AN ABSTRACT OF THE THESIS OF

Lesley M. Richman for the degree of Master of Science in

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Title: Diet Selection by Conditioned and Unconditioned Goats in the Sagebrush Steppe of Eastern Oregon.

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Douglas E. Johnson

This research examined the diets of angora goats on a sagebrush bunchgrass rangeland. Research objectives were to 1) determine the effects of a positive conditioning method on both mature and immature angora goats; and 2) to quantify plant selection and provide preliminary information as to the potential for using goats to rehabilitate degraded sagebrush rangelands. Goat diets were ascertained using focal-animal bite-count observations during five consecutive seasons, summer 1990 through summer 1991.

Treatment group goats were conditioned for 8 months by including ever-increasing amounts of sagebrush (*Artemisia tridentata* subspp. *wyomingensis*) in their daily ration, up to 25% of their total intake. Conditioning effects were evaluated in a rangeland setting by comparing relative amounts of sagebrush consumption between groups. Our results indicate that while conditioning did not significantly impact sagebrush consumption, young animals consumed significantly more sagebrush than adults. Additionally, learning throughout the first year altered dietary selection by the second summer.

Both does and kids were primarily gramnivorous, however there was strong seasonality in species preference and a significant age difference in diets selected. Age differences in the plant species selected persisted throughout the study until the summer of 1991 when kids were eighteen months old.

Diet Selection by Conditioned and Unconditioned Goats in the Sagebrush Steppe of Eastern Oregon

by

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DIET SELECTION BY CONDITIONED AND UNCONDITIONED GOATS IN THE SAGEBRUSH STEPPE OF EASTERN OREGON

CHAPTER 1

INTRODUCTION

The sagebrush grassland is the largest of the North American semi-desert ecosystem types. In the United States it comprises some 44.8 million hectares in area. 20.5% of Oregon's total land area (approximately 7.6 million hectares) is sagebrush grassland. Effective management in this type of system is necessary because significant portions of this region are in degraded condition and recovery is generally a slow and arduous process. Balanced, healthy rangelands in this region are critical for the survival of multitudinous plant and wildlife species, as well as for the long-term economic stability of the local populace.

In Oregon, deteriorating areas are often characterized by an increasing dominance of shrubby species including sagebrush, rabbitbrush and western juniper. There is often an increase in invading species such as cheatgrass, medusahead, knapweeds and white-top.

Management practices commonly employed to improve range condition include fire, herbicide application, mechanical controls such as chaining or brush-beating, and various systems of grazing management. Many techniques widely used in the past are no longer feasible due to prohibitive costs or pressure from various user-groups. Purposeful manipulation of habitats through the use of livestock grazing is receiving increased attention and is becoming more extensively used than ever before.

Learning, as it relates to diet selection, may be very useful in influencing the preference of grazing animals. Purposeful manipulation of the learning process may enable land managers to influence more effectively, the focus of livestock grazing. Dietary preference, combined with timing of grazing applications, could be a powerful rehabilitative tool for degraded rangelands. We examined a positive conditioning technique in an effort to influence the intake of big sagebrush in a rangeland setting.

This research was designed to investigate some of the possibilities that exist for manipulating vegetation on sagebrush grasslands through managed goat browsing. Goats are prevalent on the Edwards Plateau region in Texas, in localized regions in the southwest, and sporadically sprinkled throughout the United States. While goats are very common on sagebrush steppes on a worldwide basis, they are seldom encountered in this region in the U.S.. Goats have been used successfully for controlling or suppressing many undesirable species. Most of the shrubby species and invading weeds in the sagebrush steppe contain anti-herbivory compounds such as phenolic monoterpenoids or alkaloids, rendering them highly unpalatable to the common livestock species, sheep and cattle. Goats have an ability to tolerate many noxious compounds.

Since very little goat research has focused specifically on the sagebrush-bunchgrass system, we felt it was relevant to investigate what role these animals might play, and in particular, if diet training may give goats the incentive and experience to significantly utilize sagebrush forage. We evaluated the diets of goats for five consecutive seasons, using intensive bite-count observations.

CHAPTER 2

EVALUATION OF A POSITIVE CONDITIONING TECHNIQUE FOR INFLUENCING BIG SAGEBRUSH CONSUMPTION BY GOATS ON A WESTERN RANGELAND

EVALUATION OF A POSITIVE CONDITIONING TECHNIQUE FOR INFLUENCING BIG SAGEBRUSH CONSUMPTION BY GOATS ON A WESTERN RANGELAND

Abstract

Diets of angora goats (Capra hircus) positively conditioned to eat big sagebrush (Artemisia tridentata subspp. wyomingensis) were contrasted with control groups to assess the effects of positive conditioning. Goats were conditioned by including ever-increasing amounts of sagebrush in the daily ration, to a maximum of 25% by weight. Conditioning effects were evaluated by comparing relative consumption of big sagebrush in a rangeland setting. Field trials were conducted at the Squaw Butte Experimental Range, a high desert rangeland in eastern Oregon. Our results indicate that neither conditioned does nor kids had significantly different intake of sagebrush when compared to control animals. Young animals consumed shrub species sooner than adults and ate significantly more shrubs throughout all seasons until the second summer when diets did not differ between age groups.

Key Words: Angora goats, sagebrush, learning, positive conditioning.

Introduction

Relationships between grazing animals and the forage they consume are often difficult to tease apart. Some interrelated factors include: plants present, relative availability of plants, plant phenology, herbivore body size, rumen volume-to-body ratio, mouth size, and behavioral components related to the ecological hierarchy of the area (Hanley 1982 and Senft et al 1987). In spite of the complexity, knowledge of dietary traits and behaviors can be extremely useful for accomplishing specific management objectives. One objective that is likely to be increasingly beneficial in rangeland settings is to modify plant communities by controlled livestock grazing. Areas in degraded condition might be reclaimed or rehabilitated through differential exploitation by livestock. Desirable plant species in a community might be enhanced by specific season or intensity of grazing. Current ranching operations may be able to diversify and achieve additional economic returns if reclamation goals can be accomplished with alternative livestock species.

The psychology of animal learning can be a valuable resource for ecologists interested in the potential roles of learning and memory in foraging behavior (Kamil 1983). In particular, it is possible that through manipulation of dietary experience, a manager may create a foraging group better suited to specific management goals. Young livestock might be trained to increase consumption of less palatable and weedy species, ultimately increasing the value and decreasing the abundance of plants normally considered undesirable. Of particular interest to this study are the possibilities that exist for manipulating vegetation on sagebrush-bunchgrass rangelands, to improve the ecological status of areas in less than optimal condition. In order to forage effectively, animals must acquire information about resources through learning. Learning may serve to adapt herbivores to forages available within their environment, and may help to counter physical and chemical defenses of plants. Manipulation of learning might make diet training possible (Provenza and Balph 1987). Diet training in this sense is the manipulation of livestock foraging behavior to meet a management objective (Provenza and Balph 1987).

One of the critical factors that must be understood before diet training programs can be developed is the exact age at which animals should be exposed to foods (Provenza and Balph 1988). The occurrence of sensitive periods has always been regarded as one of the most important characteristics of imprinting. It is believed that dietary learning is most pronounced early in life and that there may be a sensitive period that coincides with weaning, when learning is most efficient (Provenza and Balph 1987). The most favorable learning period is generally considered to be early in the individual's life, while the young animal is still a member of the family group (Immelman 1975). Only a few studies have looked qualitatively at age and its relation to learning (Arnold and Maller 1977, Squibb 1988).

While the vast majority of diet conditioning studies have focused on aversive conditioning methods (Zahorik and Houpt 1981, Kamil and Yoerg 1982, Braverman and Bronstein 1985, Burritt and Provenza 1989), positive or motivational conditioning areas remain relatively unexplored. Our objective for this research was to examine how diet training through the use of positive or motivational conditioning affects future consumption of plant species to which the animals have been positively conditioned.

This research evaluated the effects of pre-conditioning mature, pregnant angora does to a diet that included ever-increasing amounts of sagebrush. After parturition their kids were also exposed to sagebrush. Effects of that diet learning experience were expressed by the relative amounts of sagebrush later consumed by both does and kids under free-ranging conditions.

Dietary habits of adults are apparently more stable than those of young herbivores (Provenza and Balph 1988). It is our hope that once a group of animals is trained for a specific management purpose, that training will persist, build upon itself and provide a framework for future generations to learn from their familial social group and facilitate further adaptation to that setting.

Since very little goat research has focused specifically on the sagebrush-bunchgrass system, we investigated what role these animals might have in management of problem shrubs, and in particular, if diet training may give goats the incentive and experience to significantly utilize sagebrush forage.

Animals, Materials and Methods

Animals

Thirty (30) mature female angora goats, ranging from 3 to 10 yrs of age, were bred beginning 9/15/89. The animals were housed at Oregon State University for eight (8) months, undergoing breeding, pre-conditioning and kidding. The does were randomly assigned to either the treatment or control group shortly after breeding. Both groups were full-fed a diet consisting of alfalfa hay and grain supplement (as required). In addition, the treatment group received a sagebrush component in their diet.

Conditioning

Prior to feeding, the sagebrush had been harvested and quickly frozen to preserve the volatile oil component. It was presented to the goats after being ground through a shredder/mulcher and mixed with their hay. The sagebrush component was gradually increased throughout the eight (8) month preconditioning period (10/15/89 - 6/15/90) to a maximum of 25% of the goat's diet on a dry weight basis. The does began to kid on 2/15/90. The kids became part of the group of their dam and received the same treatment. This resulted in four groups of animals: conditioned does, conditioned kids, control does, and control kids (COND DOES, COND KIDS, CTRL DOES, CTRL KIDS). Dietary treatments were maintained until the animals began foraging in their rangeland paddocks. Kids were weaned 5/21/90.

Study Site

All the goats were moved on 6/15/90 to the Eastern Oregon Agricultural Research Center, Squaw Butte Experimental Range, 56 kilometers west of Burns, Oregon, where the remainder of this study took place (Appendix Figures 1-3). The Squaw Butte site is in the high elevation intermountain region of eastern Oregon, in the sagebrush-grassland ecotype. Diet studies were conducted in a 40 hectare pasture, divided into four 10-hectare paddocks. Dominant species include Wyoming big sagebrush (Artemisia tridentata subspp. wyomingensis Nutt.), green rabbitbrush (Chrysothamnus viscidiflores (Hook.) Nutt.), Idaho fescue (Festuca idahoensis Elmer), Thurber's needlegrass (Stipa thurberiana Piper), blue-bunch wheatgrass (Agropyron spicatum (Purch.) Scribn.& J.G. Smith) and various other grasses and forbs (Appendix Table 1).

The animals required confinement at night to prevent losses due to predators. In addition, a Great Pyranees guarding dog provided constant protection for the goats. A large holding area (32 meters * 32 meters) was constructed at the junction of the four 10-hectare paddocks with a centrally placed shed/handling facility for conducting weighing and management operations (worming, hoof trimming, etc.). Shade shelters were constructed for the animals which also served as winter shelters after the addition of sides.

Diet Evaluation

Upon introduction to the experimental paddocks at the Squaw Butte Experimental Range, diets selected by goats were monitored daily for the initial 35 day period, using focal animal sampling (Altmann 1974). For each two-day sampling period, 12 individuals from each of the four groups were randomly chosen to be observation animals. During continuous 20 minute periods of observation, bite counts by plant species were recorded for each animal. During each observation season, bite equivalents were hand collected for each plant species. Samples were dried and weighed to provide a biomass equivalent per bite. Given 2 hours in the morning and 2 hours in the afternoon of actual foraging time, observations were made on 24 animals one day and the other 24 were observed the next day. This schedule provided 13 observation periods per goat over the initial 35 days. The order of observations on individuals was randomly assigned to avoid bias. Animals were weighed before introduction to the paddock and every 10 days thereafter to document changes in their condition (Appendix Figure 4). Animals were penned except during observation periods.

Fecal collections were made seasonally on randomly selected goats in each group. Total fecal output combined with hand-collected diet samples and bite count observations were used to provide an estimate of total forage consumption and pasture utilization (see Chapter 3).

Prior to introducing the animals to the paddocks, forage availability was assessed using permanent line and belt transects as well as randomly located plots. Vegetation measurements assessed include: biomass, %cover, density and frequency. Information pertaining to the diets selected by conditioned and unconditioned goats was monitored throughout the following four seasons (until 7/29/91). Studies using sheep by Arnold and Maller (1977) suggest that differences in acceptability of generally disliked species (such as big sagebrush), between groups with differing previous experience will persist until animals are forced to graze on that species for at least a month. Therefore, we monitored diet intensively for the initial 35-day period and then every phenological plant season for the following year to quantify persistence and change.

Data analysis

The dietary data were summarized by converting bites to a biomass basis and averaging each of the four groups (COND DOES, COND KIDS, CTRL DOES, CTRL KIDS) by two-day sampling period. Grams of forage (by species) consumed per hour per kilogram of body weight averaged by group were then analyzed using a General Linear Model (GLM) procedure and a Fisher's Protected Least Significant Difference (LSD) test was performed to identify significant differences. All statistical analyses were performed using SAS procedures (Statistical Analysis Systems Institute, 1988).

Results and Discussion

Initial 35-Day period

Live sagebrush consumption was very low for all groups (0.23 grams/hour/Kg of weight) during the initial 35-day period (Figure 2.1). Conditioning treatment had no effect ($P=0.9768$) on consumption of live sagebrush during this period. Dead sagebrush twig consumption, while not effected by conditioning ($P=0.2328$) tended to be higher ($P=0.1285$) for kids than for does (Figure 2.2). Control kids ate more than 375 bites per hour of dead sagebrush (Figure 2.3), but these bites translate to only 1 gram/hour/Kg of body weight. Total shrub consumption accounted for approximately one-third of the control kid's total diet for this time period (Figure 2.4).

Upon more detailed analysis of dietary trend during the initial 35-day period, we found that kids tended to eat more live sagebrush ($P=.114$) than does. Live sagebrush consumption by does increased the last four days of this observation period ($P=.006$) across both treatment groups. This change could be explained by phenology of sagebrush, which had begun to flower or by changes in availability and phenology of preferred species.

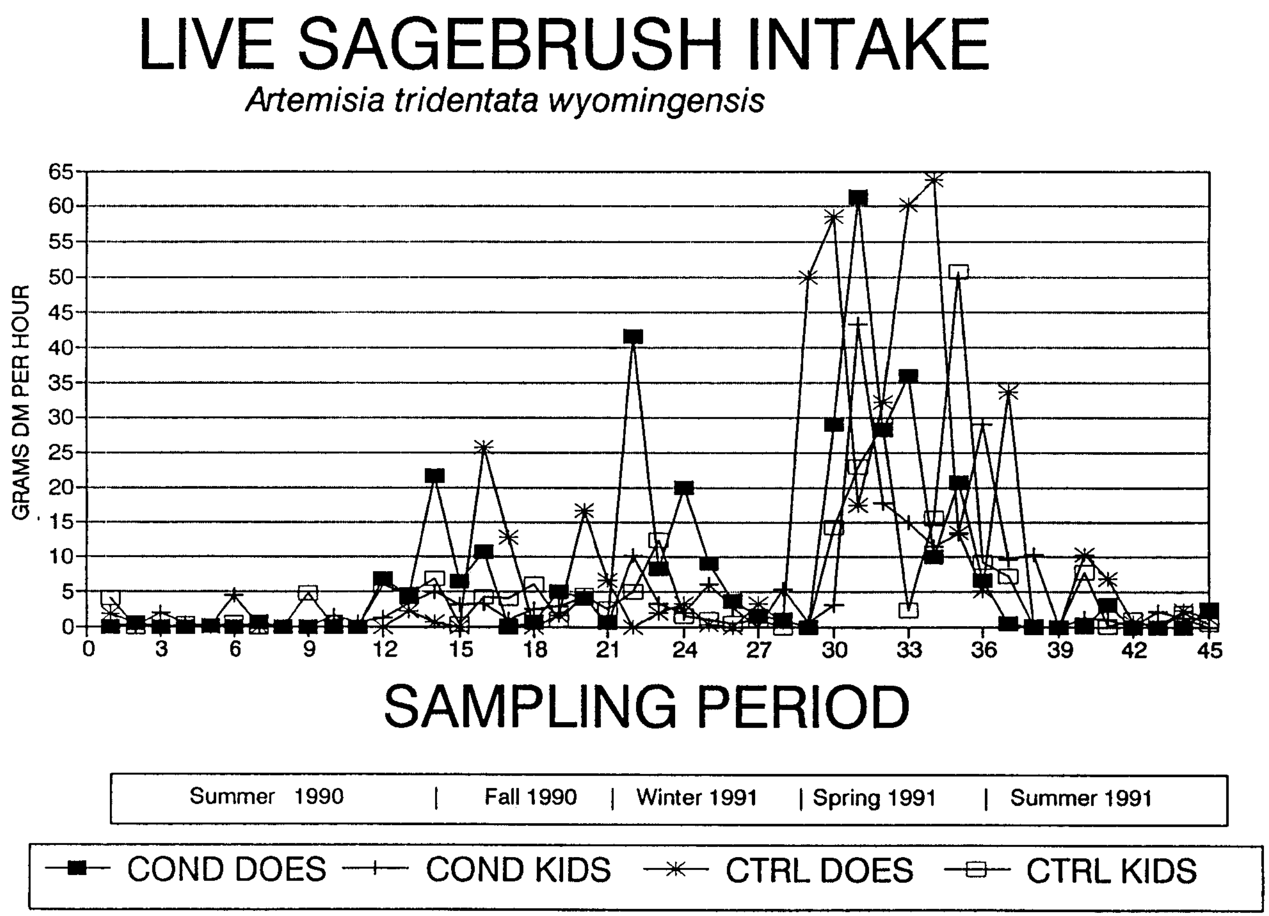

Figure 2.1 Live Sagebrush Intake. Values are presented on a grams of dry matter per hour basis. Intake was assessed seasonally and averaged by treatment group.

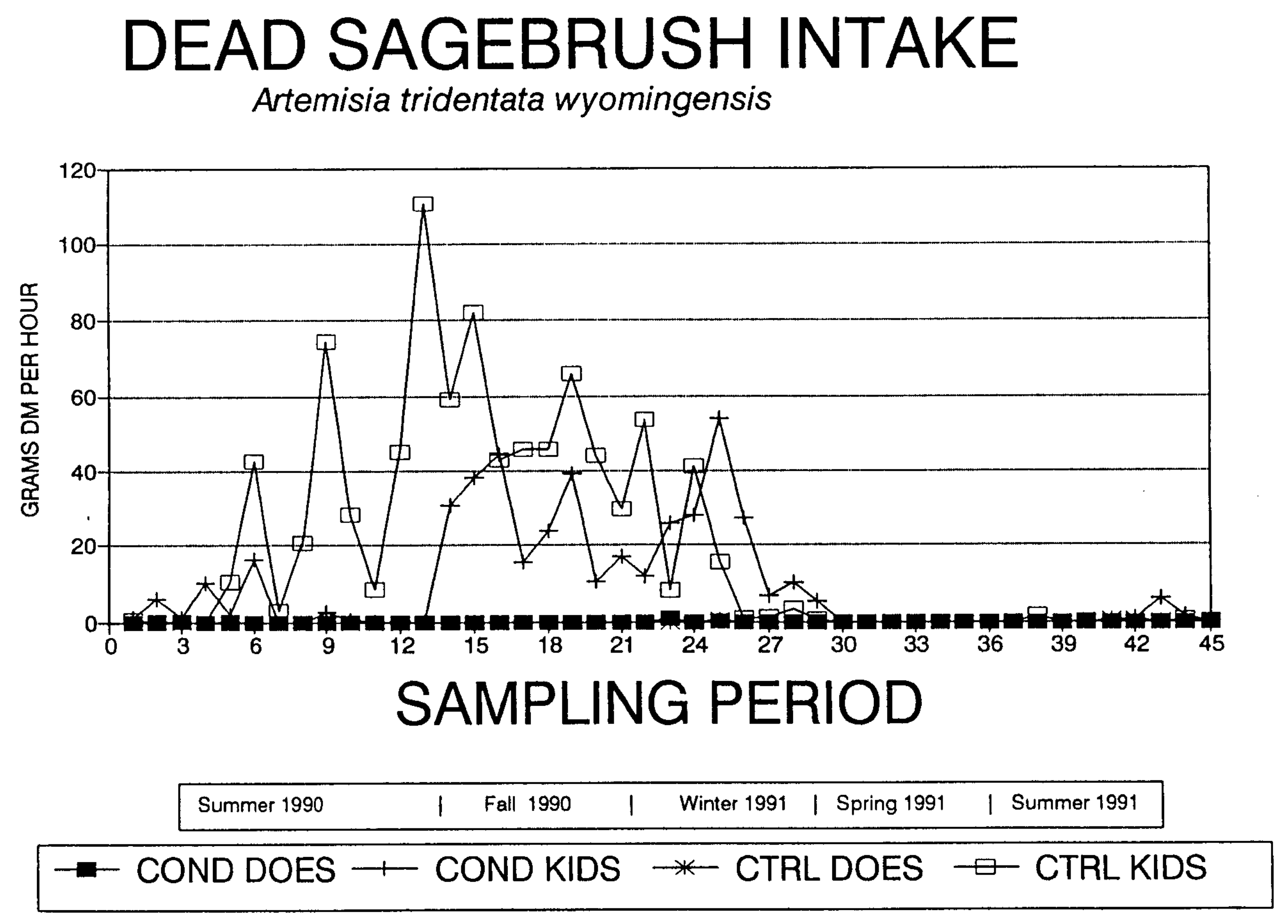

Figure 2.2 Dead Sagebrush Intake. Values are presented on a grams of dry matter per hour basis. Intake was assessed seasonally and averaged by treatment group.

