	2
Purshia tridentata	34	16	35	26	32	18	24	54	50	49	16	19	32	21	17	27	30	23	29	18
Prunus virginiana	.8	0	0	0	0	0	.3	0	0	0	0	0	0	0	0	0	0	0	0.12	2
Pseudotsuga menziesii	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.27	1
Ribes setosum	0	0	.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	1
Rosa woodsii	.6	0	.3	0	0	0	9	0	0	.3	0	0	0	0	4	4	.3	4	1.25	8
Symphoricarpos albus	14	0	0	0	.3	6	0	0	0	0	9	0	0	0	0	0	0	0	1.63	4
Tetradymia canescens	0	0	0	0	0	0	.3	0	0	0	0	0	.3	0	0	0	0	0	0.03	2

Graminoids

	Site #																			Sites
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Mean	With
Agropyron dasystachyum	0	0	0	0	0	0	0	0	0	0	.3	0	0	0	0	0	0	0	0.02	1
Agropyron smithii	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0.11	1
Agropyron spicatum	3	T	.9	.6	0	0	0	.6	.8	.1	8	2	7	11	18	6	5	5	3.77	15
Agropyron trachycaulum	0	0	0	0	.1	.1	0	0	0	0	.3	0	0	0	0	0	0	0	0.03	3
Agrostis stolonifera	0	0	0	0	0	6	.3	0	0	0	0	0	0	0	0	0	0	0	0.35	2
Agrostis scabra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0.17	1
Bromus marginatus	0	0	0	T	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0.28	2
Bromus inermis	0	0	0	0	0	0	0	0	0	0	0	0	0	.1	0	T	0	0	0.01	2
Bromus tectorum	8	.1	0	.1	T	0	T	0	3	T	.6	5	0	0	2	0	0	T	1.04	11
Carex spp.	0	0	0	.4	0	0	0	.3	0	0	.7	1	.4	.6	0	1	0	T	0.24	8
Distichlis stricta	0	0	0	0	.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	1
Elymus cinereus	0	0	0	0	16	0	13	0	0	0	0	0	0	0	0	0	0	0	1.61	2
Festuca idahoensis	0	0	0	.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	1
Festuca scabrella	0	0	0	0	0	0	0	0	0	0	0	0	12	25	2	10	0	0	2.72	4
Koeleria pyramidata	0	0	0	0	0	0	0	0	0	0	0	0	0	.4	0	0	.9	0	0.07	2
Phleum alpinum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	T	0	0	0.00	1
Phleum pratense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0	0.44	2
Poa compressa	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0.11	1
Poa juncifolia	0	0	.3	0	0	0	0	0	0	0	T	0	0	0	0	0	0	0	0.02	2
Poa nevadensis	.3	0	0	0	0	0	0	0	0	0	0	.3	0	0	0	0	0	.1	0.04	3
Poa pratensis	11	.3	11	11	2	11	0	0	5	.3	12	3	12	.1	1	7	13	3	5.70	16
Stipa columbiana	0	0	0	0	0	0	0	0	.3	0	0	0	0	0	0	0	0	.3	0.03	2
Stipa comata	0	1	0	0	0	0	0	1	2	.7	0	T	0	0	0	0	0	T	0.26	6
Stipa viridula	0	0	0	1	0	0	0	0	.3	0	0	0	0	0	0	3	12	0	0.90	4
Unknown perennial grass	0	0	0	0	.2	0	0	0	0	0	0	0	0	T	0	0	0	0	0.01	2

T = Trace

Table 15. (Continued).