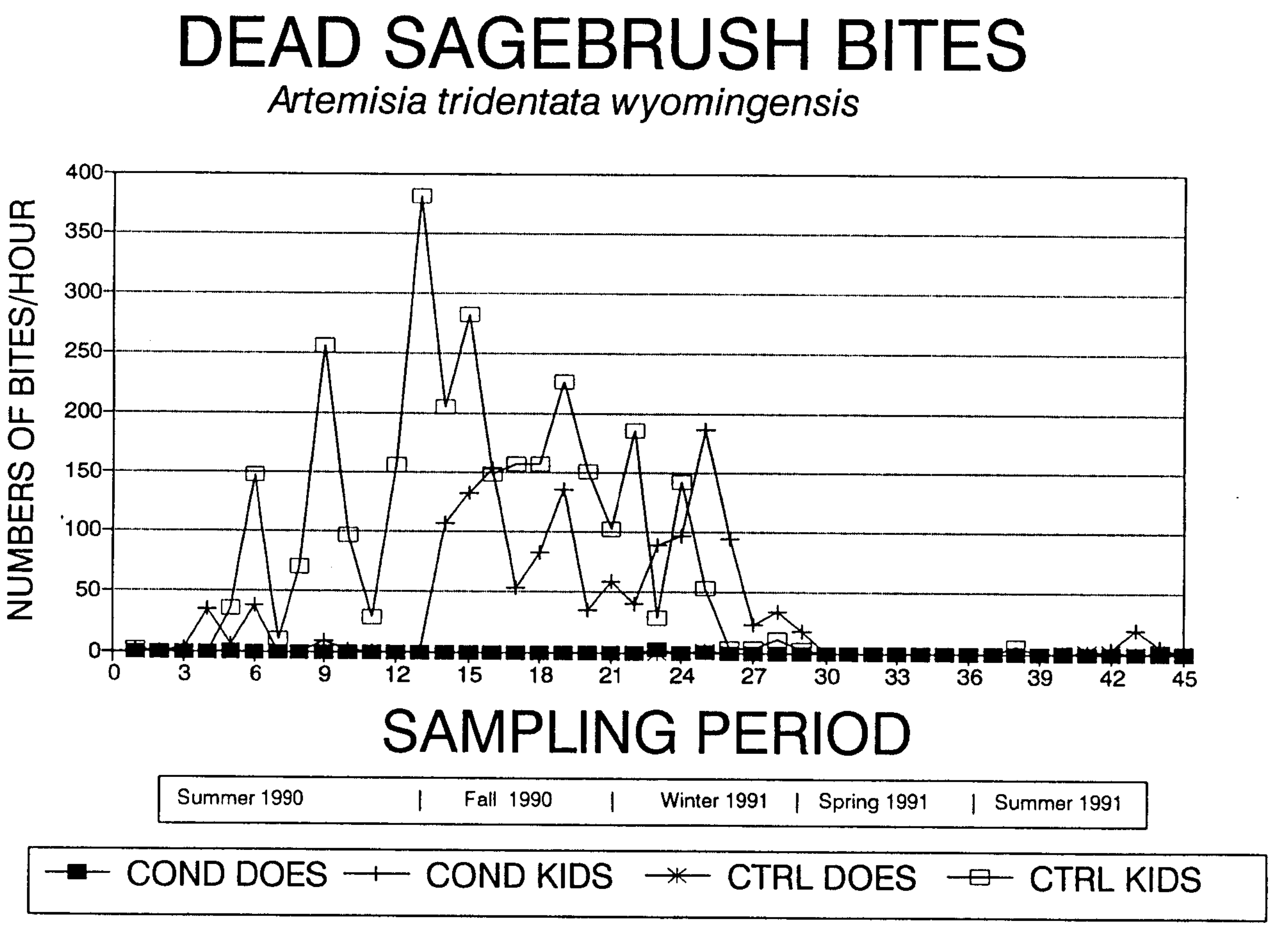

Figure 2.3 Dead Sagebrush Bites. Bites were assessed seasonally and averaged by treatment group.

Seasonal observations

The conditioning treatment had no effect on sagebrush consumption across all five observation seasons (Figure 2.1). Total shrub consumption was similar between control and conditioned groups (P=.172), however kids ate significantly greater amounts of shrubs than did does (P=0.0001) (Figure 2.9). Shrubs include live sagebrush, dead sagebrush, green rabbitbrush, rubber rabbitbrush (Chrysothamnus nauseosus (Pallas ex Pursh.) Britton), gray horsebrush (Tetradymia canescens DC.), granitegilia (Leptodactylon pungens (Torr.) Torr. ex Nutt.), and western juniper (Juniperus occidentalis Hook.).

Overall, the kid groups exhibited a tendency to explore more, especially in their consumption of the various life-forms (Figures 2.4 - 2.8). The kids seemed to compile less focused diets than adults. Kid diets contained larger proportions of minor species. Of the six shrub species monitored in our pasture, kids generally consumed more than does (Appendix Table 12). Of the eleven grass species monitored, does consumed more than kids of ten species. Kid diets remained more diverse except during dormant seasons (fall and winter) as demonstrated by Shannon's diversity index (Appendix Table 2).

In order to determine whether learning had taken place, we compared the diets from Summer 1990 to Summer 1991. In Summer 1991 we found greater consumption of green rabbitbrush (P=.0001), crested wheatgrass (Agropyron desertorum (Fisch. ex Link) J.A. Shultes) (P=0.0009), bluebunch wheatgrass (P=0.0001), Basin wild rye (Elymus cinereus Scribn.& Merrill)

(P=0.007), bottle-brush squirreltail (Sitanion hystrix (Nutt.) J.G. Smith) (P=0.0001), needle-and-thread (Stipa comata Trin.& Rupr.) (P=0.0017), and Thurber's needlegrass (P=0.0002). The two species that decreased in consumption are junegrass (Koelaria pyramidata (Lam.) Beauv.)(P=0.0013) and the bluegrasses (Poa's L.)(P=0.0005). The other species were unchanged. Both kids and does ingested more per kilogram of body weight the second summer which indicates improved foraging skills and a broader acceptability of plant species (Figure 2.10) (Appendix Table 2). This increase affected both treatment groups equally, however increase in grams of intake per kilogram of body weight was greatest for kids.

Because the kids used in this study were weaned prior to grazing in a rangeland setting, they did not have the social training from their mothers that is often considered to be critical for developing effective foraging skills. Additional research should address the role of social training.

Conclusions

Conditioning did not significantly alter dietary choices in either kids or does. Substantial changes in the diets of all groups occurred seasonally, indicating that as plant phenologies and nutritional status change, goat diets will shift as well. All our goat groups had significantly different diets the second summer from the first summer.

This preliminary study leads us to the conclusion that there are many more questions to address concerning the potential for goat research in the sagebrush-bunchgrass region. We see the need to investigate further what the differences are between kids that learn to forage with their mothers versus kids that must learn without mothers, both in new settings and settings to which the does are acclimated. We also need to investigate the impact that grazing by goats, with their unique grazing preferences and habits, will subsequently have on the vegetation and on the health and stability of the overall ecosystem.

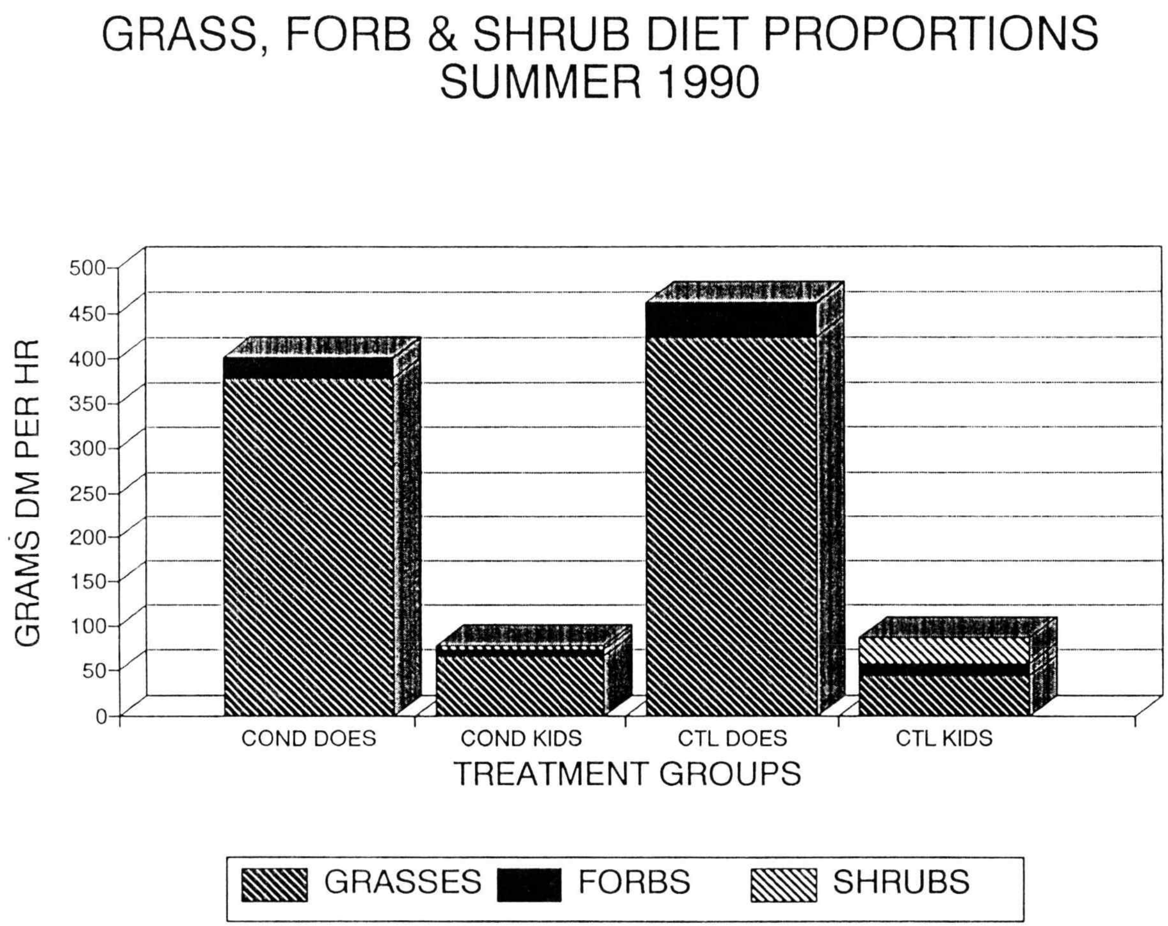

Figure 2.4 Grass, Forb and Shrub Diet Proportions - Summer 1990. Dietary proportions were averaged by treatment groups on a grams of dry matter per hour basis for this season.

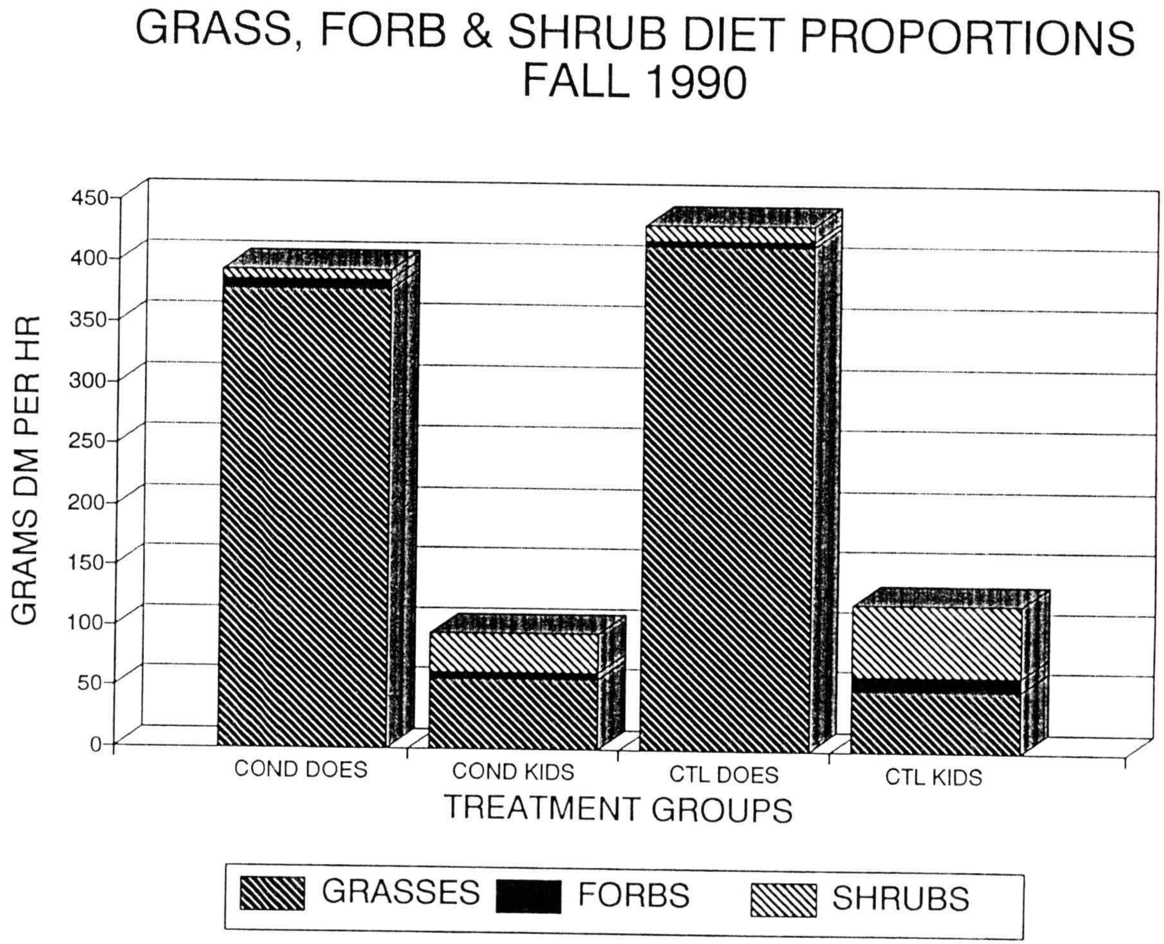

Figure 2.5 Grass, Forb and Shrub Diet Proportions - Fall 1990. Dietary proportions were averaged by treatment groups on a grams of dry matter per hour basis for this season.

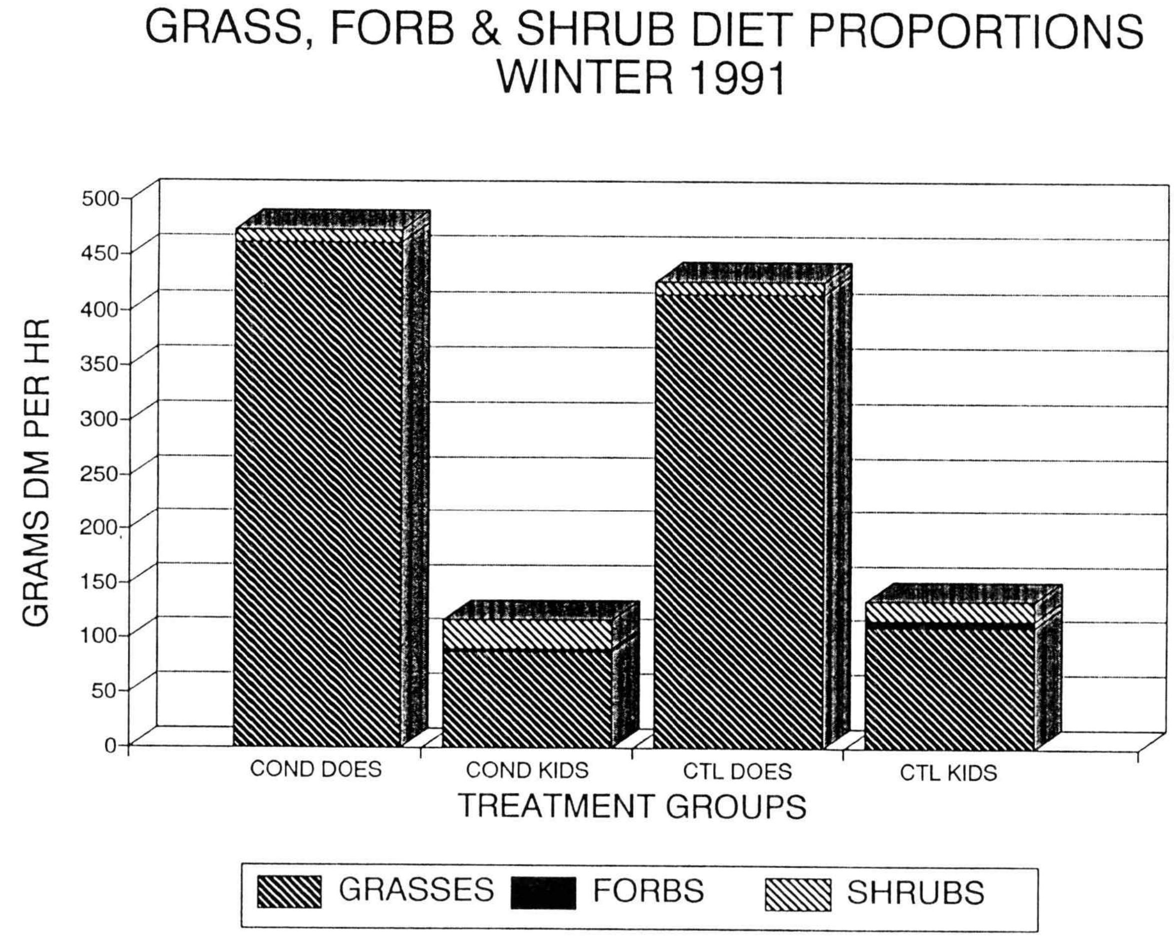

Figure 2.6 Grass, Forb and Shrub Diet Proportions - Winter 1991. Dietary proportions were averaged by treatment groups on a grams of dry matter per hour basis for this season.

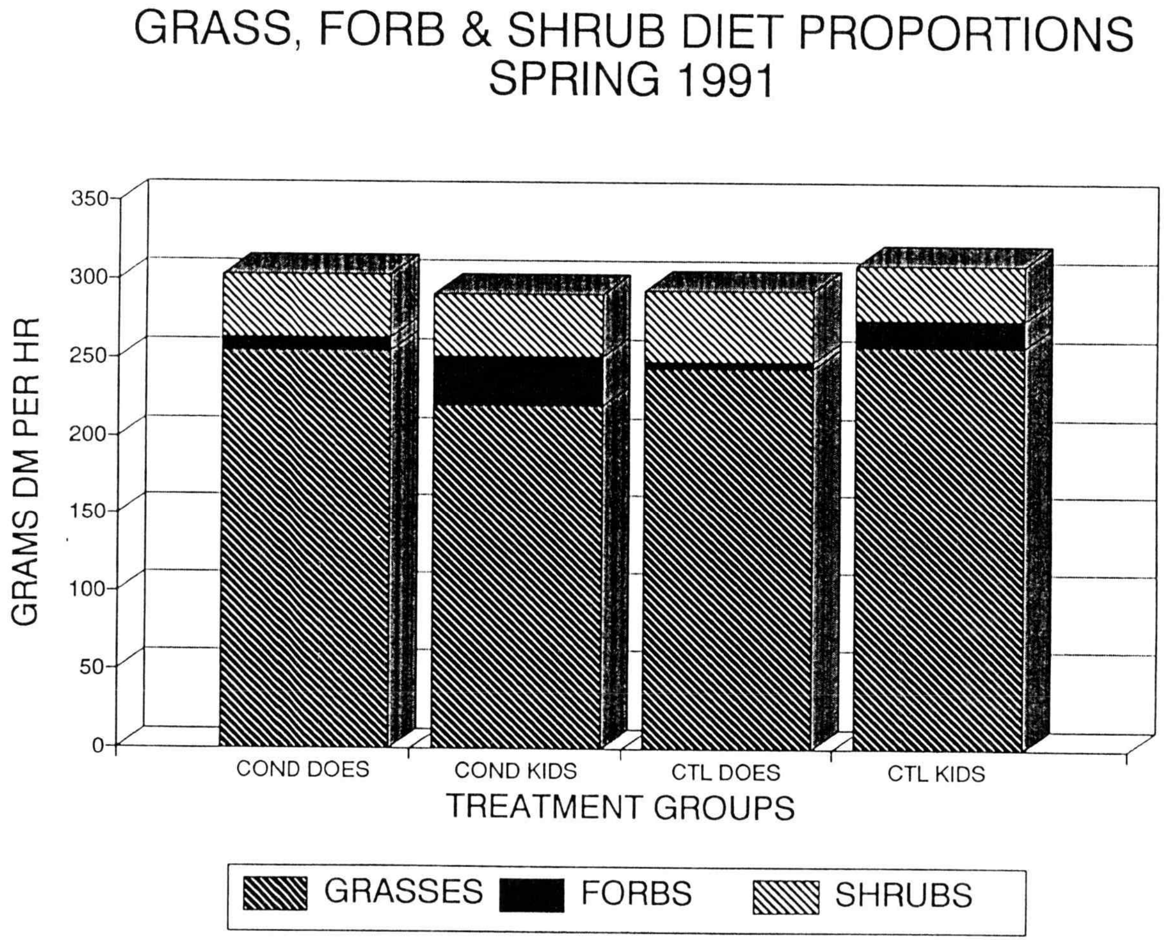

Figure 2.7 Grass, Forb and Shrub Diet Proportions - Spring 1991. Dietary proportions were averaged by treatment groups on a grams of dry matter per hour basis for this season.

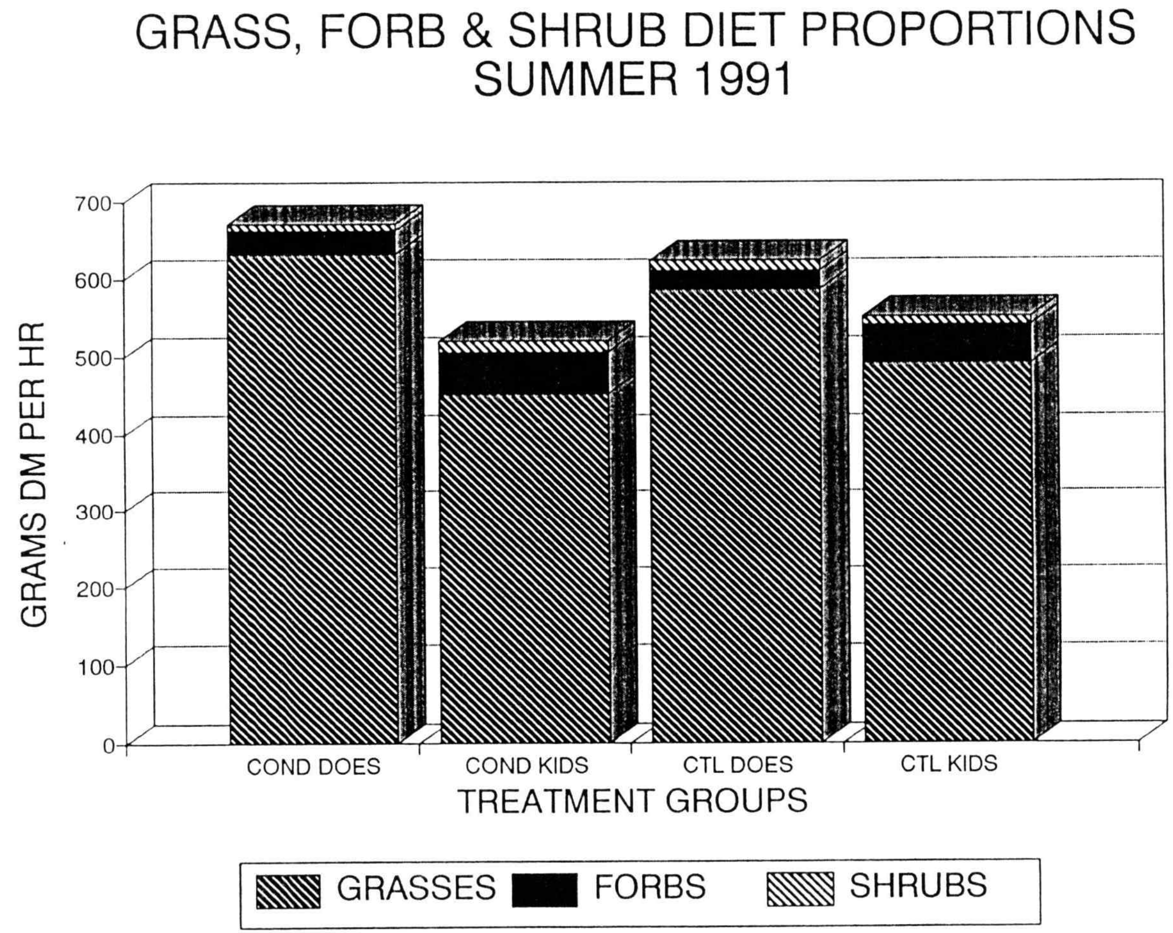

Figure 2.8 Grass, Forb and Shrub Diet Proportions - Summer 1991. Dietary proportions were averaged by treatment groups on a grams of dry matter per hour basis for this season.

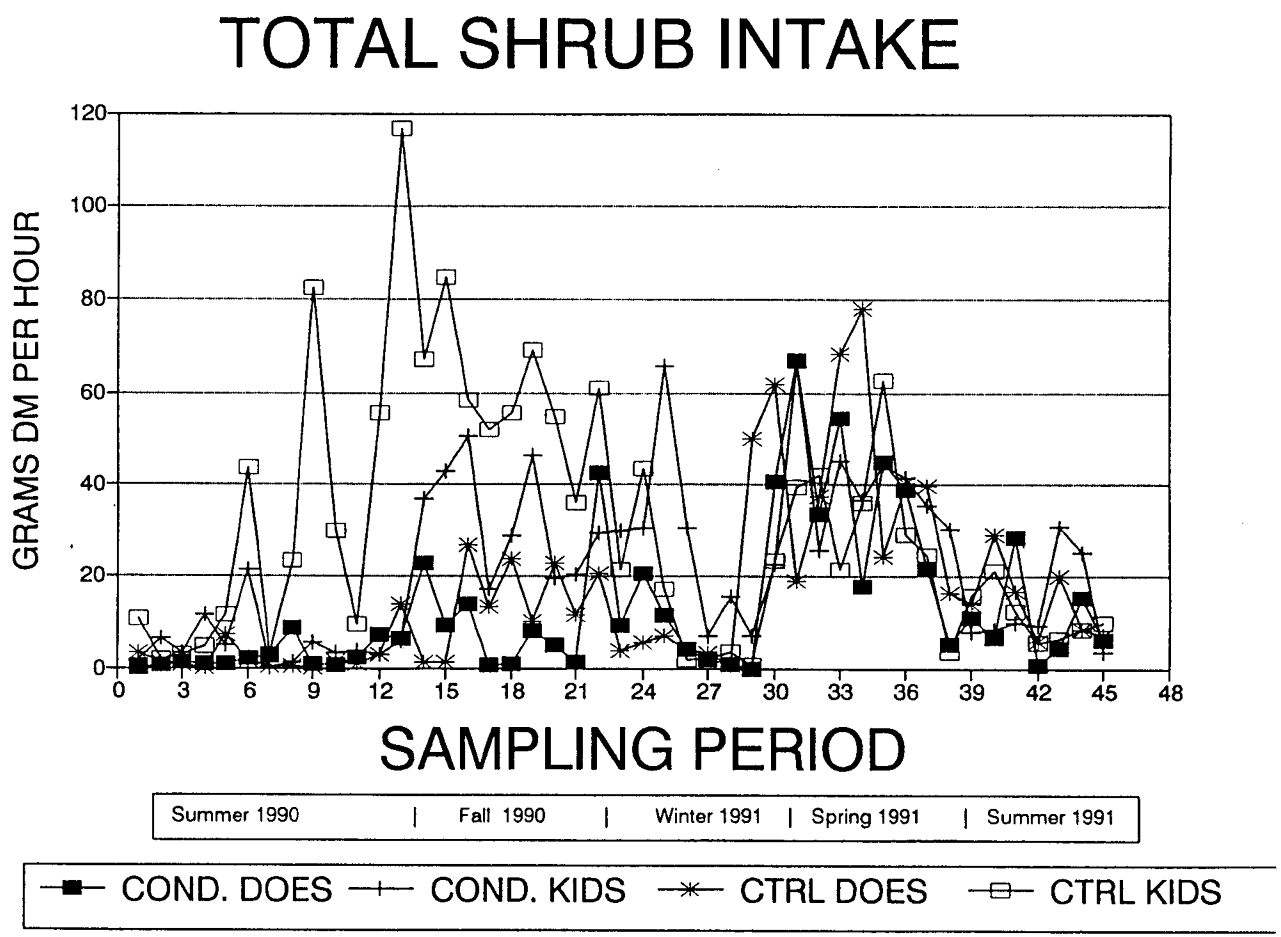

Figure 2.9 Total Shrub Intake. Values were averaged on a grams of dry matter per hour per kilogram of body weight basis. Intake was collected seasonally and averaged by treatment group.

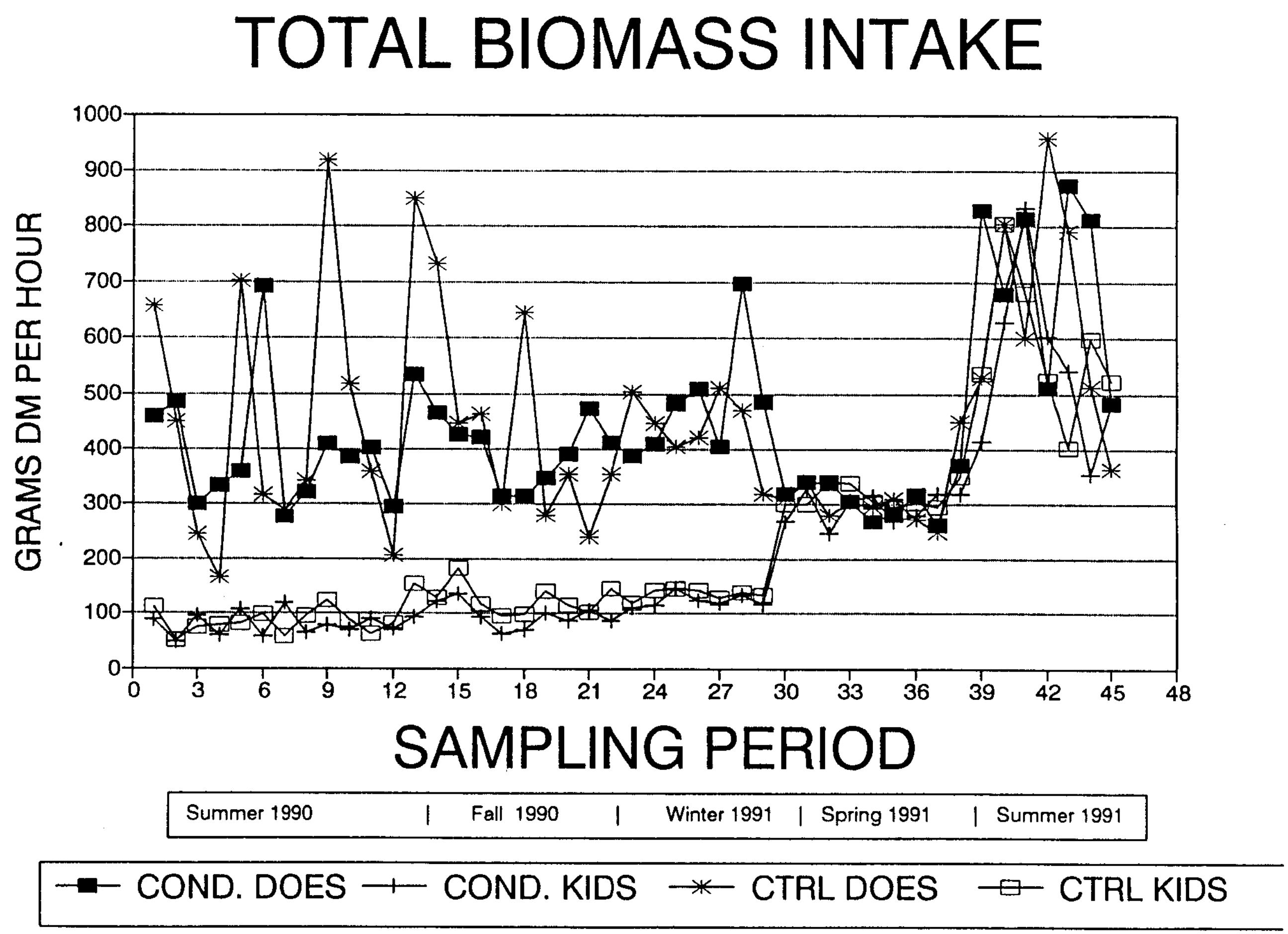

Figure 2.10 Total Biomass Intake. Values were averaged on a grams of dry matter per hour per kilogram of body weight basis. Intake was collected seasonally and averaged by treatment group.

CHAPTER 3

EVALUATION OF DIET SELECTION BY GOATS IN THE SAGEBRUSH STEPPE OF EASTERN OREGON

EVALUATION OF DIET SELECTION BY GOATS IN THE SAGEBRUSH STEPPE OF EASTERN OREGON

Abstract

This study was designed to quantify plant selection by angora goats on a sagebrush-bunchgrass rangeland and to provide preliminary information as to the potential for using goats to rehabilitate sagebrush rangelands in less than optimal condition. A flock of angora goats was purchased and housed on campus at Oregon State University. The goats were bred, randomly assigned to two blocks and kidded. When kids were weaned, all goats were introduced to sagebrush-steppe rangeland at the Squaw Butte Experimental Range, in eastern Oregon. Groups were maintained separately to avoid social learning across groups. Diets were ascertained using focal-animal bite-count observations during five consecutive seasons, beginning with the summer of 1990.

Both does and kids were primarily graminivorous, however there was strong seasonality in species preference and a significant age difference in diets selected. Kids selected a more diverse diet and consumed significantly higher amounts of sagebrush and other woody plants during the initial observation season. Age differences in the plants selected persisted throughout the study until the summer of 1991 when kids were eighteen months old.

Key Words: angora goats, diet, _Artemisia tridentata_, big sagebrush, range rehabilitation

Introduction

Rangelands comprise 40-47% of the world's land area. Effective management of these rangelands is critical, particularly in light of the fact that in much of the world, these areas are in a low state of productivity (World Resources Institute 1986). Where management efforts have been implemented for improvement, techniques that have been employed include mechanical, chemical and biological controls, prescribed fire, and various grazing systems. Many of the techniques widely used in the past are no longer feasible due to prohibitive costs or pressure from other use interests. Purposeful manipulation of habitats through the use of livestock grazing is receiving increased attention and is becoming more extensively used than ever before.

Of particular interest to this study are the possibilities that exist for manipulating vegetation on sagebrush-grassland rangelands through managed goat-browsing, in order to improve the ecological status of areas in less than optimal condition. Currently, the prevalent situation throughout the sagebrush-grass range is too much sagebrush and other low-value shrubs, too many annuals, and not enough perennial grasses and forbs. Additionally, western juniper (Juniperus occidentalis Hook.) expansion is becoming one of the most pressing problems in eastern Oregon. Management goals for this type of range often include a reduction in sagebrush, juniper, and other woody species and an increase in perennial grasses and forbs (Blaisdell et al. 1982).

Proper grazing management can be used to improve sagebrush-grass ranges. Laycock (1967) saw significant results within 2-3 years using sheep. Blaisdell et al. (1982) noted that grazing of sheep during the late fall or winter has shown significant promise for biological control of sagebrush. They felt that grazing by goats was another possibility, but it had not been adequately tested.

Use of goats for management

Because of their ability to utilize coarse forages, goats are well suited to brush control efforts (Merrill 1975). Huss (1971) observed that a prehensile tongue and mobile upper lip enable the goat to feed on browse in areas that offer no other forage. Several studies have examined the response of increaser shrub species to browsing by goats. Radcliffe (1985) has spent considerable research time investigating the potential use of angora goats to control or eradicate gorse (Ulex europaeus L.), which has become a prevalent noxious weed in New Zealand. His research suggests that given time and sufficient stocking rates, goats are very effective and could consume large quantities of gorse throughout the year. Harradine and Jones (1985) in the Tasmanian Midlands examined various stocking densities of angora goats, including one treatment combining goats and sheep. Their results indicate that many stocking densities can be effective after two years for controlling gorse in perennial ryegrass (Lolium perenne L.) pastures following burning. The mohair yields were acceptable, indicating a possibility for product diversification as well.

Norton and Deery (1985) investigated the use of angora goats for eliminating undesirable trees and shrubs from native pastures in South East Queensland. Over a 9-month period, the sprouts of acacias (Acacia flavescens A. Cunn., A.cunninghamii Hook., A. fibriata A. Cunn.) and eucalypts (Eucalyptus spp. L'Her.) less than 1.5 m high were markedly reduced, and groundsel (Baccharis halimfolia L.) was completely eliminated from the area. In another study, almost 50% reduction of undesirable brush species in rundown or abandoned pastures in Vermont was accomplished after one year of goat grazing. After 2 years goats had virtually eliminated all the brushy species from these pastures (Wood, 1987).

Davis et al. (1975) have six years of data from Colorado indicating that goats can be effective in an oakbrush (Quercus gambelii Nutt.) control program. Timing of browsing and stocking density are important considerations for this type of program and repeated treatments involving a rotational browsing scheme are necessary. Knipe (1983) initiated a study to investigate the effectiveness of goats for converting dense Arizona chaparral into a more desirable brush-grass mosaic. His results indicate this may prove to be a feasible method but will require further investigation and intensive grazing management. Provenza et al.(1983) were able to manipulate the growth of blackbrush (Coleogyne ramosissima Torr.) with goats in southwestern Utah. Goat browsing of older basal and terminal branches stimulated twig production which improved the nutritional quality of the forage available to cattle. Warren

(1984) reports on several studies indicating that goats have been used for many years in parts of Texas for control or suppression of undesirable species such as acacia (Acacia spp. Mill.), oaks (Quercus spp. L.), juniper (Juniperus spp. L.), shin oak (Q.mohriana Buckley ex Rydb.), hackberry (Celtis reticulata Torr.) and pricklyash (Zanthoxylum spp. L.). His own study found several problem brush species including blackbrush acacia (Acacia rigidula Benth.), condalias (Condalia spp. Cav.), guajillo (Acacia berlandieri Benth.), guayacan (Porliera angustifolia (Engelm.) Gray), and wolfberry (Lycium berlandieri Dunal) to be important in goat diets. This suggests a high potential for utilizing goats in conjunction with other management practices for more effective shrub control and for increasing the efficiency of forage utilization on mixed-brush rangeland.

Goat diets

Preferences of grazing animals for certain plant species in relation to others are in part determined by genetic heritage, prior experience or conditioning, environmental circumstances and the relative availability of various plants from which the choice is made (Malechek and Provenza 1981). Relatively few dietary studies have been conducted on goats (Malechek and Provenza 1981). Narjisse's (1981) research with sheep and goats indicates that animals previously exposed to sagebrush range could make substantial dietary utilization of this shrub during the spring season. Studies by Warren et al, Malechek and Leinweber and Green et al, as reported by Morrical (1984) indicate that goats exhibit a high degree of selectivity in species they will utilize. Thus the success of goats browsing as a brush control agent, may be dependent on the palatability of the shrub species to be controlled. Because goats are reported to be less affected by bitter tastes (Bell 1959), they may have an increased ability to consume browse species high in secondary compounds (Morrical 1984). In fact, studies by both Malechek (1970) and Knipe (1983) noted that juniper (Juniperus spp.) was readily eaten by goats. Consumption of browse by goats increases during the dry period of areas characterized by distinct wet and dry seasons (Malechek and Provenza 1981). Taylor's (1983) study indicates that the amount of browse consumed by goats is largely dependent on the physiological condition of the herbaceous vegetation. On the Edwards Plateau in southwest Texas, Malechek (1970) observed that grass consumption by goats during the spring, summer and fall appeared to parallel the growth cycle of warm-season perennial grasses in the study area. Grass in the diet declined as available grass dried and became less palatable. Grass and browse composed about equal proportions of the winter diets but browse consumption increased in early spring, and replaced grass as the dominant forage class in November. Several studies of goat diets on west Texas ranges noted an approximately 40% browse component averaged across seasons and years (Malecheck 1970, Bryant 1977, and Taylor 1983). Warren et al. (1984) found that shrubs were the most important food of spanish goats in the south Texas plains, contributing over 50% of the diet in summer, autumn and winter.

Because of the goats flexibility in coping with a wide variety of dietary alternatives, it is widely distributed ecologically and is of extreme value in areas of adverse forage conditions, particularly shrublands (Huss 1971). Goats graze more diverse kinds of vegetation and distribute themselves more evenly than either cattle or sheep. Their inclusion in a grazing system should therefore, increase efficiency of utilization in ecosystems exhibiting diverse life forms (Taylor 1983). However, most studies that focus on the use of goats for biological manipulation of habitat agree that this method will require some form of intensive grazing management (Davis et al. 1975, Fierro et al. 1982, Green 1982, Kiesling et al. 1982, Knipe, 1983).

Herbivory and management in sagebrush grasslands

The diet selected under a given set of conditions is the product of numerous local variables, making generalizations from studies in other areas of limited value (Malechek 1970). However, when applied to the site from which the data originated, these studies can provide range managers with a partial basis for making management decisions.

Sagebrush grasslands in the United States present a considerable challenge to managers. In deteriorated areas the sagebrush component has increased dramatically at the expense of the more desirable bunchgrasses and forbs. In some areas, this has led to even more severe problems where juniper (Juniperus spp. L.) has gained a foothold, exacerbating the degeneration of the area, or where rabbitbrush (*Chrysothamnus* spp. Nutt.) has begun to increase, often limiting management alternatives even further.

Many of the native woody species common to the sagebrush region produce anti-herbivory compounds in their leaves and stems. Many species are high in volatile oils including phenolic monoterpenoids. Whereas native herbivores (pygmy rabbits, sage grouse, mule deer, antelope) that have coevolved with these shrubs consume the plants as part of their diet, introduced domestic herbivores in general avoid or limit consumption (as reported by Kelsey et al. 1983). Because sheep and cattle tend to prefer grasses and forbs, this puts additional stress on these life-forms, giving an increased competitive advantage to the woody species. We feel that goats may provide a method for focusing browsing onto the woody components and help shift the competitive advantage more toward grasses and forbs. Managed goat browsing may substantially curb the expansion and increasing density of problematic woody species and corresponding herbaceous understory degradation.

Materials and Methods

Animals

Thirty (30) mature female angora goats, ranging from 3 to 10 years of age, were bred beginning 9/15/89. The animals were housed on the Oregon State University campus for eight (8) months, undergoing breeding, group acclimation and kidding. The does were randomly assigned to one of two groups shortly after breeding. The does began to kid on 2/15/90. Kids were weaned on 5/21/90 and divided into two groups. This resulted in four groups: Does I, Does II, Kids I, and Kids II.

Study Site

All the goats were moved on 6/15/90 to the Eastern Oregon Agricultural Research Center, Squaw Butte Experimental Range, 56 kilometers west of Burns, Oregon (Appendix Figures 1-3), where the remainder of this study took place. The Squaw Butte site is in the high elevation intermountain region of eastern Oregon in the sagebrush-grassland ecotype. Elevation ranges from 1200 to 1500 meters, with an average annual precipiataion of 280 mm. Diet studies were conducted in a 40 hectare pasture, divided into four 10-hectare paddocks. Dominant species include Wyoming big sagebrush (Artemisia tridentata subspp. wyomingensis Nutt.), green rabbitbrush (Chrysothamnus viscidiflores (Hook.) Nutt.), Idaho fescue (Festuca idahoensis Elmer), Thurber's needlegrass (Stipa thurberiana Piper), blue-bunch wheatgrass (Agropyron spicatum (Pursh.) Scribn & J.G. Smith) and various other grasses and forbs (Appendix Table 1).

The animals were confined at night to control losses due to predators. In addition, a Great Pyrenees guarding dog was purchased in the fall of 1990 to provide constant protection for the goats. A large holding area (32 meters * 32 meters) was constructed at the junction of the four 10-hectare paddocks with a centrally placed shed/handling facility for conducting weighing and management operations (worming, hoof trimming, etc.). Shade shelters were constructed for the animals which also served as winter shelters with the addition of solid sides. After an initial 5 week diet examination period, diet selection was determined seasonally over the ensuing 12 months.

Diet Evaluation

Upon introduction to the rangeland setting at the Squaw Butte Experimental Range, the diets selected by the goats were monitored daily for the initial 35 day period, using focal animal sampling (Altmann 1974). For each two-day sampling period, 12 individuals from each of the four groups were randomly chosen as observation animals. During continuous 20 minute periods of observation, bite counts by plant species were recorded for each animal. Given 2 hours in the morning and 2 hours in the afternoon of actual foraging time, observations were made on 24 animals one day and the other 24 were observed the next day. This schedule provided 13 observation periods per goat over the initial 35 days. The order of observations on individuals was randomly assigned to avoid bias. A technician was required to facilitate these observations. Animals were weighed before introduction to the paddock and every 10 days thereafter to document changes in their condition. The dietary data were summarized by converting bites to a biomass basis and averaging each of the four groups (Does I, Does II, Kids I, Kids II) by two-day sampling period. Grams of forage (by species) consumed per hour per kilogram of body weight averaged by group were then analyzed using a General Linear Model (GLM) procedure and a Fisher's Protected Least Significant Difference (LSD) test was performed to identify significant differences. All statistical analyses were performed using SAS procedures (Statistical Analysis Systems Institute, 1988). The model examined each individual plant species in the diet, as well as total grasses, forbs and shrubs. Procedures were run for each season separately, as well as across all seasons.