Forbs

	Site #																			Sites
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Mean	With
Achillea millefolium	.4	0	0	0	0	0	0	0	0	0	3	0	T	1	0	.6	.8	0	0.32	6
Allium cernuum	T	0	0	0	0	0	0	0	0	0	.3	0	0	0	0	0	0	0	0.02	2
Antennaria microphylla	0	0	0	0	0	0	0	0	0	0	0	0	.6	0	0	T	0	0	0.03	2
Apocynum androsaemifolium	0	0	3	0	0	0	0	0	9	.3	0	0	0	0	2	0	0	0	0.79	4
Arenaria congesta	0	0	0	0	0	0	0	0	0	0	0	0	.6	0	0	.6	0	0	0.07	2
Artemisia frigida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	T	.5	0	0.04	3
Artemisia ludoviciana	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	0	0	0	0	0.02	1
Asclepias speciosa	0	0	0	0	0	.3	0	0	0	0	0	0	0	0	0	0	0	0	0.02	1
Aster campestris	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	0	0	0	0.02	1
Aster chilensis	0	0	0	0	3	.8	.6	0	0	0	0	0	0	0	0	0	0	0	0.24	3
Aster conspicuus	.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	1
Balsamorhiza sagittata	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	0	1	4	0	0.29	3
Cardaria draba	0	4	0	0	0	0	0	.3	0	0	0	0	0	0	0	0	0	0	0.24	2
Centaurea maculosa	0	26	17	5	0	0	0	8	6	30	0	24	0	0	0	T	0	20	7.56	9
Cirsium flodmanii	0	.5	.1	0	0	0	.1	0	.8	0	0	0	0	2	T	0	.3	0	0.21	7
Comandra umbellata	0	0	.1	0	0	0	0	0	0	0	0	0	.3	0	0	.3	.1	0	0.04	4
Erigeron sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	.4	T	0.24	5
Eriogonum umbellatum	0	0	0	0	0	0	0	0	0	0	1	0	.3	6	0	6	2	0	0.85	5
Euphorbia esula	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0.17	1
Fragaria vesca	.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	1
Gaillardia aristata	0	0	T	0	0	0	0	0	.3	0	0	0	0	0	0	.3	0	0	0.03	3
Geranium viscosissimum	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	0	.3	0	0.03	2
Grindelia squarrosa	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	T	0	.3	0	0.03	3
Heterotheca villosa	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	1
Juniperus scopulorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	0.02	1
Lepidium densiflorum	0	0	0	0	0	0	0	0	0	0	0	T	0	0	0	0	0	0	0.00	1
Linaria vulgaris	0	0	0	0	0	0	0	0	0	0	7	0	0	2	0	.6	2	0	0.64	4
Lithospermum ruderale	0	0	1	0	0	0	0	0	0	0	0	0	0	.3	0	0	.4	0	0.09	3
Lupinus wyethii	0	0	0	0	0	0	0	0	0	0	0	0	T	0	0	.1	0	0	0.01	2
Machaeranthera canescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	.3	0	0.03	2
Mentzelia laevicaulis	0	0	0	0	.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	1
Opuntia polyacantha	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.06	1
Phacelia hastata	1	0	.3	T	0	0	0	T	.3	0	.3	.1	0	0	.5	0	.3	0	0.16	9
Phlox sp.	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	0	0	0	0	0.02	1
Physaria geyeri	.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	1
Potentilla gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0	.9	0	0	0	0	0.05	1
Sisymbrium altissimum	1	T	0	.1	0	0	0	0	3	0	T	T	0	T	.6	0	T	.5	0.29	10
Solidago missouriensis	0	.6	0	2	.8	0	0	0	0	0	0	0	4	3	.3	4	5	0	1.09	8
Taraxacum officinale	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	0	0	0	0.02	1
Tragopogon dubius	0	0	0	.3	0	0	T	0	0	0	2	0	0	0	.3	T	0	0	0.14	5
Zigadenus sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0.06	1
Unknown annual forbs	.6	0	0	0	0	0	0	.8	0	0	2	0	0	.1	T	0	0	0	0.19	5
Unknown perennial forbs	.3	0	.6	0	0	1	0	.8	T	0	0	0	.3	0	0	0	T	0	0.17	7
moss	0	0	.5	3	0	T	0	.6	.6	0	0	.7	3	.5	.3	0	0	3	0.68	10

T = Trace

APPENDIX B

PLANT COMPOSITION OF DEER PELLETS IN STUDY AREA

Table 16. Plant composition of deer pellets at 18 sites at the Mount Haggin Wildlife Management Area.

Plant	Site # 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	mean
Agropyron spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.14
Bromus spp.	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.4	0.10
Carex spp.	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.07
Festuca spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	17.1	0.0	0.4	0.7	0.0	1.06
Poa spp.	0.0	0.4	0.0	2.2	0.0	1.1	0.0	0.5	0.0	0.0	0.5	1.6	0.8	0.9	0.9	0.0	0.6	0.4	0.55
Amelanchier alnifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.4	0.0	0.0	0.05
Antennaria-Cirsium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02
Arctostaphylos uva-ursi	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03
Artemisia frigida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.8	0.0	0.4	0.8	0.0	0.13
Balsamorhiza sagittata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.4	0.0	0.0	0.05
Berberis repens	36.8	10.5	26.8	11.0	68.6	56.7	36.6	5.9	6.3	14.7	63.4	16.8	0.0	13.0	0.0	12.0	20.4	4.3	22.44
Chrysothamnus nauseosus	0.0	1.9	0.7	2.8	0.0	0.0	0.0	1.9	0.4	4.4	0.0	5.3	3.4	1.4	2.2	2.1	1.5	0.8	1.60
C. viscidiflorus	0.0	0.7	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.11
Composite spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.07
Juniperus scopulorum	10.9	3.4	0.7	6.6	12.0	24.4	24.5	11.8	0.4	8.9	8.9	2.6	48.2	5.1	27.4	7.1	12.4	0.0	11.96
Lupinus spp.	0.0	0.0	1.3	0.5	0.0	0.0	0.0	0.4	0.5	0.7	0.0	0.5	0.0	0.9	0.0	0.4	0.4	0.0	0.31
Phlox spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.03
Pinus contorta	0.0	0.0	0.6	0.0	0.3	3.6	0.0	0.0	0.0	10.9	4.0	7.4	3.6	4.3	15.1	3.5	1.0	0.0	3.02
Pseudotsuga menziesii	0.0	4.6	4.4	1.1	0.0	0.0	0.0	2.9	2.5	17.9	0.0	14.6	13.2	1.2	15.3	1.9	6.2	2.5	4.90
Purshia tridentata	50.7	76.6	61.2	74.2	19.0	14.2	36.3	76.6	87.8	40.3	21.6	49.9	29.2	53.0	38.7	70.7	55.3	91.3	52.60
Rubus spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03
Seed	0.0	0.6	0.7	0.0	0.0	0.0	0.0	0.0	1.3	1.4	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.24
Shepherdia-Elaeagnus	0.6	0.0	1.4	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.6	0.0	0.0	0.4	0.0	0.0	0.3	0.0	0.22
Symphoricarpos albus	0.0	0.0	0.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09
Tetradymia canescens	0.0	0.6	0.0	0.6	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.18
Verbascum spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.02

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