Fecal collections were made seasonally on five randomly selected goats in each of the four groups (Does I, Does II, Kids I, Kids II). Bite-count estimates of intake averaged by group and by season were compared to intake estimates generated from fecal production corrected for digestibility (Table 3.1). Correlation analysis using procedures in SAS yielded R^2 values from 0.793 to 0.979 for animals with successful fecal collections (Table 3.1). Fecal collections on does were quite difficult to obtain. Collections were often lost due to urine contamination. For kids, only male goats were used for fecal collections to

Season	Age	Group	Pearson Correlation Coefficient
Summer/Fall 1990	Doe	I	0.793
Summer/Fall 1990	Doe	II	0.979
Summer/Fall 1990	Kid	I	0.960
Summer/Fall 1990	Kid	II	0.827
Spring 1991	Doe	I	0.806
Spring 1991	Doe	II	-0.505
Spring 1991	Kid	I	0.930
Spring 1991	Kid	II	0.515
Summer 1991	Kid	I	0.845
Summer 1991	Kid	II	0.862

Table 3.1 Fecal Correlation. Correlation of fecal production was estimated by bite count intake adjusted for forage digestibility with fecal bag collection. Intake was calculated by using the formula:

$$Intake = \frac{fecal\ production}{day} \ x \ \frac{100}{100 - invitro\ digestibility}$$

avoid contamination problems. Fecal bags often had a negative impact on normal feeding behavior. Due to these limitations, we believe that the reliability of our ocular estimates are as good or better than fecal collections. We monitored goat diets intensively throughout the initial 35-day period and then every phenological plant season for the following year to quantify persistence and change.

Vegetation sampling and monitoring

Prior to introducing the animals to the paddocks, forage availability was assessed using permanent line and belt transects as well as randomly located plots. Climatic data were collected from the Squaw Butte weather station. Daily ppt and temperature readings were recorded (Appendix Table 4).

A species list of the study site was compiled (Appendix Table 1). For each 10-hectare paddock, species presence on a .25 meter^2 plot basis was determined as percent frequency in 300 plots read on a regular grid for each paddock (Appendix Table 5). Percent vegetative cover was determined for each species from five permanent 50 meter line transects per paddock, randomly stratified across each paddock (Appendix Table 6). Percent cover was read during peak standing crop in 1990 and 1991. Shrub density was measured in 1 meter belts along each line transect at peak standing crop 1990 and 1991 (Appendix Table 7).

Herbaceous biomass estimates were assessed by clipping. Two 1 meter^2 plots, randomly paced off near each 50 meter transect were clipped by species each season to provide estimates of herbaceous biomass (Appendix Tables 8 and 9). The 1990 and 1991 peak standing crop plots were assessed for density of herbaceous species prior to clipping (Appendix Table 10).

A biomass estimate of "utilizable browse" on a per-area basis was determined for the shrub species, sagebrush and green rabbitbrush, by reading fifty meter^2 plots for each paddock. Within each plot, measurements of height, maximum diameter, minimum diameter and percent alive were recorded for each shrub species. Biomass typically consumed by goats (including stems to 1/2 inch in diameter) was dried and weighed and regression equations were calculated as described by Rittenhouse and Sneva (1977), based on pre-harvest measurements of height, maximum diameter, minimum diameter and percent alive. Regressions were developed for both perennial and ephemeral (springtime) foliage using Statgraphics. Regressions required formulas to be calculated on a natural log basis for the formulas. Dry biomass antilogs were used for estimating available shrub biomass in the field (Appendix Table 11).

Step-wise Regression formulas are as follows:

ephemeral foliage (sagebrush and green rabbitbrush)

Dry weight = -3.942 + (1.131 x LN Ht) + (0.895 x LN MaxDiam)

R^2 = 0.942

perennial foliage (sagebrush and green rabbitbrush)

Dry weight = -5.413 + (1.109 x LN MaxDiam) + (0.602 x LN MinDiam) + (0.794 x %Live)

R^2 = 0.915

where: LN = natural log; Ht = shrub height; MaxDiam = maximum shrub diameter; MinDiam = minimum shrub diameter; %Live = percent of plant alive

Three permanent grazing exclosures (16 by 24 meters^2) were constructed in each paddock. These served as photo-reference plots. Photos were taken in each season, just prior to diet observations for that season.

The initial vegetation sampling was done prior to introducing the goats to the pasture. Throughout the following 12 months, photo references and clipping to estimate herbaceous biomass were conducted each phenological plant season just prior to diet evaluation during that season. All other vegetation parameters were remeasured at peak standing crop, 1991.

Results and Discussion

Grass made up the largest proportion of both adult and kid goat diets in all seasons (Figures 3.1, 3.2 and Appendix Table 12). Bluegrasses (Poa spp. L.) and crested wheatgrass (Agropyron desertorum (Fisch. ex Link) J.A. Shultes) were consistently among the main dietary constituents through most seasons but by the summer of 1991, consumption of bluegrasses was reduced because it's standing crop was reduced to only 18 KgDM/Ha (Appendix Table 8). Preference indices were calculated for all major dietary constituents for each season by age group (Table 3.2).

The species of grasses consumed varied considerably with season and age groups (Figures 3.3 - 3.10). Thurber's needlegrass was a major constituent of both doe and kid diets in the fall and the summer of 1991 but consumption was significantly less in winter and spring (P=0.0001). The pattern of Idaho fescue consumption was opposite the Thurber's needlegrass pattern. Does ate substantial amounts of Idaho fescue in the fall and winter. Kids, however, did not eat substantial amounts until winter. Idaho fescue made up the largest single constituent of doe winter diets but only a small portion of kid winter diets. Junegrass (Koelaria pyramidata Lam. Beauv) was a relatively constant component of doe diets throughout the seasons whereas it was never a large component of kid diets (P=0.0001). Bluebunch wheatgrass became a major

Table 3.2. Goat Preference Indices. Dietary preference of goats was calculated in each season for both does and kids. VD&H = Van Dyne and Heady's Index calculated as: Percent in Diet/Percent on Range. Krueger = Krueger's Index calculated as: Percent Frequency in Diet * Percent Biomass in Diet / Percent Frequency on Range * Percent Biomass on Range.

Plant Species	DOES		KIDS	
	Preference Indices		Preference Indices	
Season	VD&H	Krueger	VD&H	Krueger
SHRUBS				
Artemisia tridentata (dead)				
SUM90	0.00	0.00	0.66	0.12
FAL90	0.00	0.00	1.27	1.68
WIN91	0.00	0.00	0.45	0.37
SPR91	0.00	0.00	0	0
SUM91	0.00	0.00	0	0
Artemisia tridentata (live)				
SUM90	0.01	0.00	0.06	0
FAL90	0.06	0.00	0.1	0.01
WIN91	0.06	0.01	0.08	0.01
SPR91	0.48	0.18	0.29	0.08
SUM91	0.01	0.00	0.01	0
Chrysothamnus viscidiflores				
SUM90	0.01	0.00	0.07	0
FAL90	0.02	0.00	0.04	0
WIN91	0.03	0.00	0.04	0
SPR91	0.23	0.03	0.33	0.06
SUM91	0.07	0.00	0.09	0.01

Table 3.2 (continued)

Plant Species	DOES		KIDS	
	Preference Indices		Preference Indices	
Season	VD&H	Krueger	VD&H	Krueger
GRASSES				
Agropyron desertorum				
SUM90	29.17	41.66	17.16	38
FAL90	43.88	1.11	27.12	32.57
WIN91	3.03	4.07	1.88	1.81
SPR91	6.94	8.32	8.29	10.21
SUM91	8.94	20.19	11.85	29.81
Agropyron spicatum				
SUM90	0.74	0.11	0.15	0
FAL90	0.22	0.01	0	0
WIN91	3.55	3.36	1.27	0.46
SPR91	7.08	2.87	5.44	1.54
SUM91	14.66	28.19	7.71	8.75
Festuca idahoensis				
SUM90	0.16	0.01	0.08	0
FAL90	1.37	0.71	0.2	0
WIN91	7.55	3.35	0.98	0.12
SPR91	1.99	0.33	1.75	0.19
SUM91	0.28	0.00	0.35	0.03

Plant Species	DOES		KIDS	
	Preference Indices		Preference Indices	
Season	VD&H	Krueger	VD&H	Krueger
Koelaria pyramidata				
SUM90	13.13	22.25	1.14	0.11
FAL90	6.76	2.56	0.7	0.01
WIN91	0.56	0.02	0	0
SPR91	37.53	1.29	33.07	2.01
SUM91	2.49	0.52	4.18	1.06
Poa spp.				
SUM90	3.72	1.37	4.82	2.48
FAL90	5.60	1.70	2.99	0.74
WIN91	0.31	0.00	0.25	0
SPR91	16.57	8.76	14.03	5.99
SUM91	0.60	0.01	0.32	0
Sitanion hystrix				
SUM90	1.13	0.17	1.14	0.17
FAL90	2.68	0.63	1.26	0.14
WIN91	2.11	0.18	1.27	0.08
SPR91	4.94	1.23	5.44	1.62
SUM91	3.08	1.14	2.21	0.72
Stipa comata				
FAL90	13.68	38.14	8.26	6.72
SUM91	13.25	28.74	57.67	435.38

Plant Species	DOES		KIDS	
	Preference Indices		Preference Indices	
Season	VD&H	Krueger	VD&H	Krueger
Stipa thurberiana				
SUM90	1.52	0.28	0.56	0.02
FAL90	5.56	2.34	1.89	2.34
WIN91	0.82	0.02	0.26	0.02
SPR91	1.96	0.13	2.77	0.13
SUM91	2.92	0.66	1.99	0.66
FORBS				
annual forbs				
SUM91	4.02	0.37	7.9	1.35
perennial forbs				
SUM90	30.00	5.48	57.9	18.74
SUM91	0.78	0.05	1.31	0.19

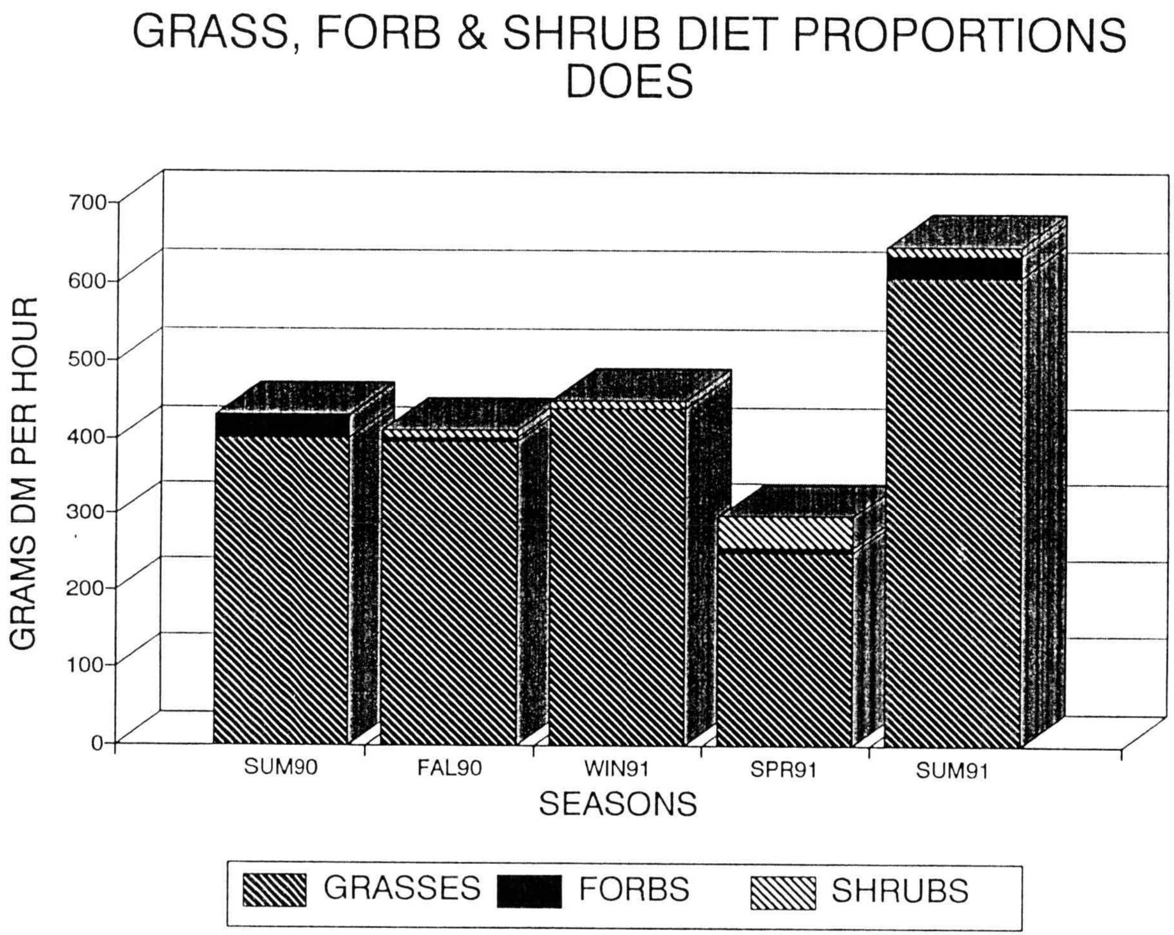

Figure 3.1. Grass, Forb and Shrub Diet Proportions - Does. Dietary proportions were averaged on a grams of dry matter per hour basis for each season.

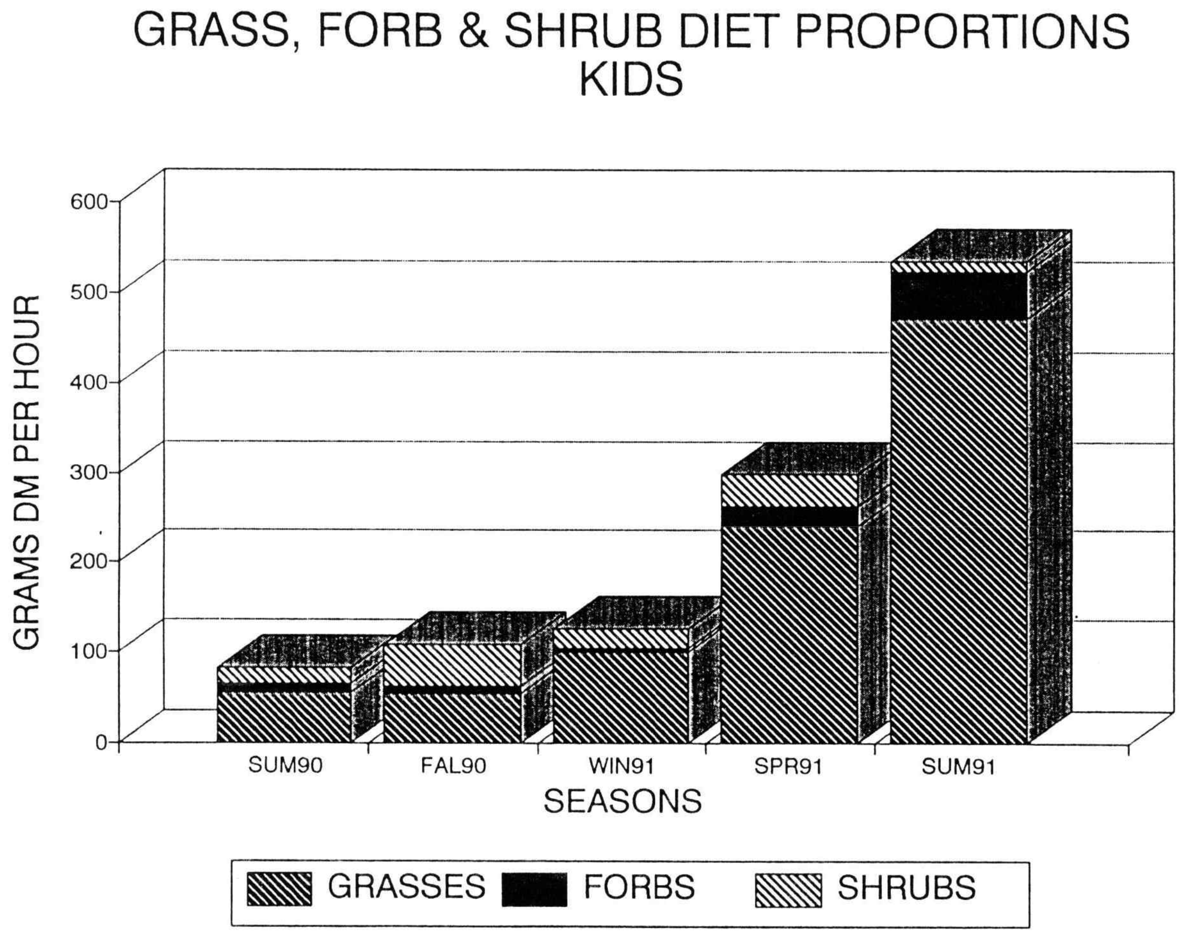

Figure 3.2. Grass, Forb and Shrub Diet Proportions - Kids. Dietary proportions were averaged on a grams of dry matter per hour basis for each season.

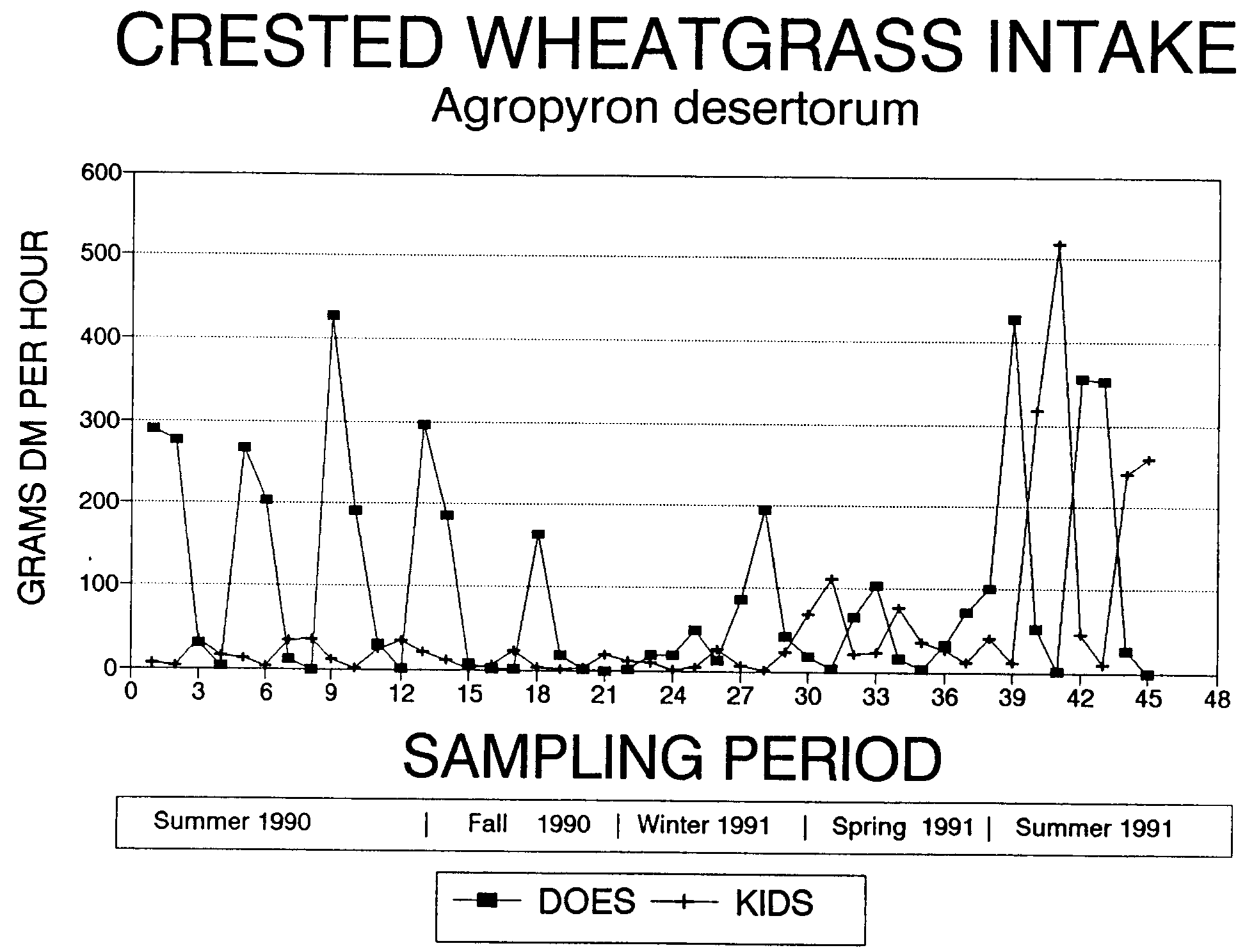

Figure 3.3. Crested Wheatgrass Intake. Intake was averaged on a grams of dry matter per hour basis for each age group in each season.

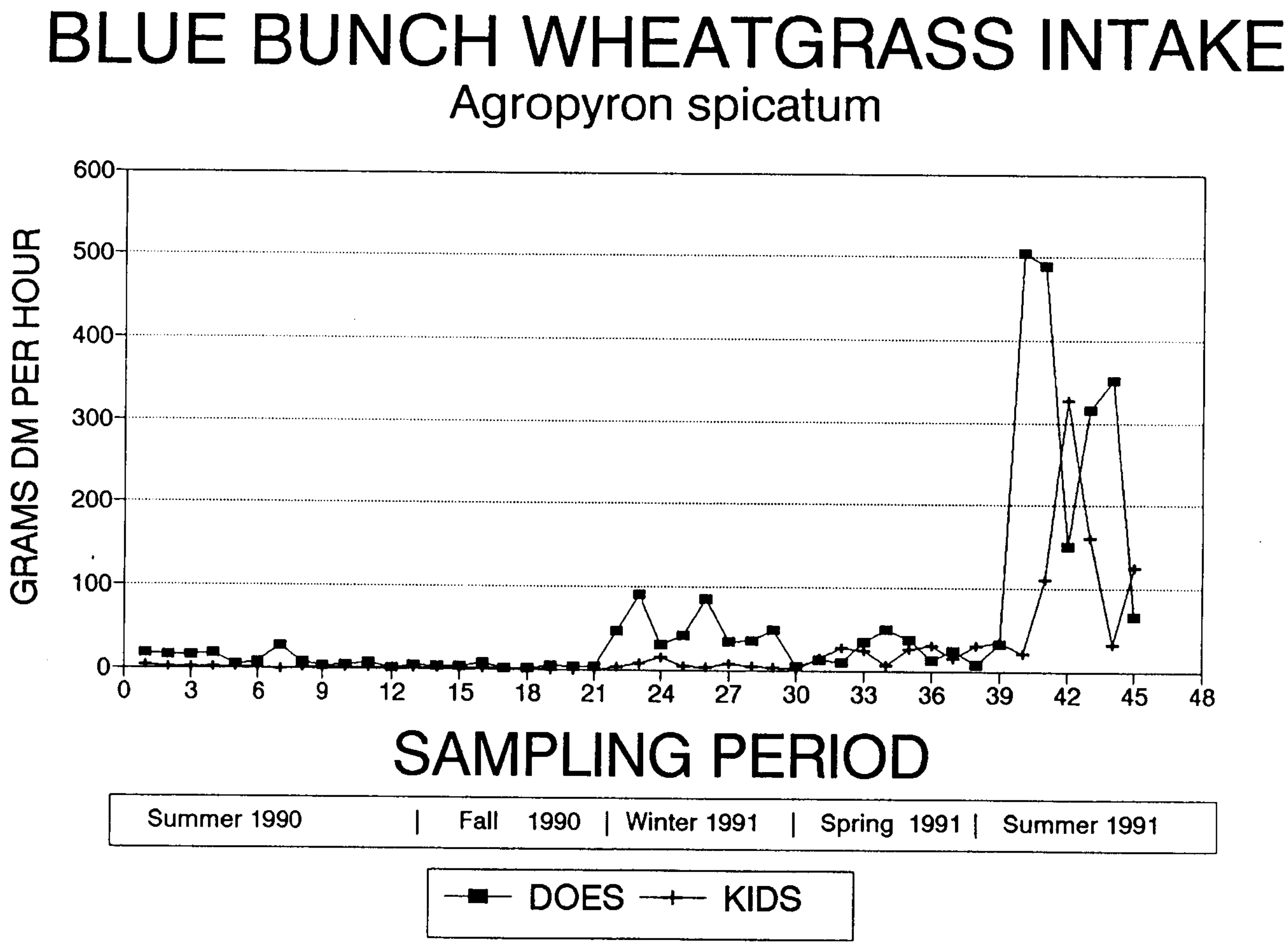

Figure 3.4. Blue Bunch Wheatgrass Intake. Intake was averaged on a grams of dry matter per hour basis for each age group in each season.

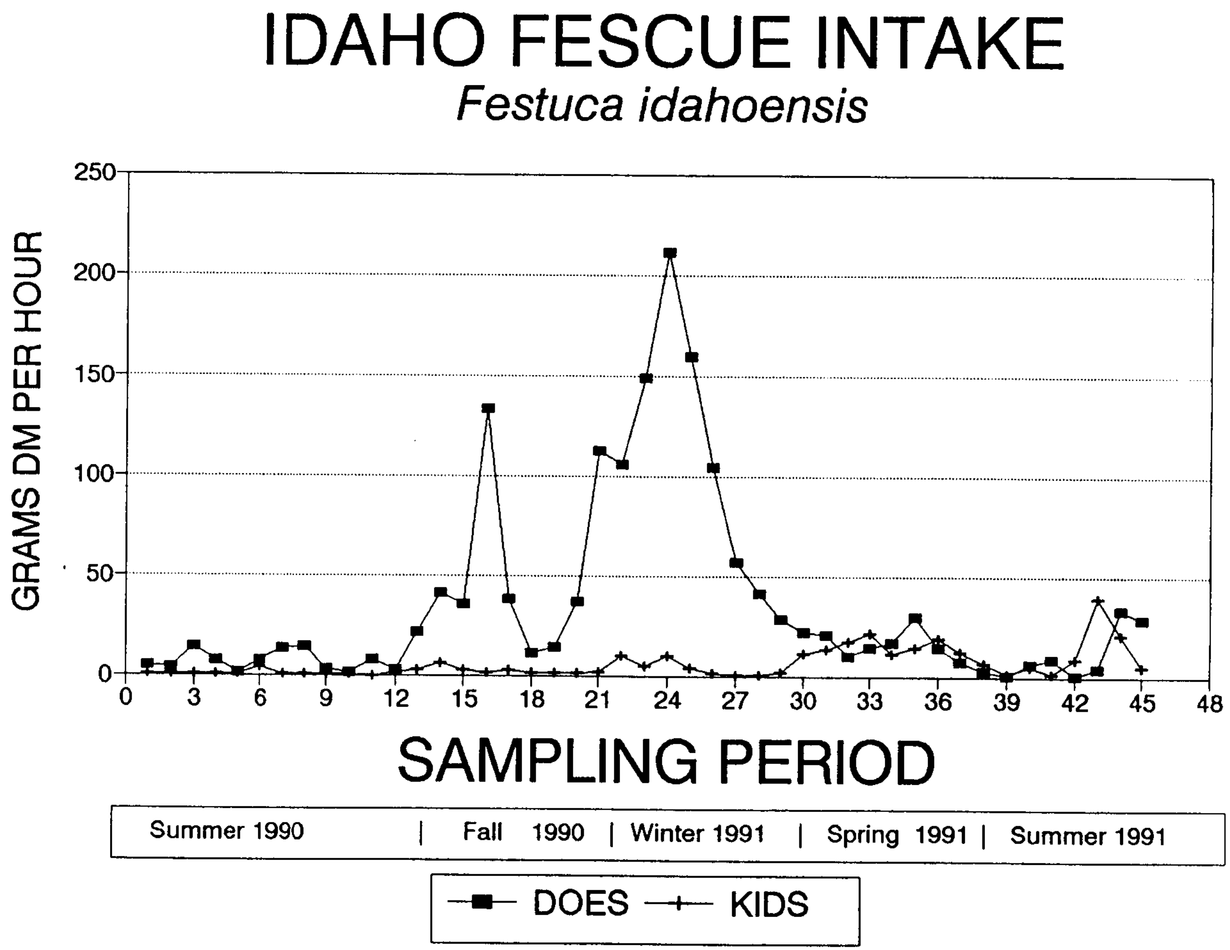

Figure 3.5. Idaho Fescue Intake. Intake was averaged on a grams of dry matter per hour basis for each age group in each season.

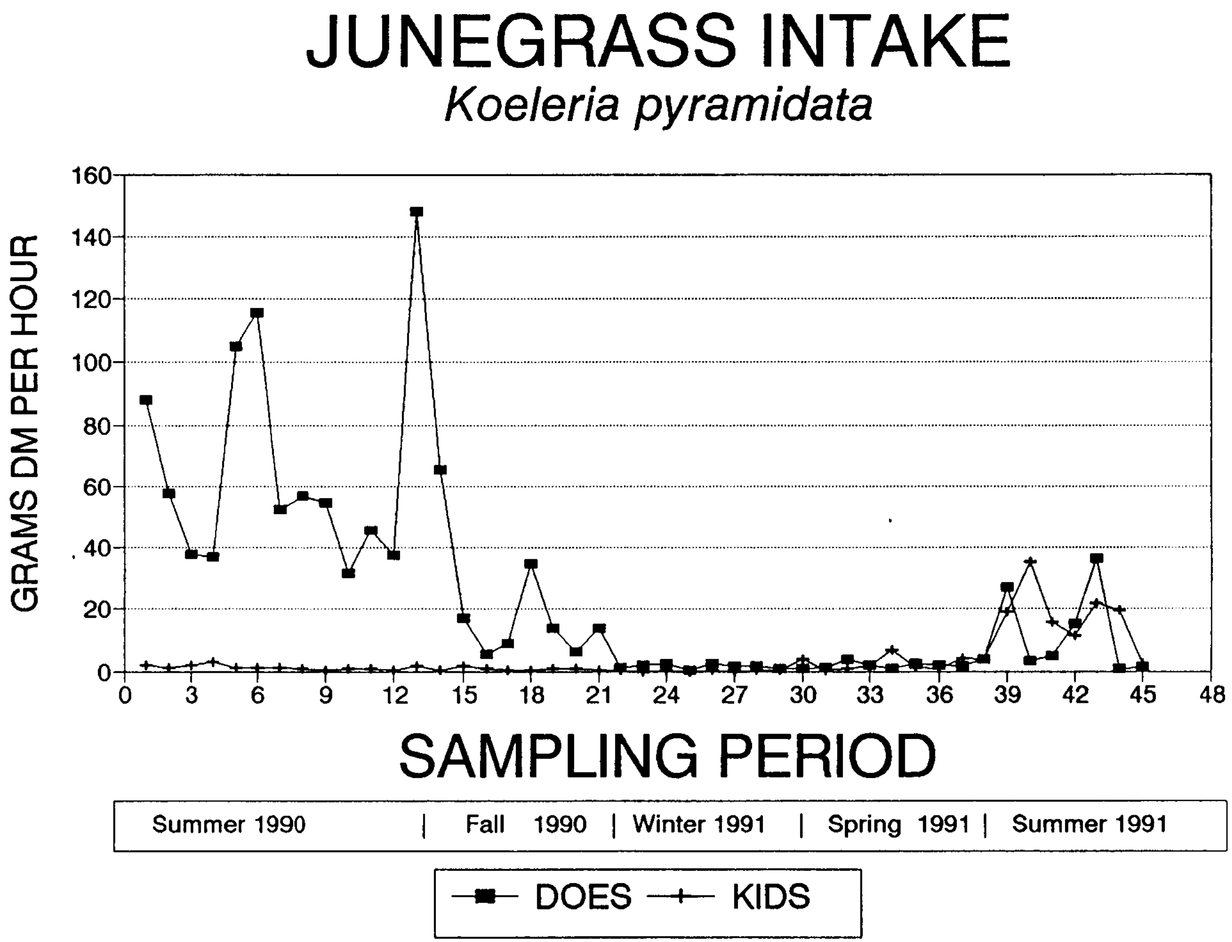

Figure 3.6. Junegrass Intake. Intake was averaged on a grams of dry matter per hour basis for each age group in each season.

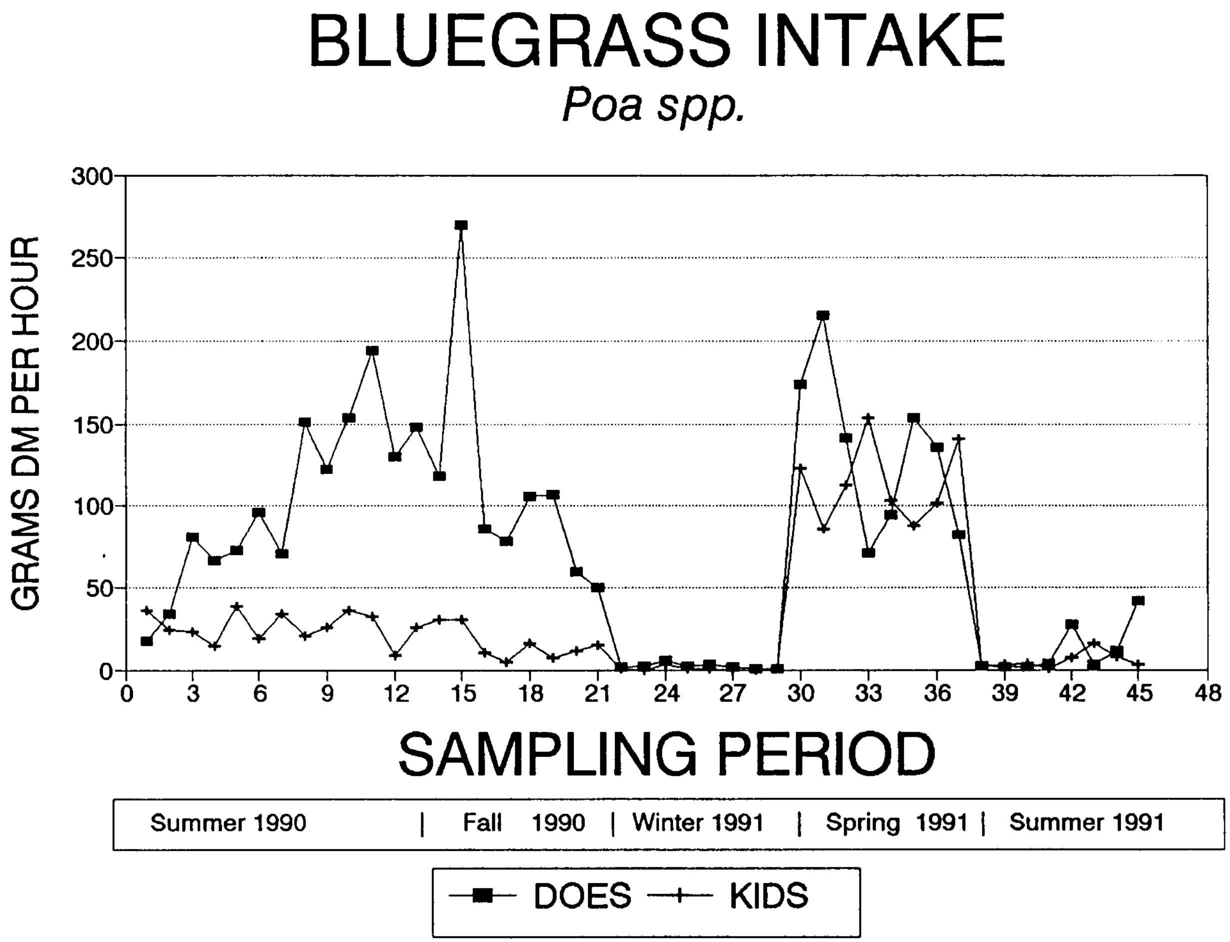

Figure 3.7. Bluegrass Intake. Intake was averaged on a grams of dry matter per hour basis for each age group in each season.

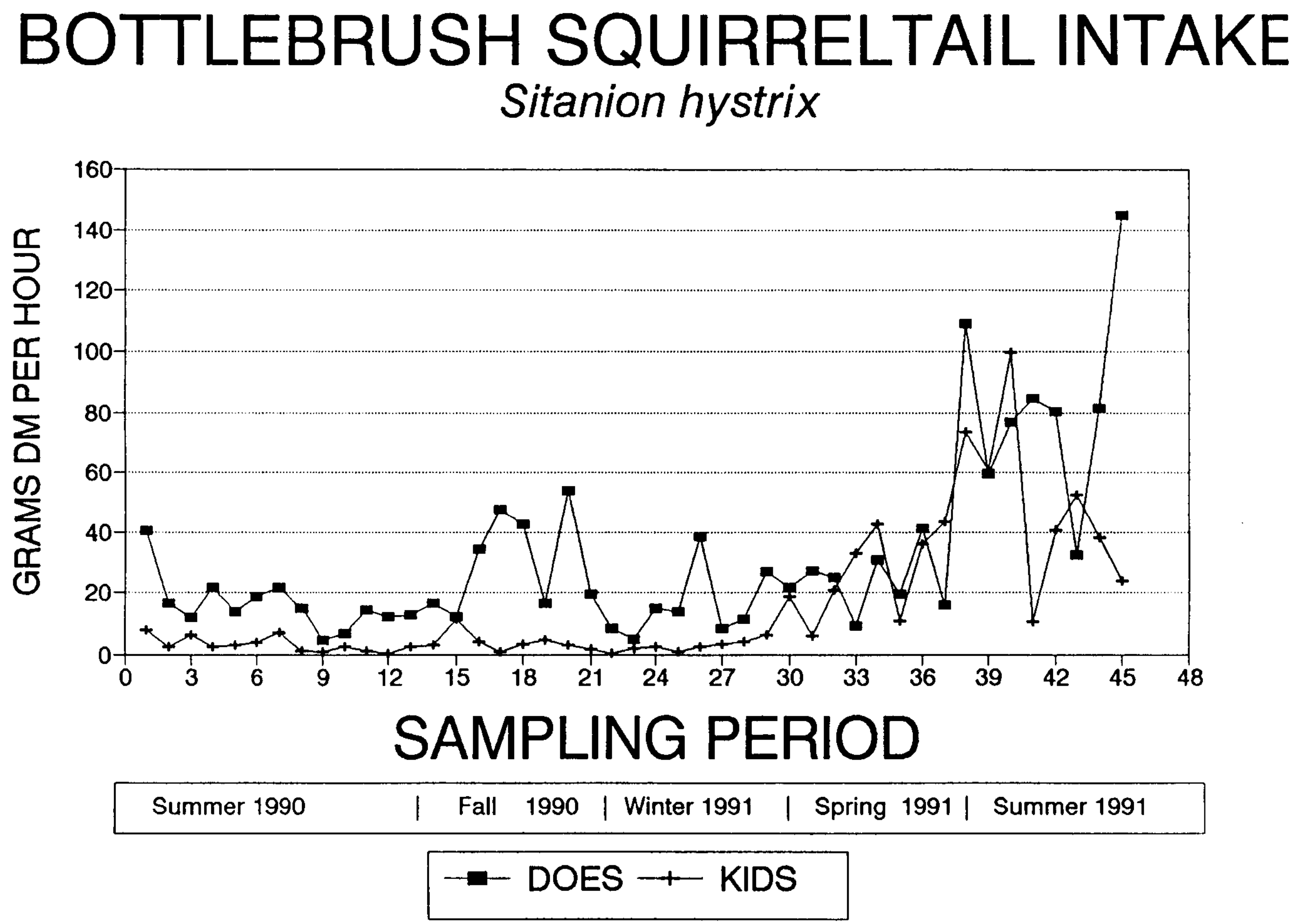

Figure 3.8. Bottlebrush Squirreltail Intake. Intake was averaged on a grams of dry matter per hour basis for each age group in each season.

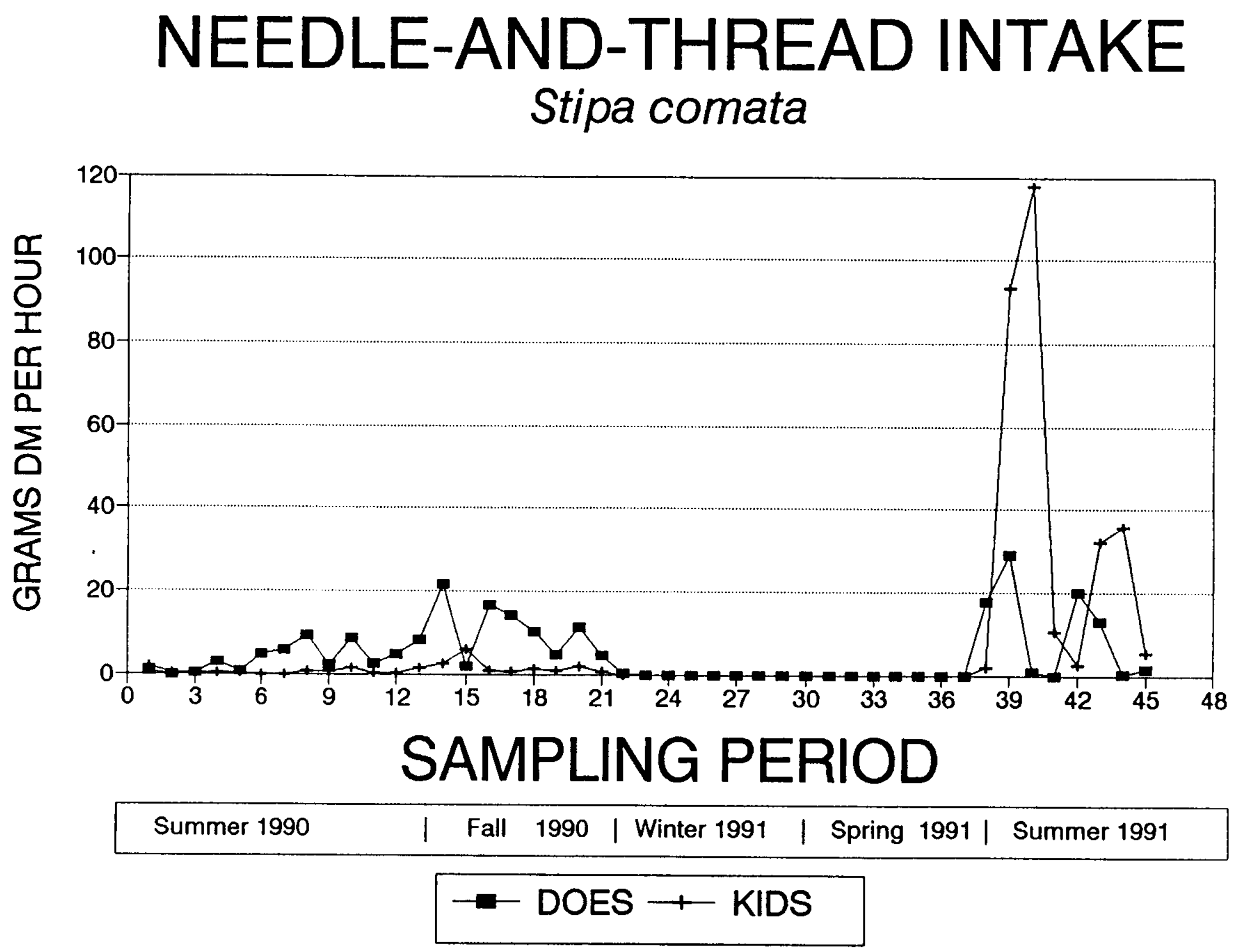

Figure 3.9. Needle-and-Thread Intake. Intake was averaged on a grams of dry matter per hour basis for each age group in each season.

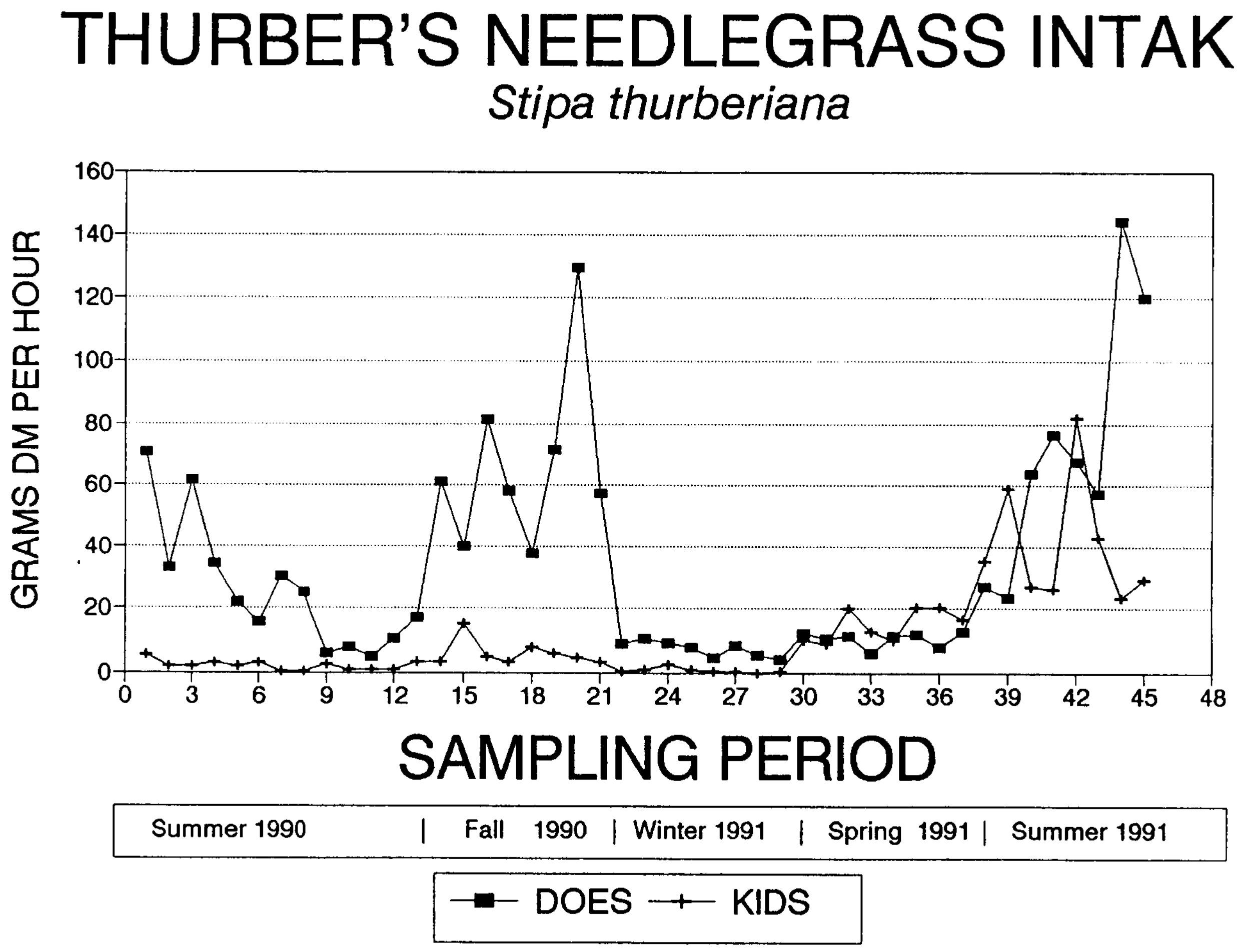

Figure 3.10. Thurber's Needlegrass Intake. Intake was averaged on a grams of dry matter per hour basis for each age group in each season.

component for both does and kids during the winter and was increasingly important through the springand second summer when it made up the largest portion of doe diets and the second-largest portion of kid diets. Because bluebunch wheatgrass was present all through the study but not utilized until later, it is possible that the goats became accustomed or acclimated to it, indicating that learning in the form of preference development, took place.

Kids consumed more total shrubs than does until spring 1991 (P=0.0001) During the study, available biomass of sagebrush ranged from 212 KgDM/Ha to 340 KgDM/Ha. Available green rabbitbrush biomass ranged from 92 KgDM/Ha to 108 KgDM/Ha (Appendix Table 11). Shrubs made up only a small portion of total intake for the does in all seasons except spring 1991. In contrast, kids consumed substantial amounts of shrubby species during the summer, fall and winter of 1990-1991. Total shrub consumption as a percentage of total intake in kid diets was 21% during summer 1990, 42% in the fall and 18% during the winter. During these time periods, kids ate dead as well as live sagebrush. Dead sagebrush consumption was anomalous feeding behavior that is difficult to explain but constituted a substantial portion of kid diets.

Winter 1991 was very mild with little persistent snow cover. The bluegrasses began to grow very early and we feel that this is one reason why the goats shifted away from shrubs during late winter. We suspect that a colder, more normal winter with snow cover, would induce higher winter shrub consumption by goats. Summer 1991 was the season of least shrub consumption

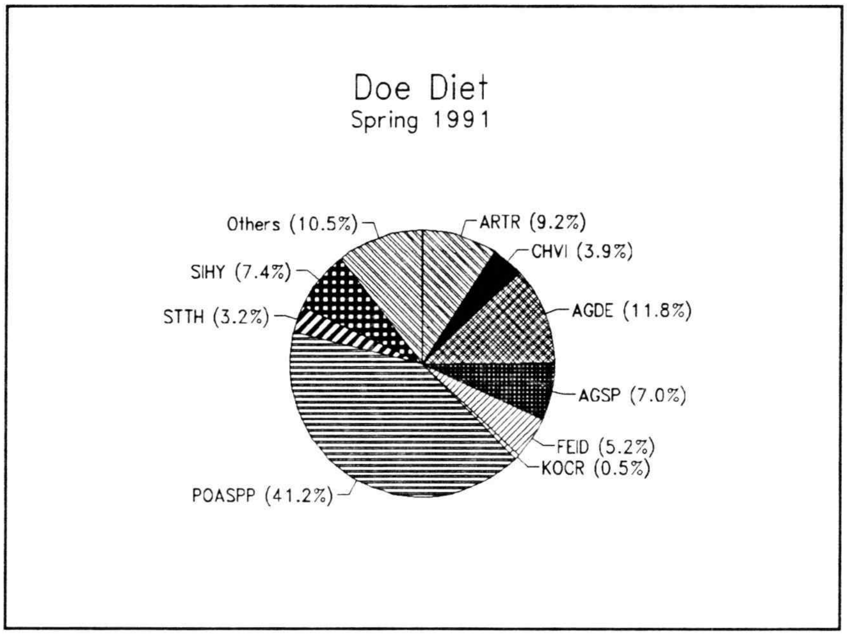

Figure 3.11. Spring Diet Pie - Does. Figure illustrates proportions of major dietary components in spring doe diets.

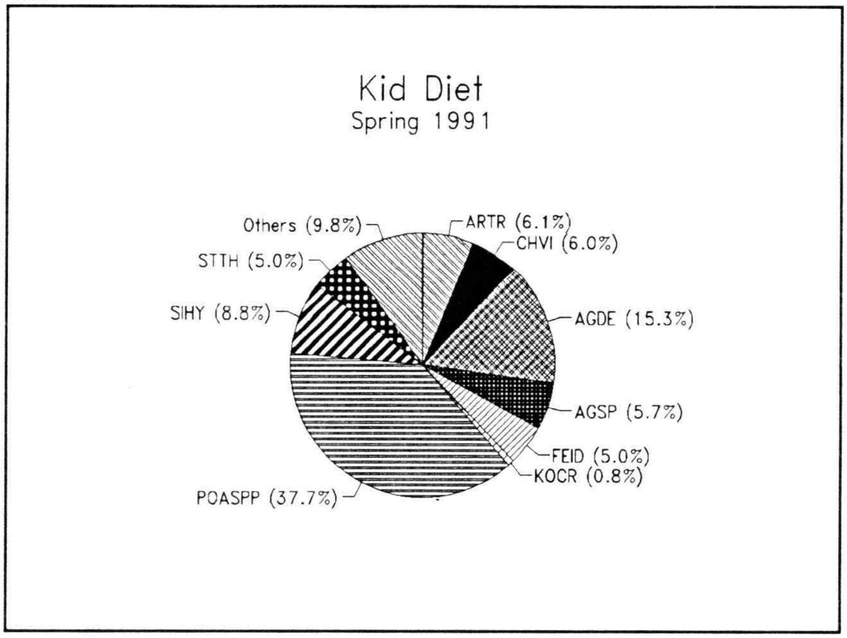

Figure 3.12 Spring Diet Pie - Kids. Figure illustrates proportions of major dietary components in spring kid diets.

by kids (Figure 3.2).

Spring shrub consumption, as shown in Figures 3.11 and 3.12, was 14% of total doe diets and consisted primarily of sagebrush and green rabbitbrush, making up 9% and 4% of their total diet, respectively. Kids also consumed shrubs readily in the spring, accounting for 12% of their total intake, with sagebrush and green rabbitbrush each constituting 6% of total kid diets. The goats consumed shrubs very enthusiastically during the spring season, biting off 6-10 cm twig lengths. Crude protein in shrubs was high during this season (Appendix Table 3), with sagebrush at 12% CP and green rabbitbrush at 19% CP. Since water content was also high during this season, plant chemical defenses were probably more dilute and shrubs more palatable.

Our study site did not have western juniper present in sufficient quantity for statistical analysis of this dietary component; however, our observations indicate that juniper is readily eaten by goats. Goats consumed western juniper most actively during the summer and fall. All juniper trees on the study site under 2 meters in height were completely defoliated and stripped of bark by the fall of 1990. Upon completion of our diet study (in July, 1991), the goats were moved to a neighboring pasture which had an abundance of young junipers (approximately 150 trees in a 10 hectare area). We monitored the sequence of juniper consumption on a daily basis and noticed an interesting pattern. Within the first three days, all terminal buds on all branches of all trees examined had been nipped off. By the third week, the central trunks of virtually all trees had been stripped of bark. Approximately 30 percent of the trees had been totally defoliated by the third week. Trees with both mature and juvenile foliage were consumed readily. Goats continued to eat the juniper trees during their entire four-week occupancy of the site. Upon revisiting the site one year after goat-browsing, we observed that while many trees were dead, an equal number were regrowing. Some trees were severely damaged while others appeared relatively unharmed. While it is impossible to know what the tree mortality might be over time from this casual observation, it is a fairly safe assumption that goat browsing would be necessary in more than one season to severely impact juniper sites.

Big sagebrush and green rabbitbrush have low preference overall (Table 3.2) however, there are certain times of year when individual shrub species are used heavily. We observed that damage, either mechanical or browsing-induced, appears to adversely impact the shrubs causing them to become more palatable to the goats who then browse them ever more heavily. There may be a potential for multiplicative effects of shrub browsing over time.

Conclusions

In this study, angora goats were principally graminivorous but did consume significant amounts of woody plant species on a seasonal basis. Species utilized include big sagebrush, green and rubber rabbitbrush and western juniper. Species consumption varied considerably by season, both for shrub and herbaceous species. Because preference for plants changes with season and plant development (Table 3.2), it seems reasonable that strategies can be developed that damage shrubs without severely impacting associated vegetation. Biological control strategies using goats need further study to determine plant response, season of use, and intensity of utilization and should be given high priority and support by research organizations looking for solutions to problematic shrub management in the sagebrush steppe.

The fact that the young angora goats in our study ingested proportionally larger quantities of woody species than adults, especially upon initial introduction to this sagebrush-bunchgrass system, indicates that younger animals may be more exploratory and may potentially have diets that adapt more readily to new systems. Over time, even mature goats learned to utilize more plant species in this ecosystem. An acclimation period of one year or more may be necessary for adjustment to a new system. Individual and social learning as it pertains to grazing management is an important area for continued research and will undoubtedly continue to offer valuable insights for land managers.

In our study, moderate range utilization with minimal supplemental feeding, adequately maintained productivity of angora goats on this big sagebrush rangeland (Appendix Figure 4). Mohair production was above average, with does growing 4.5 Kilograms per year and kids growing 3.6 Kilograms/year of superior quality mohair. We believe that including fiber producing goats in a sagebrush region ranching operation has the potential to provide economic diversification and restitution while accomplishing restorative goals. The potential benefits to public rangelands in degraded condition are extremely high as well. Well designed grazing systems that include fiber-producing goats may offer public land managers an alternative to other costly woody plant control methods in the sagebrush steppe.

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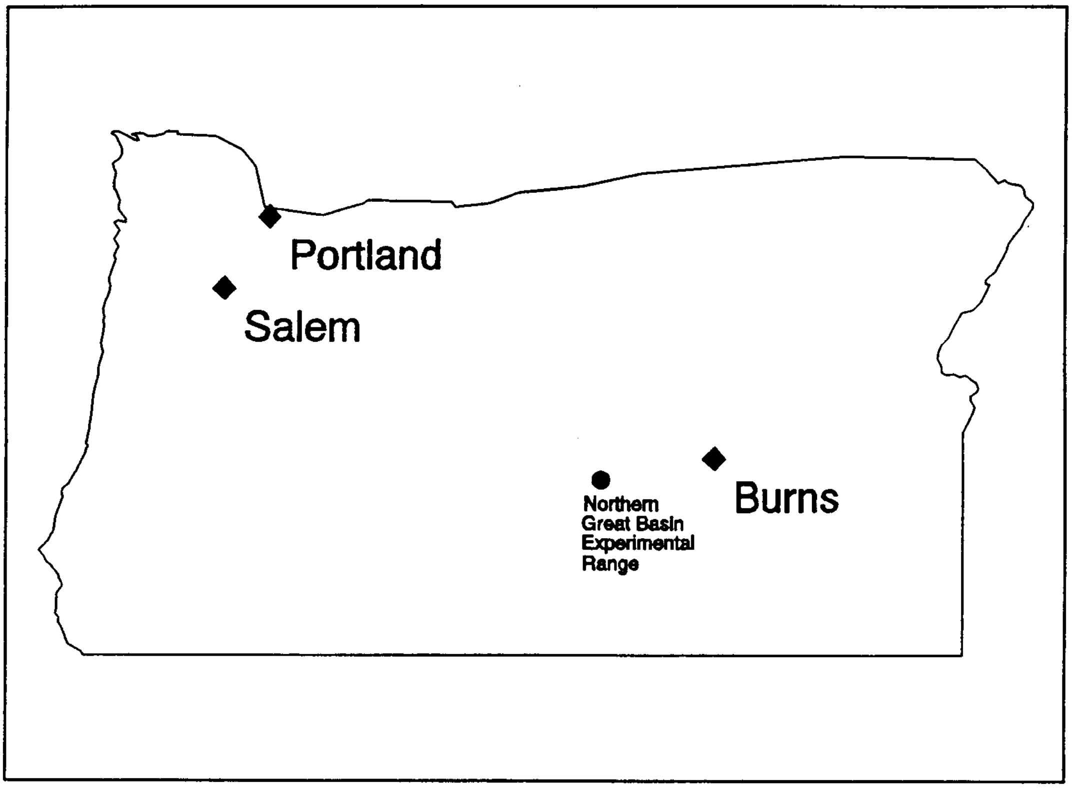
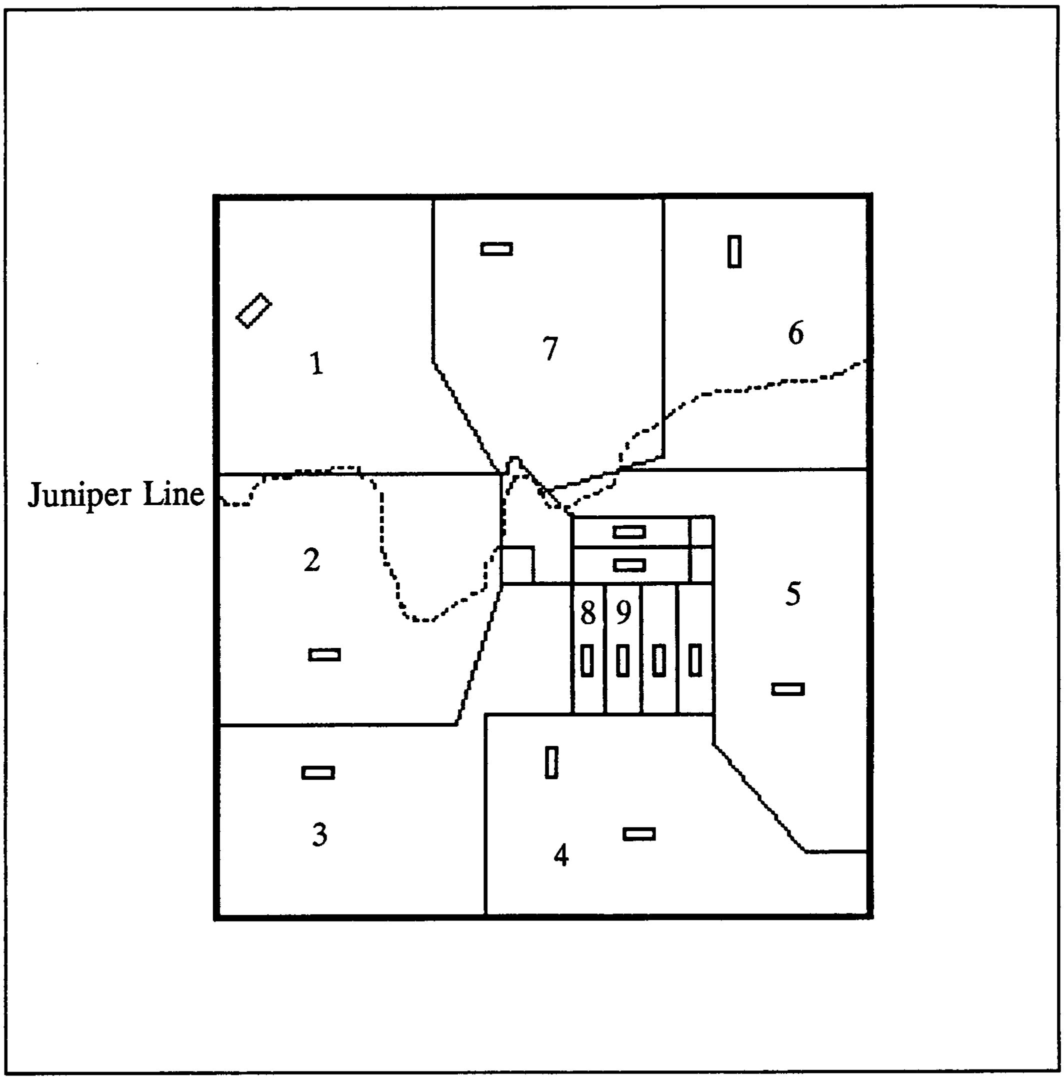
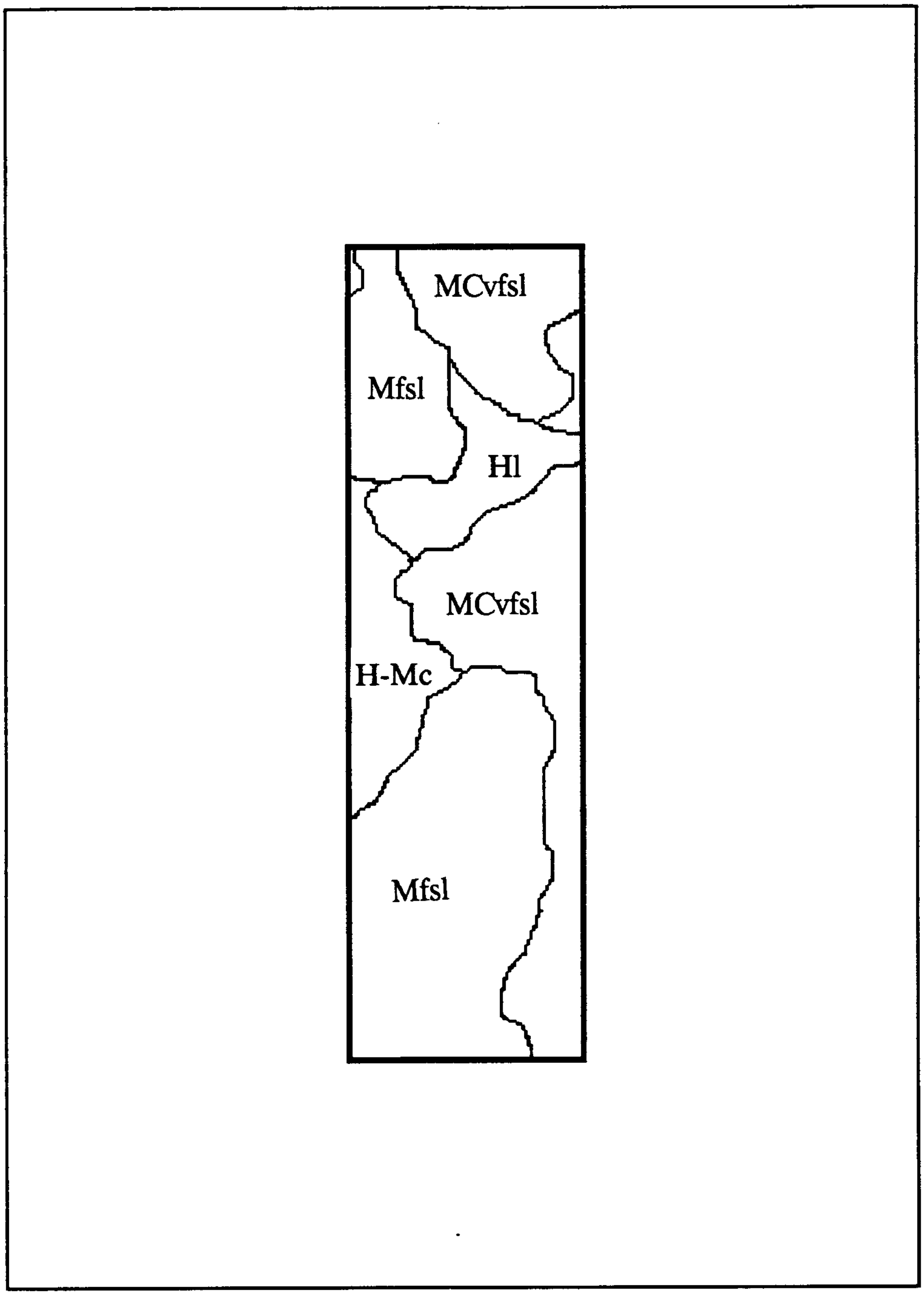
APPENDICES



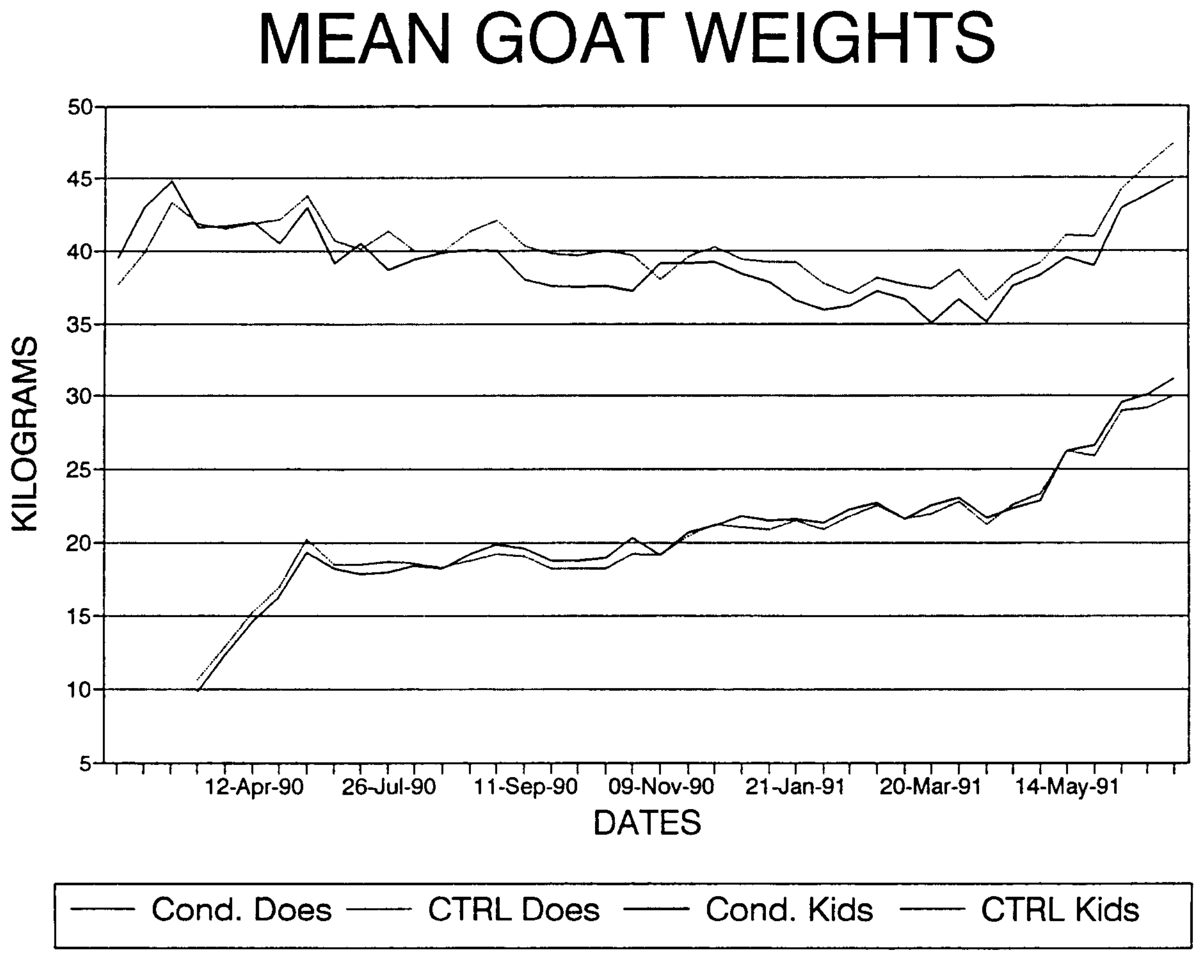
Appendix Figure 1. State Map - Location of the Northern Great Basin (Squaw Butte Range) Experimental Range in southeastern Oregon.



Appendix Figure 2. Experimental Range Map - Squaw Butte Experiment station pasture layout.



Appendix Figure 3. Pasture Map - Map of our study site at the Squaw Butte Experimental Range Number 9, illustrating layout and soil complexes. Hl = Holte loam, H-Mc = Holte-Milican complex, MCvfsl = Madeline Cobbly very fine sandy loam, Mfsl = Millican fine sandy loam.



Appendix Figure 4. Goat Weights. Goats were weighed every 10 days and weights were averaged by group throughout the study period.

APPENDIX TABLE 1. Species list - Range 9. This list represents species observed growing on the study site (Range 9).

SHRUBS

Artemisia tridentata spp. *wyomingensis*
Chrysothamnus nauseosus
Chyrsothamnus viscidiflores
Leptodactylon pungens
Tetradymia canescens

GRASSES

Annuals

Bromus tectorem

Grasslike

Carex rossi
Carex spp.

Perennials

Agropyron desertorum
Agropyron smithii
Agropyron spicatum
Festuca idahoensis
Koelaria pyramidata
Oryzopsis hymenoides
Poa cusickii
Poa nevadensis
Poa sandbergii
Sitanion hystrix
Stipa comata
Stipa thurberiana

FORBS

Annuals

Boraginaceae
Collinsia parviflora
Descurainia pinnata
Gayophytum ramosissium
Lepidium spp.
Lithofragma spp.
Microsterus gracilis
Ranunculus testiculatus

Perennials

Agoseris glauca
Allium spp.
Antenarria corymbosa
Antennaria dimorpha
Arabis spp.
Arenaria franklinii
Aster spp.
Astragalus curvicarpus
Boraginaceae family
Calachortus spp.
Chaenactis douglasii
Crepis acuminata
Delphinium spp.
Erigeron bloomeri
Erigeron filifolius
Erigeron linearis
Erigeron spp.
Eriogonum heracleoides
Eriogonum ovalifolium
Eriogonum umbellatum
Fritillaris spp.
Haplopappus stenophyllus
Lomatium spp.
Lomatium triternatum
Lupinus caudatus
Lupinus spp.
Penstemon spp.
Phlox diffusa
Phlox hoodii
Phlox longifolia
Tortula ruralis
Zygadenus paniculatus

Appendix Table 2. Number of plant species that made up 1% or more of Doe and kid diets and Shannon's Diversity Index of Dietary Components. Dietary diversity was calculated using Shannon's Diversity Index by group and by season.

Dietary Diversity				
	Number of Species		Shannon Index	
Season	Does	Kids	Does	Kids
Summer 1990	9	10	1.79	1.93
Fall 1990	9	9	1.81	1.51
Winter 1991	6	5	1.18	0.94
Spring 1991	9	10	1.82	2.01
Summer 1991	11	12	1.79	2.07

Appendix Table 3. Composition of Goat Dietary Components. Chemical composition of plant species found in goat diets during this study. Data is expressed as a percentage on a dry matter basis.

SPECIES	Crude Protein (%)	Digestibility (%)	Neutral Detergent Fiber (%)	Acid Detergent Fiber (%)	Lignin (%)
Alfalfa Pellets (Standard)	19.5	76.9	47.4	28.4	7.9
GRASSES					
Agropyron desertorum					
Sum 1990	5.1	71.6	65.2	29.4	4.9
Fal 1990	4.1	*	*	*	*
Win 1991	4	63.1	74	37.4	4.3
Spr 1991	7.9	73.4	67.1	35.8	3.9
Sum 1991	6.9	70.6	61.6	28.9	4.5
Agropyron smithii					
Sum 1991	13.4	81.6	56.7	23.3	5.2
Agropyron spicatum					
Sum 1990	4.9	64.9	67.3	30.6	5
Fal 1990	4.2	62	66	30.3	3.7
Win 1991	4.1	55.9	72.6	37.9	4.3
Spr 1991	13.2	83.3	61.5	30.2	3.1
Sum 1991	6.9	69.7	61.8	27.2	5
Elymus cinereus					
Sum 1990	3.5	59.1	78.3	41.3	3.8
Spr 1991	15.4	92.2	70.1	30.1	1.6

SPECIES	Crude Protein (%)	Digestibility (%)	Neutral Detergent Fiber (%)	Acid Detergent Fiber (%)	Lignin (%)
Festuca idahoensis					
Sum 1990	4.5	59.4	69	31.3	3.8
Fal 1990	4.8	61.7	64.9	30.3	3.7
Win 1991	4.5	60.8	70.6	37.3	4.5
Spr 1991	9.4	76.6	63.9	32.3	3
Sum 1991	6.4	66.2	61	28.3	3.6
Koelaria pyramidata					
Sum 1990	5.4	66.2	66.1	32.1	4
Fal 1990	5.3	66.5	65.6	32.3	4.2
Win 1991	4	56	77.2	37.6	4.5
Spr 1991	20	89.6	*	*	*
Sum 1991	11.1	78.5	56.4	19.1	14.7
Poa spp.					
Sum 1990	6.2	65.3	71.9	34.9	4.1
Fal 1990	6	62.5	70.3	36.5	4.3
Win 1991	12.6	78.6	63.6	29.8	4.4
Spr 1991	18	87.9	49.6	23.8	3.2
Sum 1991	7.7	69.8	60.6	30.1	3.6
Sitanion hystrix					
Sum 1990	6	67.7	64.4	28.1	4.7
Fal 1990	4.5	60.7	66.7	30	4.8
Win 1991	5.5	54.6	72.3	33.1	4.9
Spr 1991	13.9	84.4	59.7	28.6	3.6
Sum 1991	9.6	71.3	61.1	28.7	3.9

SPECIES	Crude Protein (%)	Digestibility (%)	Neutral Detergent Fiber (%)	Acid Detergent Fiber (%)	Lignin (%)
Stipa comata					
Sum 1990	7.7	*	63.6	23.4	6.6
Sum 1991	11.1	67.6	65	28.3	4.8
Stipa thurberiana					
Sum 1990	6.1	69.9	64.5	27.2	4.5
Fal 1990	5	66.8	65.7	28.8	4.5
Win 1991	4.9	61	72.9	32.9	4.4
Spr 1991	16.1	83	59.4	26.5	2.4
Sum 1991	9.4	71.9	66.2	29.5	4.9
FORBS					
Annual Forbs					
Sum 1991	10.3	59.7	55.3	31	9.5
Annual Mustard					
Sum 1990	9.8	61.6	60	36.5	9.1
Lepidium spp.					
Sum 1990	5.5	56.8	68.2	37.3	10.5
Sum 1991	6.7	44.1	69.6	40.3	13.6
Perennial Forbs					
Win 1991	3.8	39.4	82	46	15.7
Sum 1991	10.6	74.3	42.1	24.5	6.9

SPECIES	Crude Protein (%)	Digestibility (%)	Neutral Detergent Fiber (%)	Acid Detergent Fiber (%)	Lignin (%)
SHRUBS					
Artemisia tridentata (dead)					
	4.5	31.9	79.1	38.5	24.1
Artemisia tridentata (live)					
Sum 1990	9	71.6	38.1	18.9	9.2
Win 1991	6.4	49.8	62.9	29.7	16.9
Spr 1991	11.8	61.7	36.4	17.1	11.4
Sum 1991	11.1	76.2	37.4	19.4	7.5
Chrysothamnus viscidiflores					
Sum 1990	9	79.9	33.1	16.2	9
Win 1991	5	35.4	74.9	37.5	20.2
Spr 1991	19	*	*	18.9	11.3
Sum 1991	13	74.4	31.3	17.2	6.4
Leptodactylon pungens					
Sum 1991	6.7	44.1	69.6	40.3	13.8
Tetradymia canescens					
Sum 1991	5.9	*	*	29.9	16.6

Appendix Table 4. Climatic table of maximum and minimum temperatures, monthly precipitation and long term means collected from the Squaw Butte weather station in eastern Oregon.

	1989			1990			1991			Long Term Mean		
	max. Temp. °F	min. Temp. °F	precip. (in.)	max. Temp. °F	min. Temp. °F	precip. (in.)	max. Temp. °F	min. Temp. °F	precip. (in.)	max. Temp. °F	min. Temp. °F	precip. (in.)
Sep	72.57	44.7	1.49	79.77	50.10	0.30	79.00	47.13	0.01	74.27	41.80	0.56
Oct	60.13	35	0.28	59.84	33.10	0.45	64.58	37.29	0.99	62.05	33.78	0.90
Nov	49.93	27.7	0.50	46.93	26.63	1.04	43.30	27.53	1.58	46.37	25.33	1.20
Dec	42.84	23.19	0.30	--	--	0.00	39.58	21.13	0.85	37.90	20.04	1.28
Jan	33.26	16.71	1.14	40.39	23.48	0.56	39.94	19.65	0.32	35.12	16.41	1.28
Feb	30.04	11.43	0.96	40.54	19.04	0.26	50.21	28.46	0.45	40.86	21.45	0.87
Mar	45.81	28.13	2.86	50.23	28.45	1.17	45.19	25.77	1.48	46.71	24.72	0.95
Apr	59.27	34.60	0.98	64.40	36.40	0.52	52.73	29.67	0.99	56.46	29.42	0.72
May	61.55	36.87	1.74	61.23	33.87	1.07	58.35	29.67	2.19	64.85	35.75	1.24
Jun	76.60	46.13	0.31	73.3	44.70	0.57	67.13	40.67	1.41	73.3	42.59	1.07
Jul	84.81	49.39	0.17	86.1	54.13	0.04	85.19	53.55	0.28	83.85	49.66	0.33
Aug	77.13	47.17	0.98	82.29	52.84	0.66	85.01	53.06	0.59	82.79	48.76	0.61
Total			11.71			6.64			11.14			11.01

Appendix Table 5. Percent frequency of major plant species encountered in study pasture. Presence/absence was sampled on a regular grid in three hundred 0.25 meter^2 plots in each paddock.

SPECIES	PERCENT FREQUENCY BY PADDOCK				
	A	B	C	D	TOTAL PASTURE
GRASSES					
Agropyron desertorum	28.7	15.7	0.3	1.0	11.4
Agropyron smithii	0.3	1.0	0.3	0.6	0.6
Agropyron spicatum	11.7	31.7	24.0	9.0	19.1
Bromus tectorum	7.0	11.0	11.0	13.7	10.7
Festuca idahoensis	30.3	43.3	53.0	19.3	36.5
Koelaria pyramidata	25.3	7.7	8.0	14.3	13.8
Poa spp.	78.0	93.3	79.7	81.0	83.0
Sitanion hystrix	22.3	29.3	34.7	41.0	31.8
Stipa comata	2.3	0.3	1.7	0.0	1.1
Stipa thurberiana	44.7	50.0	48.7	47.3	47.7
SHRUBS					
Artemisia tridentata	49.3	49.7	34.0	38.7	42.9
Chrysothamnus nauseosus	0.3	0.3	0.0	0.0	0.2
Chrysothamnus viscidiflores	30.0	29.0	38.7	43.3	35.3
Leptodactylon pungens	7.3	4.3	0.7	0.0	3.1
Tetradymia canescens	1.7	0.0	0.0	0.7	0.6
MISC.					
Carex spp.	0.0	0.0	1.7	1.7	0.9
Lepidium spp.	18.3	14.7	49.7	38.3	30.3
perennial forbs	16.7	32.7	21.0	7.0	19.4

Appendix Table 6. Vegetative Cover. Percent cover was determined along ten 50 meter permanenet transects in each paddock. Cover was assessed at Peak Standing Crop during both 1990 and 1991.

SPECIES	A		B		C		D		PASTURE	
	mean	se	mean	se	mean	se	mean	se	mean	se
	%		%		%		%		%	
SUMMER 1990										
GRASSES										
Agropyron desertorum	6.78	5.07	1.59	0.91	0.06	0.06	0.00	0.00	2.11	1.54
Agropyron smithii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agropyron spicatum	0.74	0.25	0.73	0.37	0.55	0.23	1.13	0.52	0.79	0.18
Elymus cinereus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Festuca idahoensis	3.11	0.78	3.51	1.14	5.25	2.00	3.17	1.07	3.76	0.68
Koelaria pyramidata	1.39	0.44	0.62	0.10	0.23	0.12	0.18	0.10	0.60	0.18
Oryzopsis hymenoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poa spp.	3.00	1.21	3.24	1.07	1.88	0.60	1.94	0.76	2.51	0.43
Sitanion hystrix	1.06	0.58	0.92	0.19	0.17	0.07	0.81	0.32	0.74	0.20
Stipa comata	0.00	0.00	0.07	0.07	0.02	0.01	0.00	0.00	0.02	0.00
Stipa thurberiana	1.87	0.58	1.00	0.70	1.38	0.69	2.12	1.05	1.60	0.38
SHRUBS										
Artemisia tridentata (dead)	5.83	1.81	5.07	0.93	2.29	1.09	2.29	0.78	3.87	0.71
Artemisia tridentata (live)	5.06	1.31	1.21	0.29	4.32	2.13	3.41	1.31	3.50	0.77
Chrysothamnus viscidiflores (dead)	0.26	0.26	0.05	0.05	0.00	0.00	0.38	0.16	0.17	0.09
Chrysothamnus viscidiflores (live)	4.13	1.78	1.73	0.68	0.33	0.17	0.85	0.49	1.76	0.63
Leptodactylon pungens (dead)	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.01	0.00
Leptodactylon pungens (live)	0.32	0.09	0.13	0.11	0.11	0.09	0.04	0.02	0.15	0.04
Tetradymia canescens (dead)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetradymia canescens (live)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISC.										
Carex spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.01	0.01
perennial forbs	0.52	0.28	0.31	0.24	0.23	0.09	0.25	0.15	0.33	0.09
TOTAL COVER	34.09	2.10	20.19	2.29	16.81	5.69	16.62	5.20	21.93	5.20

SPECIES	A		B		C		D		PASTURE	
	mean	se	mean	se	mean	se	mean	se	mean	se
	%		%		%		%		%	
SUMMER 1991										
Agropyron desertorum	3.34	2.69	1.19	0.52	0.08	0.08	0.00	0.00	1.15	0.80
Agropyron smithii	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agropyron spicatum	0.72	0.34	0.80	0.45	0.42	0.13	1.13	0.59	0.77	0.20
Elymus cinereus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Festuca idahoensis	0.83	0.18	1.22	0.29	1.35	0.57	1.39	0.64	1.19	0.24
Koelaria pyramidata	0.31	0.28	0.06	0.06	0.00	0.00	0.01	0.01	0.09	0.08
Oryzopsis hymenoides	0.02	0.02	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01
Poa spp.	1.42	0.32	1.06	0.24	0.86	0.34	1.51	0.63	1.21	0.22
Sitanion hystrix	0.73	0.17	0.69	0.17	0.24	0.12	0.60	0.20	0.56	0.09
Stipa comata	0.09	0.06	0.01	0.01	0.00	0.00	0.00	0.00	0.03	0.02
Stipa thurberiana	1.03	0.27	0.53	0.24	0.59	0.21	0.83	0.39	0.75	0.15
Artemisia tridentata (dead)	2.82	0.57	3.83	1.29	2.59	1.11	2.24	0.73	2.87	0.39
Artemisia tridentata (live)	6.10	0.93	2.20	0.62	4.59	2.28	4.27	1.53	4.29	0.80
Chrysothamnus viscidiflores (dead)	0.25	0.25	0.06	0.05	0.00	0.00	0.21	0.11	0.13	0.08
Chrysothamnus viscidiflores (live)	2.86	1.08	0.39	0.19	0.13	0.08	0.62	0.36	1.00	0.41
Leptodactylon pungens (dead)	0.00	0.00	0.04	0.03	0.06	0.05	0.02	0.01	0.03	0.02
Leptodactylon pungens (live)	0.14	0.10	0.14	0.12	0.02	0.02	0.00	0.00	0.08	0.03
Tetradymia canescens (dead)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetradymia canescens (live)	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.01	0.01
Carex spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.01
perennial forbs	0.56	0.20	0.35	0.09	0.22	0.14	0.32	0.16	0.36	0.08
TOTAL COVER	12.32	2.08	6.53	0.27	4.00	1.27	6.70	2.24	7.39	1.19

Appendix Table 7. Shrub Density. Density was assessed in one meter belts along ten 50 meter permanent transects in each paddock. Density was assessed by species and by size class, where class 1 = plants up to 10 cm in height, class 2 = plants 11-50 cm in height, class 3 = plants 51-100 cm in height, and class 4 = plants >100 cm in height.

SPECIES	Paddock A		Paddock B		Paddock C		Paddock D		Total	
	mean	se	mean	se	mean	se	mean	se	mean	se
1990										
Artemisia tridentata										
Class 1	46.80	30.54	10.40	4.99	8.00	3.62	5.54	1.00	17.90	8.14
Class 2	19.20	3.51	15.60	4.03	5.00	4.35	4.46	0.22	13.40	1.89
Class 3	10.60	2.46	5.40	1.86	4.50	0.68	2.35	0.88	7.50	1.13
Class 4	0.40	0.40	0.20	0.20	2.50	0.58	1.09	0.55	1.25	0.38
Dead	15.00	3.24	18.00	2.30	12.00	2.33	5.54	2.50	14.40	1.37
Total Live	77.00	33.79	31.60	8.24	20.00	4.79	11.01	3.57	40.05	9.48
Chrysothamnus viscidiflores										
Class 1	40.80	12.48	19.80	7.34	67.80	18.42	89.20	25.15	54.40	9.93
Class 2	17.20	5.62	10.80	2.58	10.40	7.41	20.80	10.33	14.80	3.40
Class 3	2.20	1.20	1.60	1.03	2.00	1.26	6.40	3.75	3.05	1.07
Class 4	0.00	0.00	0.00	0.00	0.20	0.20	0.20	0.20	0.10	0.07
Dead	3.00	1.90	1.00	0.77	3.60	1.69	6.60	2.36	3.55	0.94
Total Live	60.20	12.66	32.20	6.51	80.40	11.60	116.6	13.29	72.35	8.76
Leptodactylon pungens										
Class 1	9.00	4.97	11.25	5.95	6.00		0.00	0.00	9.67	3.22
Class 2	4.25	1.11	5.25	2.50	1.00		0.00	0.00	4.33	1.20
Class 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Class 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dead	1.00	0.71	1.00	0.58	0.00	0.00	0.00	0.00	0.89	0.39
Total Live	13.25	6.02	16.50	7.44	7.00		0.00	0.00	14.00	4.04
Tetradymia canescens										
Class 1	0.00	0.00	1.00	-	0.00	0.00	0.00	0.00	0.25	0.25
Class 2	2.00	-	0.00	0.00	0.50	0.50	0.00	0.00	0.75	0.48
Class 3	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.25	0.25
Class 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Live	2.00	-	1.00	-	1.00	0.00	0.00	0.00	1.25	0.25

SPECIES	Paddock A		Paddock B		Paddock C		Paddock D		Total	
	mean	se	mean	se	mean	se	mean	se	mean	se
1991										
Artemisia tridentata										
Class 1	2.80	1.56	8.00	3.90	7.60	3.66	3.00	0.89	5.48	1.48
Class 2	15.80	3.37	12.67	1.99	9.00	3.03	9.80	1.83	11.86	1.33
Class 3	9.20	2.48	7.17	1.08	6.80	0.97	8.60	1.96	7.90	0.81
Class 4	0.20	0.20	0.33	0.21	1.60	0.75	1.80	0.73	0.95	0.29
Dead	1.60	3.94	16.17	1.45	12.80	2.40	14.80	2.52	13.95	1.28
Total Live	28.00	5.65	28.17	4.85	25.00	4.00	23.20	3.76	26.19	2.20
Chrysothamnus viscidiflores										
Class 1	5.20	1.53	3.83	1.51	4.50	3.50	3.40	1.50	4.17	0.80
Class 2	13.20	6.18	5.83	1.49	17.00	3.00	16.80	8.60	12.17	2.98
Class 3	1.40	0.93	0.83	0.65	2.00	2.00	3.80	2.15	1.94	0.72
Class 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dead	0.80	0.58	1.00	0.63	1.00	1.00	1.40	0.87	1.06	0.35
Total Live	19.80	7.15	10.50	2.77	23.50	1.50	24.00	10.62	18.28	3.66
Leptodactylon pungens										
Class 1	5.25	1.97	3.80	1.59	0.50	0.50	0.00	0.00	3.73	1.08
Class 2	3.25	1.25	4.80	1.50	0.00	0.00	0.00	0.00	3.36	0.94
Class 3	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.09
Class 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dead	0.75	0.75	2.60	1.17	1.00	1.00	0.00	0.00	1.64	0.64
Total Live	8.75	2.29	8.60	2.98	0.50	0.50	0.00	0.00	7.18	1.78
Tetradymia canescens										
Class 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Class 2	2.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.50	0.29
Class 3	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.25	0.25
Class 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Live	2.00	0.00	0.00	0.00	1.50	1.50	0.00	0.00	1.75	0.25

Appendix Table 8. Herbaceous standing crop available for grazing on the study site. Herbaceous dry biomass was estimated from ten meter^2 clipped plots per paddock each season and converted to a KgDM/Ha basis. T indicates a trace value which was less than 0.005 but greater than 0.

SPECIES	PADDOCK A		PADDOCK B		PADDOCK C		PADDOCK D		TOTAL PASTURE	
	mean	se	mean	se	mean	se	mean	se	mean	se
SUMMER 1990										
Agropyron desertorum	13.32	12.14	14.99	9.69	0.00	0.00	0.00	0.00	7.85	3.90
Agropyron smithii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agropyron spicatum	2.22	1.70	36.63	21.45	18.87	9.33	13.32	9.44	19.71	6.39
Elymus cinereus	2.78	2.78	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.69
Festuca idahoensis	58.28	21.71	38.85	12.30	110.45	43.57	50.51	17.85	71.62	13.53
Koelaria pyramidata	11.77	5.79	4.44	3.29	2.78	2.23	8.33	6.53	7.58	2.37
Poa spp.	28.31	6.33	37.74	4.12	28.31	7.60	53.84	12.08	41.12	4.22
Sitanion hystrix	9.99	4.88	24.98	11.56	7.77	3.33	34.41	12.81	21.41	4.72
Stipa comata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stipa thurberiana	18.87	7.68	17.76	4.88	32.19	12.18	24.42	8.80	25.87	4.32
annual forbs	T	T	T	T	T	T	T	T	T	T
perennial forbs	T	T	T	T	2.22	2.22	T	T	0.62	0.56
Total Herbaceous Biomass	145.5	21.5	175.4	24.9	202.6	49.6	184.8	24.9	196.6	15.8

Appendix Table 8. (continued)

SPECIES	PADDOCK A		PADDOCK B		PADDOCK C		PADDOCK D		TOTAL PASTURE	
	mean	se	mean	se	mean	se	mean	se	mean	se
FALL 1990										
Agropyron desertorum	5.00	5.00	1.00	0.67	0.00	0.00	0.00	0.00	1.50	1.26
Agropyron smithii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agropyron spicatum	17.00	11.43	16.50	7.68	37.00	15.58	0.00	0.00	17.63	5.42
Elymus cinereus	0.00	0.00	0.00	0.00	0.00	0.00	4.50	4.50	1.13	1.13
Festuca idahoensis	51.50	18.27	39.00	14.51	75.00	22.52	59.00	27.50	56.13	10.42
Koelaria pyramidata	6.50	3.73	4.00	1.94	4.50	2.41	2.50	1.34	4.38	1.23
Poa spp.	33.20	6.61	33.50	5.53	14.50	2.52	30.00	9.25	27.80	3.34
Sitanion hystrix	30.00	10.27	11.00	4.82	7.50	3.52	17.00	5.12	16.38	3.40
Stipa comata	2.50	2.01	1.00	1.00	0.50	0.50	0.50	0.50	0.00	0.00
Stipa thurberiana	14.50	4.37	14.50	6.17	20.00	10.22	20.50	8.51	17.38	3.70
annual forbs	T	T	T	T	T	T	T	T	T	T
perennial forbs	T	T	T	T	T	T	T	T	T	T
Total Herbaceous Biomass	160.2	23.0	120.5	13.2	159.0	32.7	134.0	21.1	143.4	11.6

Appendix Table 8. (continued)

SPECIES	PADDOCK A		PADDOCK B		PADDOCK C		PADDOCK D		TOTAL PASTURE	
	mean	se	mean	se	mean	se	mean	se	mean	se
WINTER 1991										
Agropyron desertorum	26.00	20.72	60.00	55.70	0.00	0.00	0.00	0.00	21.50	14.81
Agropyron smithii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agropyron spicatum	3.00	3.00	49.00	28.26	19.00	11.69	0.00	0.00	17.75	8.01
Elymus cinereus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Festuca idahoensis	14.00	5.42	35.00	11.95	16.00	8.72	1.00	1.00	16.50	4.26
Koelaria pyramidata	6.00	4.99	1.00	1.00	1.00	1.00	5.00	2.24	3.25	1.40
Poa spp.	10.00	2.11	5.00	1.67	7.00	1.53	7.00	1.53	7.25	0.88
Sitanion hystrix	14.00	4.76	5.00	1.67	9.00	4.07	6.00	2.21	8.50	1.74
Stipa comata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stipa thurberiana	13.00	3.35	7.00	2.13	10.00	1.49	12.00	2.91	10.50	1.29
annual forbs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
perennial forbs	T	T	T	T	T	T	T	T	T	T
Total Herbaceous Biomass	86.0	20.3	162.0	55.6	62.0	16.6	31.0	5.9	85.2	16.7

Appendix Table 8. (continued)

SPECIES	PADDOCK A		PADDOCK B		PADDOCK C		PADDOCK D		TOTAL PASTURE	
	mean	se	mean	se	mean	se	mean	se	mean	se
SPRING 1991										
Agropyron desertorum	32.00	25.58	5.50	3.83	0.00	0.00	0.00	0.00	9.38	6.57
Agropyron smithii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agropyron spicatum	10.50	5.60	1.00	1.00	7.50	4.36	2.50	1.12	5.38	1.85
Elymus cinereus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Festuca idahoensis	22.00	5.97	25.00	6.87	3.50	1.07	7.00	4.48	14.38	2.87
Koelaria pyramidata	0.00	0.00	1.50	1.07	0.00	0.00	1.50	1.07	0.75	0.38
Poa spp.	18.00	3.09	10.00	0.75	8.50	1.98	18.00	3.74	13.63	1.45
Sitanion hystrix	6.00	1.94	6.50	2.24	7.50	2.91	13.00	5.44	8.25	1.70
Stipa comata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stipa thurberiana	10.50	3.53	6.00	1.94	9.50	2.17	10.50	3.02	9.13	1.35
annual forbs	T	T	T	T	T	T	T	T	T	T
perennial forbs	T	T	T	T	T	T	T	T	T	T
Total Herbaceous Biomass	99.0	23.0	55.5	6.8	36.5	5.3	52.5	6.6	60.9	7.1

Appendix Table 8. (continued)

SPECIES	PADDOCK A		PADDOCK B		PADDOCK C		PADDOCK D		TOTAL PASTURE	
	mean	se	mean	se	mean	se	mean	se	mean	se
SUMMER 1991										
Agropyron desertorum	56.50	31.18	5.00	5.00	0.00	0.00	7.00	7.00	17.13	8.59
Agropyron smithii	0.00	0.00	0.00	0.00	0.00	0.00	23.00	23.00	5.75	5.75
Agropyron spicatum	3.50	1.50	21.00	10.19	16.50	8.63	20.00	13.42	15.25	4.70
Elymus cinereus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Festuca idahoensis	68.50	21.14	31.50	7.07	20.50	6.21	16.50	11.06	34.25	6.98
Koelaria pyramidata	9.00	3.86	2.50	1.71	3.00	1.70	3.00	1.53	4.38	1.23
Poa spp.	9.50	2.29	18.00	1.53	14.00	1.94	30.50	5.35	18.00	1.97
Sitanion hystrix	18.00	6.67	25.50	4.68	45.50	32.10	12.50	6.02	25.38	8.33
Stipa comata	0.00	0.00	0.00	0.00	1.50	1.50	1.50	1.50	0.75	0.52
Stipa thurberiana	11.50	4.15	21.50	7.11	15.50	4.25	44.00	13.70	23.13	4.45
annual forbs	0.00	0.00	0.00	0.00	1.50	1.50	13.00	3.74	3.63	1.30
perennial forbs	6.00	2.45	16.50	2.99	10.50	3.29	7.50	2.27	10.13	1.48
Total Herbaceous Biomass	182.5	26.5	141.5	16.9	128.5	29.0	178.5	27.4	157.8	12.8

APPENDIX TABLE 9. Summary of Total Herbaceous Dry Biomass. Seasonal and paddock totals based on ten meter^2 clipped plots per paddock per season and presented on a KgDM/Ha basis.

Herbaceous Biomass Totals in KGDM/ha					
Season	Paddock A	Paddock B	Paddock C	Paddock D	Pasture Average
	KgDM/ha	KgDM/ha	KgDM/ha	KgDMG/ha	KgDM/ha
Summer 1990	145 SE=21	175 SE=25	203 SE=50	185 SE=25	197 SE=16
Fall 1990	155 SE=23	120 SE=13	190 SE=34	133 SE=21	143 SE=12
Winter 1991	81 SE=20	116 SE=57	48 SE=18	24 SE=6	85 SE=17
Spring 1991	99 SE=23	56 SE=7	34 SE=5	53 SE=7	61 SE=7
Summer 1991	183 SE=26	142 SE=17	129 SE=29	179 SE=27	158 SE=13

Appendix Table 10. Herbaceous Plant Densities. Density was measured in ten meter^2 plots per paddock at Peak Standing Crop in both 1990 and 1991.

Species	Paddock A		Paddock B		Paddock C		Paddock D		Total Pasture	
	mean	se	mean	se	mean	se	mean	se	mean	se
SUMMER 1990										
Agropyron desertorum	1.3	1	0.2	0.1	0	0	0	0	0.4	0.3
Agropyron smithii	0	0	0	0	0	0	0	0	0	0
Agropyron spicatum	0.3	0.2	2.1	0.7	0.4	0.2	1	0.6	1	0.3
Bromus tectorem	0	0	0	0	0	0	0	0	0	0
Elymus cinereus	0.5	0.5	0	0	0	0	0	0	0	0
Festuca idahoensis	3.3	0.8	2.5	0.6	3.7	1	1.7	0.7	2.8	0.4
Koelaria pyramidata	2.6	1.4	1.3	1.2	0.5	0.4	1.1	0.5	1.4	0.5
Poa spp.	18.1	5.6	21.7	2.9	9.9	2.7	10.1	3.6	15	2
Sitanion hystrix	1.9	0.7	1.4	0.5	2.1	1	2.1	0.6	1.9	0.4
Stipa comata	0	0	0	0	0.1	0.1	0	0	0	0
Stipa thurberiana	3.2	0.7	2.6	0.5	3	0.8	2.3	0.8	2.8	0.3
Annual Forbs	0	0	0	0	0	0	0	0	0	0
Perennial Forbs	0	0	0	0	0.4	0.4	0	0	0.1	0.1

Appendix Table 10. (continued)

Species	Paddock A		Paddock B		Paddock C		Paddock D		Total Pasture	
	mean	se	mean	se	mean	se	mean	se	mean	se
SUMMER 1991										
Agropyron desertorum	3.6	1.8	0.1	0.1	0	0	0.1	0.1	1	0.5
Agropyron smithii	0	0	0	0	0	0	26.8	26.8	6.7	6.7
Agropyron spicatum	1	0.4	1.5	0.9	1.3	0.8	0.6	0.4	1.1	0.3
Bromus tectorum	0.1	0.1	0	0	0	0	0.1	0.1	0.1	0
Elymus cinereus	0	0	0	0	0	0	0	0	0	0
Festuca idahoensis	5.2	1.2	4.2	1	2.8	0.9	0.6	0.4	3.2	0.5
Koelaria pyramidata	2.9	1	0.4	0.3	0.7	0.4	0.6	0.4	1.2	0.3
Poa spp.	10.8	2.6	17.2	2.5	16.3	2.5	13.6	4.2	14.5	1.5
Sitanion hystrix	3.6	1	4.1	0.8	1.7	0.5	1.4	0.6	2.7	0.4
Stipa comata	0	0	0	0	0.2	0.2	0.1	0.1	0.1	0.1
Stipa thurberiana	2.4	0.6	3.6	1.6	2.8	1	3.9	1.2	3.2	0.6
Annual Forbs	0.8	0.3	0.6	0.4	1.9	1.2	8.7	5.2	3	1.4
Perennial Forbs	4	1.5	7.7	2.8	9.3	4.5	1.6	0.5	5.7	1.4

Appendix Table 11. Shrub Biomass Totals. Shrub biomass totals were calculated from measuring 50 meter^2 plots in each paddock. Measurements of shrub height, shrub maximum diameter, shrub minimum diameter and percent of plant alive were recorded and used in regression formulas developed from clipped plants to estimate shrub biomass available for goat consumption.

Species	Paddock A	Paddock B	Paddock C	Paddock D	Total Pasture
	KgDM/ha	KgDM/ha	KgDM/ha	KgDM/ha	KgDM/ha
Spring Sagebrush	242	223	117	265	212
Fall Sagebrush	400	298	225	436	340
Spring Green Rabbitbrush	90	44	113	123	92
Fall Green Rabbitbrush	101	64	150	118	108

Appendix Table 12. Doe and Kid Diets. Diets were averaged on a grams per hour per Kilogram of body weight basis. P-value indicates the probability that doe and kid diets for that species in that season are different. Data is presented on a percent of total basis as well as actual grams of intake basis.

Species & Date	Does	Kids	Does		Kids		
	(% ofDiet)		mean	se	mean	se	P
	%	%	gms/hr		gms/hr		
SUMMER 1990							
Artemisia tridentata (live)	0.19	1.56	0.02	0.01	0.07	0.02	0.11
Artemisia tridentata (dead)	0.00	17.37	0.00	0.00	0.78	0.27	0.13
Chrysothamnus viscidiflores	0.19	1.11	0.02	0.01	0.05	0.03	0.29
Leptodactylon pungens	0.09	0.45	0.01	0.00	0.02	0.01	0.12
Tetradymia canescens	0.09	0.45	0.01	0.01	0.02	0.01	0.93
TOTAL SHRUBS	0.66	21.16	0.07	0.02	0.95	0.29	0.09
Annual forbs	0.47	0.67	0.05	0.02	0.03	0.01	0.63
Perennial forbs	3.00	5.79	0.32	0.06	0.26	0.05	0.41
Lepidium spp.	3.38	5.79	0.36	0.08	0.26	0.07	0.15
TOTAL FORBS	6.95	12.69	0.74	0.09	0.57	0.10	0.09
Agropyron desertorum	35.59	20.94	3.79	1.11	0.94	0.20	0.00
Agropyron spicatum	2.25	0.45	0.24	0.05	0.02	0.01	0.01
Elymus cinereus	0.28	2.67	0.03	0.02	0.12	0.03	0.01
Festuca idahoensis	1.78	0.89	0.19	0.04	0.04	0.01	0.00
Koelaria pyramidata	15.49	1.34	1.65	0.27	0.06	0.01	0.00
Poa spp.	23.76	30.73	2.53	0.31	1.38	0.19	0.09
Sitanion hystrix	3.76	3.79	0.40	0.08	0.17	0.04	0.04
Stipa comata	0.94	0.67	0.10	0.02	0.03	0.01	0.05
Stipa thurberiana	6.10	2.23	0.65	0.13	0.10	0.02	0.03
TOTAL GRASS	92.49	66.15	9.85	0.94	2.97	0.23	0.00
TOTAL BIOMASS	100.0	100.0	10.7	0.9	4.5	0.3	0.0

Species & Date	Does	Kids	Does		Kids		
	(% ofDiet)		mean	se	mean	se	P
	%	%	gms/hr		gms/hr		
FALL 1990							
Artemisia tridentata (live)	1.73	2.96	0.18	0.05	0.17	0.03	0.96
Artemisia tridentata (dead)	0.00	36.35	0.00	0.00	2.09	0.26	0.00
Chrysothamnus viscidiflores	0.38	0.70	0.04	0.01	0.04	0.01	0.84
Leptodactylon pungens	0.19	0.52	0.02	0.01	0.03	0.01	0.24
Tetradymia canescens	0.29	1.04	0.03	0.03	0.06	0.02	0.55
TOTAL SHRUBS	2.60	42.43	0.27	0.06	2.44	0.26	0.00
Annual forbs	0.00	0.00	0.00	0.00	0.00	0.00	n/a
Perennial forbs	1.44	4.00	0.15	0.03	0.23	0.06	0.40
Lepidium spp.	0.00	0.00	0.00	0.00	0.00	0.00	n/a
TOTAL FORBS	1.44	8.17	0.15	0.03	0.47	0.09	0.02
Agropyron desertorum	10.97	6.78	1.14	0.72	0.39	0.17	0.00
Agropyron spicatum	0.67	0.00	0.07	0.02	0.00	0.00	0.02
Elymus cinereus	0.00	0.00	0.00	0.00	0.00	0.00	n/a
Festuca idahoensis	12.99	1.91	1.35	0.38	0.11	0.04	0.01
Koelaria pyramidata	5.00	0.52	0.52	0.14	0.03	0.01	0.00
Poa spp.	26.37	14.09	2.74	0.43	0.81	0.18	0.02
Sitanion hystrix	7.41	3.48	0.77	0.14	0.20	0.05	0.01
Stipa comata	2.60	1.57	0.27	0.05	0.09	0.03	0.06
Stipa thurberiana	16.36	5.57	1.70	0.22	0.32	0.07	0.00
TOTAL GRASS	95.86	49.39	9.96	0.80	2.84	0.24	0.00
TOTAL BIOMASS	100.00	100.00	10.39	0.79	5.75	0.40	0.00

Species & Date	Does	Kids	Does		Kids		
	(% ofDiet)		mean	se	mean	se	P
	%	%	gms/hr		gms/hr		
WINTER 1991							
Artemisia tridentata (live)	2.03	2.53	0.24	0.10	0.15	0.04	0.62
Artemisia tridentata (dead)	0.00	14.36	0.00	0.00	0.85	0.21	0.09
Chrysothamnus viscidiflores	0.51	0.84	0.06	0.03	0.05	0.03	0.88
Leptodactylon pungens	0.00	0.00	0.00	0.00	0.00	0.00	n/a
Tetradymia canescens	0.00	0.00	0.00	0.00	0.00	0.00	n/a
TOTAL SHRUBS	2.54	17.91	0.30	0.10	1.06	0.24	0.20
Annual forbs	0.00	0.00	0.00	0.00	0.00	0.00	n/a
Perennial forbs	0.00	0.84	0.00	0.00	0.05	0.01	0.00
Lepidium spp.	0.00	0.00	0.00	0.00	0.00	0.00	n/a
TOTAL FORBS	0.00	3.89	0.00	0.00	0.23	0.08	0.20
Agropyron desertorum	12.26	7.60	1.45	0.62	0.45	0.16	0.22
Agropyron spicatum	11.83	4.22	1.40	0.35	0.25	0.08	0.00
Elymus cinereus	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Festuca idahoensis	23.42	3.04	2.77	0.55	0.18	0.06	0.05
Koelaria pyramidata	0.34	0.00	0.04	0.01	0.00	0.00	0.00
Poa spp.	0.42	0.34	0.05	0.02	0.02	0.01	0.21
Sitanion hystrix	3.38	2.03	0.40	0.09	0.12	0.04	0.07
Stipa comata	0.00	0.00	0.00	0.00	0.00	0.00	n/a
Stipa thurberiana	1.61	0.51	0.19	0.03	0.03	0.01	0.01
TOTAL GRASS	97.46	78.38	11.53	0.65	4.64	0.31	0.00
TOTAL BIOMASS	100.00	100.00	11.83	0.59	5.92	0.20	0.00

Species & Date	Does	Kids	Does		Kids		
	(% ofDiet)		mean	se	mean	se	P
	%	%	gms/hr		gms/hr		
SPRING 1991							
Artemisia tridentata (live)	9.89	6.07	0.79	0.14	0.82	0.15	0.91
Artemisia tridentata (dead)	0.00	0.00	0.00	0.00	0.00	0.00	n/a
Chrysothamnus viscidiflores	4.13	5.92	0.33	0.06	0.80	0.07	0.01
Leptodactylon pungens	0.00	0.07	0.00	0.00	0.01	0.00	0.42
Tetradymia canescens	0.13	0.22	0.01	0.01	0.03	0.01	0.49
TOTAL SHRUBS	14.27	12.36	1.14	0.12	1.67	0.15	0.02
Annual forbs	0.50	2.07	0.04	0.02	0.28	0.07	0.07
Perennial forbs	1.63	5.92	0.13	0.03	0.80	0.17	0.00
Lepidium spp.	0.00	0.00	0.00	0.00	0.00	0.00	n/a
TOTAL FORBS	2.25	7.99	0.18	0.04	1.08	0.17	0.00
Agropyron desertorum	12.77	15.25	1.02	0.33	2.06	0.60	0.06
Agropyron spicatum	7.51	5.77	0.60	0.15	0.78	0.14	0.34
Elymus cinereus	0.63	0.74	0.05	0.01	0.10	0.03	0.04
Festuca idahoensis	5.63	4.96	0.45	0.07	0.67	0.11	0.07
Koelaria pyramidata	0.63	0.74	0.05	0.01	0.10	0.04	0.17
Poa spp.	44.56	37.75	3.56	0.42	5.10	0.42	0.05
Sitanion hystrix	8.01	8.81	0.64	0.11	1.19	0.23	0.09
Stipa comata	0.00	0.00	0.00	0.00	0.00	0.00	n/a
Stipa thurberiana	3.50	4.96	0.28	0.03	0.67	0.07	0.01
TOTAL GRASS	83.48	79.64	6.67	0.22	10.76	0.40	0.00
TOTAL BIOMASS	100.00	100.00	7.99	0.20	13.51	0.29	0.00

Species & Date	Does	Kids	Does		Kids		
	(% ofDiet)		mean	se	mean	se	P
	%	%	gms/hr		gms/hr		
SUMMER 1991							
Artemisia tridentata (live)	0.28	0.33	0.04	0.02	0.06	0.02	0.57
Artemisia tridentata (dead)	0.00	0.11	0.00	0.00	0.02	0.01	0.31
Chrysothamnus viscidiflores	1.31	1.62	0.19	0.04	0.29	0.06	0.12
Leptodactylon pungens	0.14	0.06	0.02	0.01	0.01	0.00	0.34
Tetradymia canescens	0.14	0.28	0.02	0.01	0.05	0.02	0.19
TOTAL SHRUBS	1.86	2.40	0.27	0.05	0.43	0.07	0.10
Annual forbs	2.41	4.74	0.35	0.16	0.85	0.23	0.19
Perennial forbs	1.31	2.18	0.19	0.06	0.39	0.13	0.42
Lepidium spp.	0.55	2.73	0.08	0.04	0.49	0.14	0.14
TOTAL FORBS	4.27	9.65	0.62	0.22	1.73	0.34	0.19
Agropyron desertorum	25.29	33.54	3.67	1.41	6.01	2.00	0.09
Agropyron spicatum	36.94	19.42	5.36	1.36	3.48	1.09	0.27
Elymus cinereus	0.34	3.74	0.05	0.03	0.67	0.22	0.05
Festuca idahoensis	1.59	1.95	0.23	0.10	0.35	0.16	0.64
Koelaria pyramidata	1.79	3.01	0.26	0.12	0.54	0.12	0.14
Poa spp.	1.79	0.95	0.26	0.10	0.17	0.05	0.66
Sitanion hystrix	12.89	9.26	1.87	0.25	1.66	0.32	0.57
Stipa comata	1.59	6.92	0.23	0.09	1.24	0.57	0.09
Stipa thurberiana	11.16	7.59	1.62	0.26	1.36	0.28	0.57
TOTAL GRASS	93.87	87.95	13.62	1.18	15.76	1.38	0.05
TOTAL BIOMASS	100.00	100.00	14.51	1.09	17.92	1.28	0.02